Bay Area Clean Water Agencies (Lorien Fono)

What is your submittal about?

Please select one:
Pesticide group

Provide the name of the pesticide and, if possible, its Chemical Abstracts Service (CAS) Registry Number.

You may use DPR's CalPEST Public Search to look up the CAS Registry Number.
ACTIVE INGREDIENTS FOR ON-PET FLEA & TICK TREATMENTS USED IN CALIFORNIA

Active Ingredient; CAS Number

AFOXOLANER; FDA registered
BIFENTHRIN; 82657-04-3
CYPHENOTHRIN; 39515-40-7
DELTAMETHRIN ; 52918-63-5
DINOTEFURAN;165252-70-0
ETOFENPROX; 80844-07-1
FIPRONIL; 120068-37-3
FLUMETHRIN; 69770-45-2
FLURALANER; FDA registered
IMIDACLOPRID; 138261-41-3; also FDA registered
LIMONENE; 138-86-3 AND 5989-27-5
LOTILANER; FDA registered
LUFENURON; FDA registered
NITENPYRAM; FDA registered
PERMETHRIN; 52645-53-1
PHENOTHRIN; 26002-80-2
PYRETHRINS; 8003-34-7
PYRIPROXYFEN (NYLAR); 95737-68-1
SAROLANER; FDA registered
SELAMECTIN; FDA registered
S-METHOPRENE; 65733-16-6
SODIUM DIISOOCTYLSULFOSUCCINATE; 577-11-7

SPINETORAM; 187166-40-1 AND 187166-15-0
SPINOSAD; 131929-60-7; also FDA registered
TETRACHLORVINPHOS; 961-11-5
UNDECYLENIC ACID; 112-38-9

(Short Format) In one to three sentences, please describe your pesticide-related concern.

The description provided will appear in the online summary.
DPR is currently assessing mitigation options for on-pet use of fipronil for flea/tick control, in part due to human health risk assessment findings. BACWA requests that DPR assess the human health impacts of the alternative pet flea/tick control products to avoid the situation that if fipronil is restricted, other chemicals—with regrettable human and environmental health consequences—may be substituted.

(Long Format) Please describe your pesticide-related concern and why it should be a DPR priority.

What type of information should you include?

- **Who or what is affected** (e.g. worker, community, residential, consumer health, sensitive populations, environmental endpoint, pesticide use, or other human health or environmental concern)
- **Description of the situation of concern**, including use site (e.g., crop or residential), region, type of pesticide use and application method (e.g., ground spraying; soil fumigation; bait applications; etc.)

WHO IS AFFECTED:

DPR is currently assessing mitigation options for on-pet use of fipronil for flea/tick control due to both human health and environmental risk assessment findings. DPR determined that health risks for pet groomers and residential users are largely driven by the dermal exposure route for pet spot-on and spray products. For children, the risks stem from dermal and incidental oral exposure. Alternative chemical treatments to fipronil may impact the same populations: children, pet groomers and residential users. (See Situation of Concern #1.) Further, there are indications that on-pet pesticides transported down the drain to sewage treatment plants could impact future availability of potable drinking water in arid, disadvantaged communities. (See Situation of Concern #2.)

THE SITUATION OF CONCERN #1. DATA GAPS FOR FIPRONIL ALTERNATIVES

Evaluating and managing on-pet alternatives as a group is necessary to avoid the situation that if one pesticide is restricted, another pesticide—one with regrettable consequences—may be substituted. Currently, the overarching U.S. veterinary recommendation is year-round, life-long use of flea and tick control, for both dogs and cats, rather than a risk-based or sustainable pest management (SPM) approach (See ATTACHMENT 1). Given the backdrop of this recommendation for continuous, prophylactic use of flea and tick products, DPR's fipronil mitigation could ultimately encourage pet owners to pivot to either (1) other on-pet pesticide formulation(s) for which there is incomplete human health information for one or more active ingredients or (2) FDA-regulated pharmaceuticals that lack human health information. This could lead consumers to select an alternative containing one or more active ingredients with negative human health consequences. ATTACHMENT 2 provides a list of all on-pet flea/tick pesticides and pharmaceuticals currently available in California, including their uses and existing human health information. (See "Flea/Tick Pesticidal or Pharmaceutical Formulations Available in California," BACWA/BAPPG Pesticide Workgroup, lead author Stephanie Hughes, 2026.)

1.1 PESTICIDE HUMAN HEALTH DATA GAPS

EPA is years behind in human health risk assessments, and human health benchmarks are rarely updated. For example, ATTACHMENT 2 includes five pyrethroids that have major gaps in human health benchmark data, including acute, chronic, and carcinogen data. Further, DPR's Fipronil Risk Characterization Document (Fipronil RCD, March 2023) was more comprehensive and inclusive of many more components than EPA's human health studies. DPR's Fipronil RCD also included detailed evaluation of occupational exposure to pet groomers, which EPA neglected.

Many of EPA's standards for assessing on-pet pesticide use are based on its 2012 Standard Operating Procedures (SOP) for Residential Pesticide Exposure Assessment (ATTACHMENT 3). This document has not been updated, with the exception of the flea collar subsection, which EPA was required to update as part of a court settlement. The SOP ignores occupational impacts (such as pet groomers) and assumes that consumers are exposed to a maximum of two dogs treated with on-pet flea and tick products (SOP, p.8-4). The SOP does not consider risks to pregnant people, and limits the valuation of risk to two categories of humans: children ages 1-2, and adults. While EPA identified many areas for future refinement of the SOP (including pesticide residue studies, pet contact exposure time studies, and refinement to the amount of product applied for particular application methods (SOP, pp. 8-11 to 8-12)), no such refinements have been published.

The lack of thorough human health information has put pressure on states and local communities to fill the gaps. For example, in July 2022, Washington, D.C. published an alert to discourage citizens from buying inexpensive and readily-available pet collars containing tetrachlorvinphos (TCVP), a known carcinogen. (Link here:

https://oag.dc.gov/release/consumer-alert-flea-and-tick-prevention-pet)

1.2 PHARMACEUTICAL HUMAN HEALTH DATA GAPS

Unlike EPA, FDA does not require human health data for on-pet pesticides or, if such data are required, they are not available to the public. Five of the FDA-regulated active ingredients are per- and polyfluoroalkyl substances (PFAS), a group of synthetic organofluorine chemical compounds commonly referred to as “forever chemicals.” Many PFAS are carcinogens and/or endocrine disruptors and have been linked to a myriad of other serious human health issues.

Four of the FDA-regulated PFAS compounds are in the isoxazoline family, associated with adverse pet neurological events. Toxicology researchers recently raised the alarm regarding isoxazolines: "… the occurrence of neurological adverse effects reported in veterinary practice emphasizes the need for thorough evaluation of neurotoxicity, exposure thresholds, and susceptibility in humans." (See ATTACHMENT 4, Pharmacology and Toxicology of Veterinary Isoxazolines: A Review, by Markowska-Bunka et al., 2026.)

One isoxazoline product is topically applied; the transport of topically applied flea/tick treatments in a home are well documented, including by DPR-led studies. The other isooxazoline products are ingested or injected; the human exposure pathways for ingested or injected treatments are unclear. Early studies have found evidence of transport of these oral medications to the external environment, with researchers calling for improvements in the assessment of exposure pathways (DOI: 10.1016/j.scitotenv.2022.159550).

SITUATION OF CONCERN #2. HUMAN HEALTH IMPACTS RELATED TO LACK OF POTABLE DRINKING WATER

A less obvious but also possible impact to human health is that on-pet pesticides in treated wastewater effluent could pose a serious challenge to the feasibility of potable water reuse. As DPR scientists are aware, pet flea and tick treatments have transport mechanisms to wastewater treatment plants. Several of these pesticides have been observed in California treated wastewater effluent at concentrations that exceed the EPA benchmarks for chronic exposure to aquatic invertebrates. Many more pesticides would exceed these benchmarks when concentrated by a factor of 5 (or greater) in the wastewater stream generated as a byproduct of reverse osmosis to create water suitable for potable reuse. Given the growing efforts toward potable use of wastewater effluents, the presence of pesticides in this concentrated waste stream could render such water supply projects technologically or economically infeasible. Pesticides in reverse osmosis concentrate will increase costs for public agencies or entirely prevent potable reuse of wastewater effluent in economically disadvantaged communities. Reducing uses of persistent mobile pesticides in ways that avoid sewer discharges may be the best—and perhaps only—means to allow society to access this future water supply, which could ultimately impact human health.

REQUESTING A BROAD-BASED FLEA/TICK ALTERNATIVES ASSESSMENT

Assessing individual pesticides one-by-one may lead to regrettable substitutions that could harm families, especially vulnerable children, pregnant people, and pet groomers. This points to a need for a broad-based alternatives assessment akin to DPR's alternatives assessments for copper-based root control products and tributyltin cooling water biocide additives—which assessed both chemical and mechanical alternatives. [Reference: Davidson, N. (1995) Evaluation of Copper- and Tributyltin-containing Compounds, Report Number EH-95-07, DPR Environmental Monitoring & Pest Management Branch. (ATTACHMENT 5)] Analogously, an assessment of pet flea/tick control would include other on-pet and indoor pesticide formulations, physical alternatives (such as vacuuming), and FDA-approved pharmaceuticals. Given that the FDA-regulated alternatives require a prescription, cost and availability of on-pet treatment options should also be considered to ensure that all Californians have access to low cost, safe on-pet flea and tick products.

BACWA appreciates DPR's continued data-driven and thoughtful approach to understand the human health and environmental impacts of on-pet uses of parasiticides. California families with pets need DPR's help in filling in data gaps for on-pet products so that they can make safe and effective choices.

What scientific information or additional information supports your submittal?

DPR will collect pesticide use reports, pesticide illness reports, environmental and human health data for each submission; submitters do not need to provide this information. Description of DPR collected data can be found on slide 52 of August 7th SPARC Meeting Slides.

Attach supporting documents using the "Upload a File" option below.

Please provide a brief rationale for each file you attach. Explain why each attachment is being included and how it supports your submittal.
RATIONALE FOR ATTACHED FILES:
1. Evidence that Current U.S. Veterinary Guidance re. Fleas/Ticks is Neither Risk-Based or SPM, but Year-Round Throughout Their Lives

BACWA obtained screenshots from the Companion Animal Parasite Council website, which is seen as the source of parasite recommendations for U.S. veterinarians. Website accessed August 21, 2026.

2. Flea/Tick Pesticidal or Pharmaceutical Formulations Available in California; BACWA/BAPPG Pesticide Workgroup, lead author Stephanie Hughes, 2026.

BACWA prepared this list of on-pet chemical alternatives available in California as of December 2025.

3. Standard Operating Procedures for Residential Pesticide Exposure Assessment; Health Effects Division, Office of Pesticide Programs, Office of Chemical Safety and Pollution Prevention, U.S. Environmental Protection Agency (October 2012), see Section 8: Treated Pets.

This document presents the operating procedures and assumptions of EPA when they assess human health effects.

4. Markowska-Bunka et al., Pharmacology and Toxicology of Veterinary Isoxazolines: A Review, International Journal for Parasitology: Drugs and Drug Resistance 31 (2026) 100645.

This 2026 article presents the state of currently available toxicology data including significant data gaps, particularly with respect to human health.

5. Davidson, N. (1995) Evaluation of Copper- and Tributyltin-containing Compounds, Report Number EH-95-07, DPR Environmental Monitoring & Pest Management Branch.

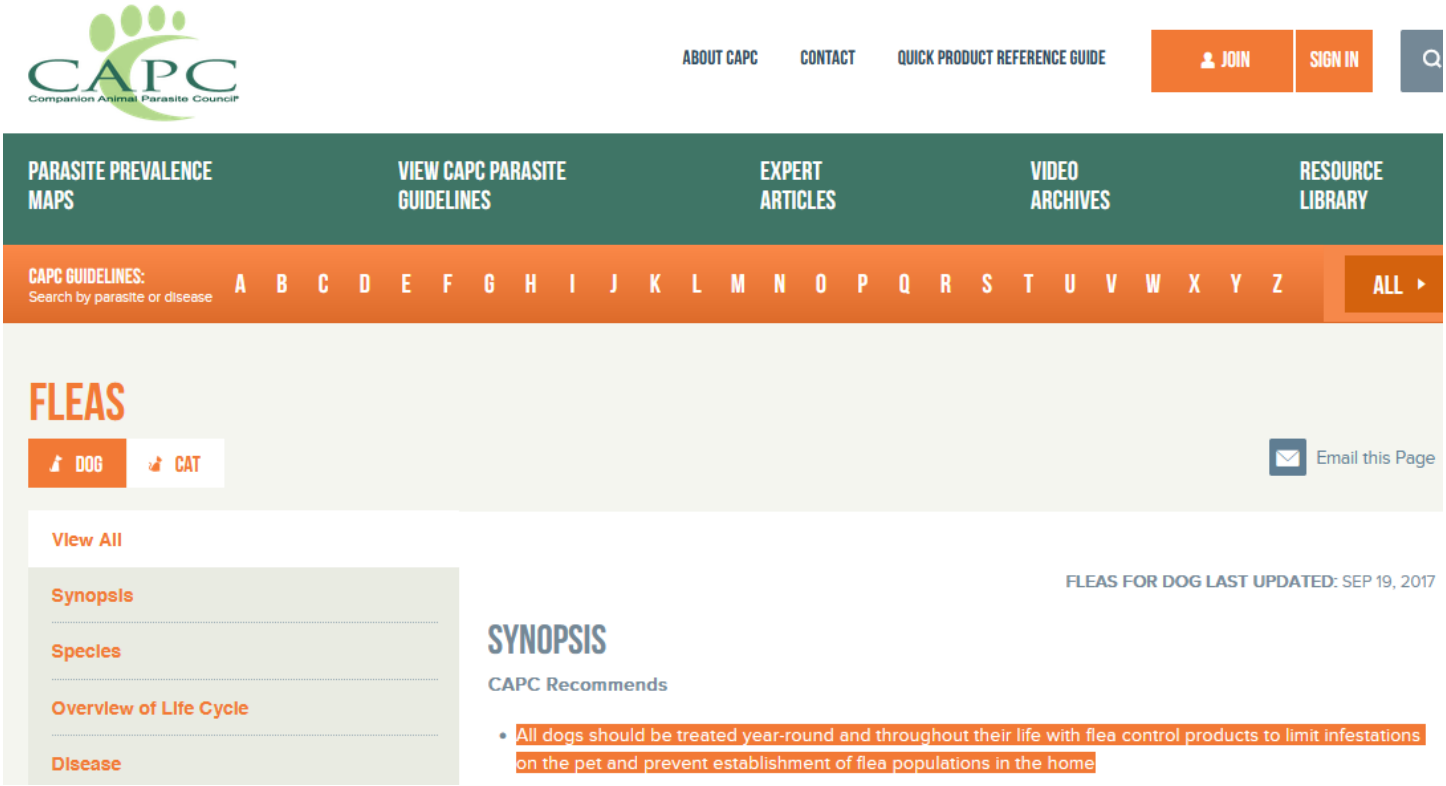
This document is an example of a DPR approach to a pesticidal use that included mechanical and other chemical alternatives.

Evidence that Current U.S. Veterinary Guidance re. Fleas/Ticks is Neither Risk-Based or SPM, but Year-Round Throughout Their Lives

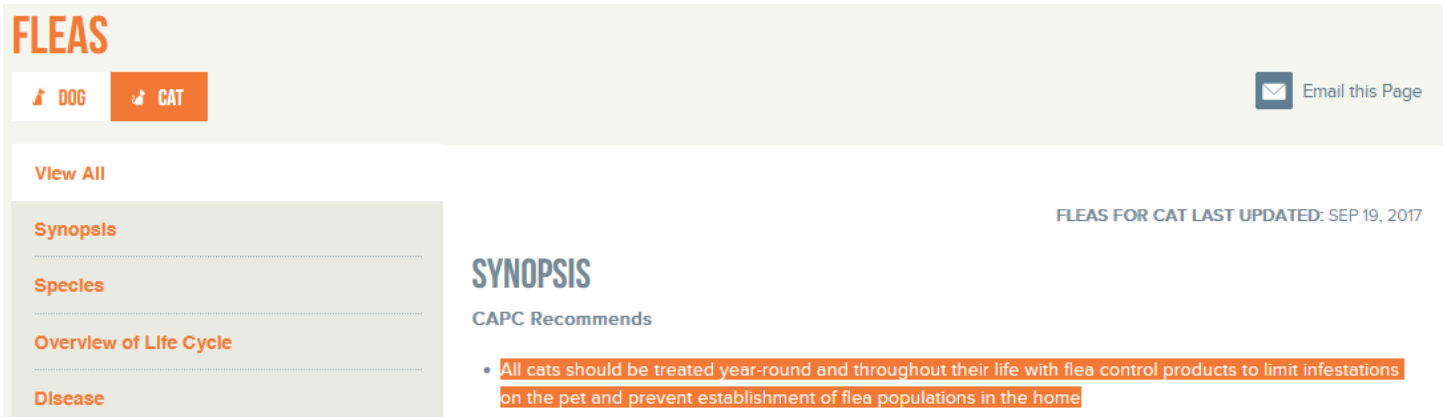
The American Veterinary Medical Association and the World Small Animal Veterinary Association recommend that U.S. veterinarians refer to the flea and tick control guidance from the Companion Animal Parasite Council (CAPC). Below are excerpts from CAPC's website that guide all veterinarians to treat all dogs and cats year-round throughout their lives for both fleas and ticks, regardless of individual circumstances. The website was visited August 21, 2026.

FLEA CONTROL GUIDANCE IS HERE: https://capcvet.org/guidelines/fleas/

FLEA CONTROL - DOGS:

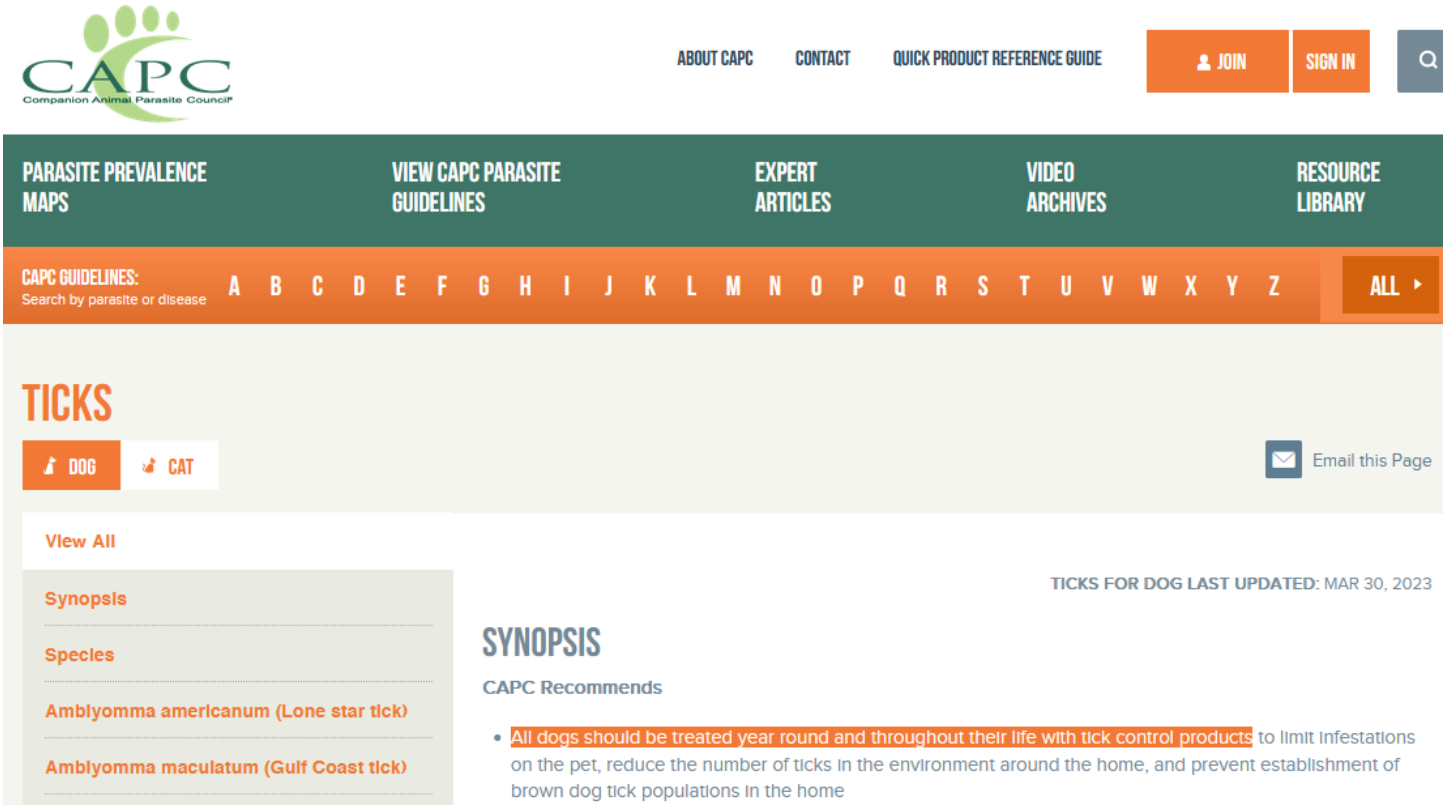


FLEA CONTROL - CATS:

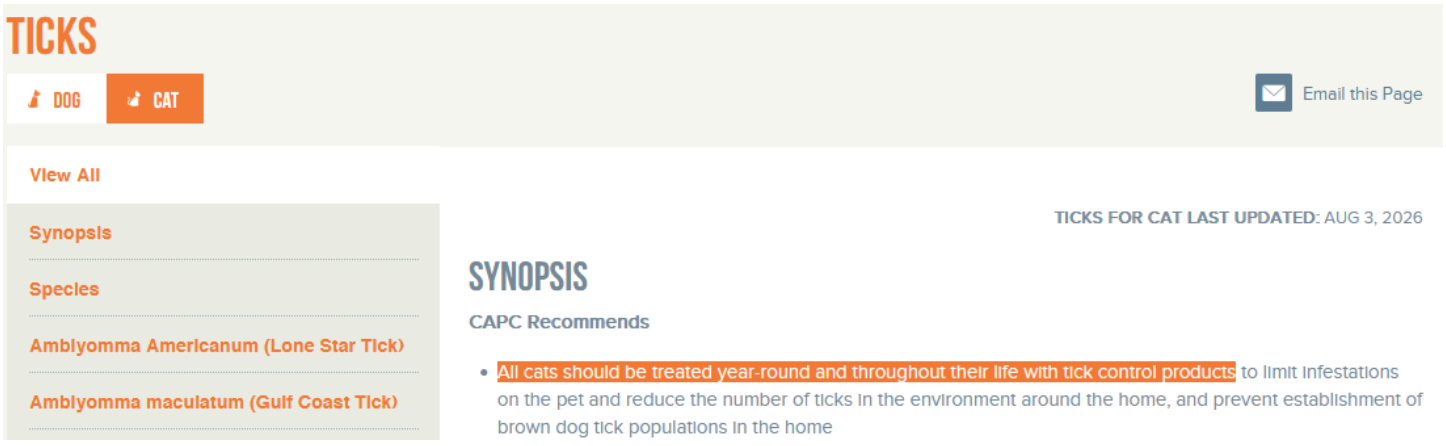


TICK CONTROL GUIDANCE IS HERE: https://capcvet.org/guidelines/ticks/

TICK CONTROL - DOGS:



TICK CONTROL - CATS:



Flea/Tick Pesticidal or Pharmaceutical Formulations Available in California prepared by BACWA, August 2026							Legend: Bold indicates result is within 50% of the fipronil result (acute < 255, chronic < 1.5). Italics indicates a possible data gap. Bold and italicized indicates a data gap that may be of particular concern.						
Flea and/or Tick Pesticidal or Pharmaceutical Formulations Available in California													
Active Ingredient CAS Number(s) (if available)	# Reg. Products in California (DPR, Dec. 2025)	Only Formulated with Other Active Ingredients	Fed Regulated		Target Pests (* as blended)		Target Pets		Human Health Benchmarks (HHB) (ppb) (Note 1)			PFAS (as defined in Note 2)	
			EPA	FDA	Flea	Tick	Dog	Cat	Acute	Chronic	Carcinogen		
AFOXOLANER (an isoxazoline)	NA (FDA oral)			X	X	X	X		Unassessed by FDA (Note 3)			YES	
BIFENTHRIN 82657-04-3	1 shampoo		X		X	X	X		210	No EPA HHB	"Possible human carcinogen" per EPA Revised HH RA (2020)	YES	
CYPHENOTHRIN 39515-40-7	1 spot	X	X		X*	X*	X		No EPA HHB	No EPA HHB	"Not Likely to be Carcinogenic to Humans." per EPA Updated HH RA (2019)	NO	
DELTAMETHRIN 52918-63-5	17 collars		X		X	X	X		100	No EPA HHB	"Not Likely to be Carcinogenic to Humans." per EPA Revised HH RA (2020)	NO	
DINOTEFURAN 165252-70-0	12 spots	X	X		X*	X*	X	X	8330	6000	"Not Likely to be Carcinogenic to Humans" per EPA Updated HH RA (2017)	NO	
ETOFENPROX 80844-07-1	17 spots, 4 sprays		X		X	X	X	X	No EPA HHB	151	"Not Likely to be Carcinogenic to Humans." per EPA Revised HH RA (2022)	NO	
DPR currently assessing mitigation alternatives: FIPRONIL 120068-37-3	52 spots; 2 sprays		X		X	X	X	X	170	1	"Possible human carcinogen" per EPA HH RA (2020)	YES	
FLUMETHRIN 69770-45-2	4 collars	X	X		X*	X*	X	X	No EPA HHB	No EPA HHB	"Not Likely to be Carcinogenic to Humans." per EPA Updated HH RA (2019)	YES	
FLURALANER (an isoxazoline)	NA (FDA oral, spot, and dog-injectable)			X	X	X	X	X	Unassessed by FDA (Note 3)			YES	
IMIDACLOPRID 138261-41-3	4 collars; 44 spots (plus FDA oral&spot)		X	X	X		X	X	500	500	"Evidence of non-carcinogenicity for humans" per EPA PID (2020)	NO	
LIMONENE 138-86-3 5989-27-5	1 shampoo		X		X	X	X	X	No EPA HHB	No EPA HHB	Not known to be carcinogenic (no EPA reference)	NO	
LOTILANER (an isoxazoline)	NA (FDA oral)			X	X	X	X		Unassessed by FDA (Note 3)			YES	
LUFENURON	NA (FDA oral&inject)			X	X		X	X	Unassessed by FDA (Note 3)			YES	
NITENPYRAM	NA (FDA oral)			X	X		X	X	Unassessed by FDA (Note 3)			NO	
PERMETHRIN 52645-53-1	1 dip; 9 shampoos; 40 spots; 3 sprays		X		X	X	X		2900	No EPA HHB	"Suggestive Evidence of Carcinogenic Potential." per EPA Amendment to PID (2021)	NO	
PHENOTHRIN 26002-80-2	3 shampoos		X		X	X	X		8000	400	"Not Likely to be Carcinogenic to Humans." per EPA Amendment to PID (2021)	NO	

PYRETHRINS 8003-34-7	2 dips; 14 ear drops; 21 shampoos; 9 sprays; 1 wipe		X		X	X	X	X	500	20	"Not Likely to be Carcinogenic to Humans." per EPA PID (2021)	NO
PYRIPROXYFEN (NYLAR) 95737-68-1	5 collars; 9 shampoos; 68 spots; 5 sprays	X	X		X*	X*	X	X	No EPA HHB	2100	"No evidence for carcinogenicity to humans" per EPA HH RA (2017)	NO
SAROLANER (an isoxazoline)	NA (FDA oral&spot)			X	X	X	X	X	Unassessed by FDA (Note 3)			YES
SELAMECTIN	NA (FDA spot)			X	X	X			Unassessed by FDA (Note 3)			NO
S-METHOPRENE 65733-16-6	15 collars; 7 shampoos; 55 spots; 9 sprays	X	X		X*	X*	X	X	No EPA HHB	No EPA HHB	Not known to be carcinogenic (no EPA reference)	NO
SODIUM DIISOOCTYLSULFOSUCCINATE 577-11-7	1 shampoo	X	X		X*	X*	X		No EPA HHB	No EPA HHB	Not known to be carcinogenic (no EPA reference)	NO
SPINETORAM 187166-40-1 187166-15-0	3 spots		X		X			X	No EPA HHB	147	"Not Likely to be Carcinogenic to Humans." per EPA Updated HH RA (2016)	NO
SPINOSAD 131929-60-7	NA (FDA oral)			X	X		X	X	No EPA HHB	147	"Not Likely to be Carcinogenic to Humans." per EPA Updated HH RA (2016)	NO
TETRACHLORVINPHOS (TCVP) 961-11-5	22 collars; 4 sprays		X		X	X	X	X	19	16	16.2 - 1620 (E-6 to E-4) (Note 4)	NO
UNDECYLENIC ACID 112-38-9	1 shampoo	X	X		X*	X*	X		No EPA HHB	No EPA HHB	Not known to be carcinogenic (no EPA reference)	NO
Notes and References:												
1. Source of HHBs: https://www.epa.gov/sdwa/2021-human-health-benchmarks-pesticides and https://www.epa.gov/sdwa/2026-human-health-benchmarks-pharmaceuticals-hhb-rx (none of the FDA pharmaceuticals were listed) Carcinogen: Also checked the International Agency for Research on Cancer (IARC) and the US National Toxicology Program (NTP) lists; none of the FDA pharmaceuticals were on the IARC or NTP lists.												
2. OECD (2021), Reconciling Terminology of the Universe of Per- and Polyfluoroalkyl Substances: Recommendations and Practical Guidance, OECD Series on Risk Management, No. 61, OECD Publishing, Paris.												
3.The FDA does not assess human health risks of on-pet pharmaceuticals, even when there are special cautionary statements about impacts to pet health (e.g., "neurologic adverse reactions").												
4. EPA Formula for deriving carcinogenic HHB (ppb) = [10-6 or 10-4/Drinking Water Unit Risk (ppb-1), where Drinking Water Unit Risk (ppb-1) = [CSF (per mg/kg/day) x 0.0338 (L/kg/day) adult DWI-BW ratio]/[1000 (µg/mg)]. See here for more information: https://www.epa.gov/sdwa/2021-human-health-benchmarks-pesticides												

Standard Operating Procedures for Residential Pesticide Exposure Assessment

October 2012

Health Effects Division
Office of Pesticide Programs
Office of Chemical Safety and Pollution Prevention
U.S. Environmental Protection Agency
Washington, DC

Preamble

The 1996 Food Quality Protection Act (FQPA) expanded EPA risk assessment requirements under the Federal Insecticide Fungicide and Rodenticide Act (FIFRA) and the Federal Food, Drugs, and Cosmetics Act (FFDCA) by emphasizing protection of infants and children including combining exposures from all potential pathways. Its directive for pesticide assessments to provide "reasonable certainty that no harm will result from aggregate exposure to the pesticide chemical residue, including all anticipated dietary exposures and all other exposures for which there is reliable information" resulted in the Agency routinely conducting both aggregate and cumulative risk assessments. Aggregate risk assessments include all exposure pathways (i.e., food, drinking water, and residential non-dietary) and routes (i.e., oral, dermal, inhalation) to a single chemical. Cumulative risk assessments include all exposure pathways (i.e., food, drinking water, and residential) and routes (i.e., oral, dermal, inhalation) to multiple chemicals with a common mechanism of toxicity. In response, the Agency developed a series of science policies[1] which included the initial version of its *Standard Operating Procedures (SOPs) for Residential Exposure Assessments* (i.e., "SOPs" or "Residential SOPs") which addressed non-dietary exposure pathways.

The SOPs were generally based on the Agency's *Exposure Assessment Guidelines.*[2] The document outlined a wide array of exposure scenarios that were intended to address all major possible means by which individuals in the general public could be exposed to pesticides in a residential environment (e.g., home, schools, parks, athletic fields or other publicly accessible locations). Some notable scenarios include children playing on treated lawns or homeowners spraying their gardens. Specifically tailored for each scenario, methods for estimating dermal, inhalation, and non-dietary oral exposure were presented including descriptions and sources for factors included in exposure algorithms. Due to some novel aspects and the overall groundbreaking nature of the SOPs, they were first presented to the FIFRA Scientific Advisory Panel (SAP) in 1997 with a follow-up review of some modifications in 1999.[3]

Since 1997, the SOPs have been used to assess exposure in residential settings for pesticide regulatory decisions within the Office of Pesticide Programs (OPP) as required under FQPA. This document represents the Agency's revised set of Residential SOPs and was presented to the FIFRA SAP in 2009[4]. In most cases, the exposure scenarios and basic algorithms remain the same with changes made only to the algorithm inputs using more recent data sources. However, some new scenarios have been added to this set of SOPs reflecting new products and uses and some existing scenarios have modified exposure algorithms. In addition, appendices for each SOP section provide extensive details on the underlying data that are recommended for the algorithm inputs. This information can provide the basis for future probabilistic exposure assessments.

[1] http://www.epa.gov/oppfead1/trac/science/
[2] http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=15263
[3] http://www.epa.gov/scipoly/sap/meetings/1997/090997_mtg.htm#materials and http://www.epa.gov/scipoly/sap/meetings/1999/092199_mtg.htm
[4] http://www.epa.gov/scipoly/sap/meetings/2009/100609meeting.html

The concept of using a "scenario-based" approach to complete exposure assessments is longstanding and outlined in many Agency guidance documents and is consistent with federal government risk assessment guidance (NRC, 2009). In this document, the Agency developed scenarios which can be used to calculate all manner of possible pesticide exposures that can occur in the general population. Quantifying human behaviors is critical for development of pertinent exposure assessment methods and can be complex. For example, three separate methods and sets of factors for children playing football, baseball, and soccer on fields treated with pesticides could be used as the basis for an assessment. Instead, one broad category for children playing on lawns is considered applicable to all potential exposure scenarios on treated grass because the exposure metric on which it is based monitored individuals involved in a routine that comprehensively reflected typical outdoor behaviors based on reported time-activity data. This approach was broadly applied in the development of previous versions of the Residential SOPs and throughout the development of this document because it reduces needed resources and reasonably reflects typical behavior patterns. Given this premise, exposure assessors should not view this document as a prescriptive checklist, but as a guide to performing residential exposure assessments in conjunction with other relevant information pertinent to the pesticide under examination.

The Residential SOPs are based on a number of intentional exposure human studies, which are subject to ethics review pursuant to 40 CFR 26. Each of those studies has been reviewed for ethics and is compliant with applicable ethics requirements. Additionally, as this document is used to assess, and potentially support, proposed pesticide registrations, and much of the data underlying the exposure factors is subject to the data protection provisions of FIFRA and the Agency's implementing regulations, compensation may be required for reliance on certain datasets.

To facilitate version control and tracking, the following table documents the progression of the Residential SOPs, including a detailed accounting of edits/revisions/corrections.

Date	Documentation of Revisions (as of October 2012)
Dec 1997	Original version
Feb 2001	• Supplemental document (ExpoSAC Policy 12), establishing revisions to: o Transfer coefficients o Transfer efficiency o Area treated o Revised breathing rates for inhalation exposure assessment
Jan 2012	• Comprehensive overhaul of 1997 and 2001 supplemental versions
Feb 2012	• Rounded body weights to 2 significant figures (e.g., 80 kg, 69 kg, etc.) throughout entire document • Added language regarding data requirement for surface residue (Sections 4.2.2, 8.2.2) • Corrected page numbering in Section 7 and Appendix C • Corrected illegible formulas throughout • Page 8-13, corrected "E" in equation 8.7 to "DE" • Page 7-24, corrected Box 3a from 10 µg/cm^2 to 15 µg/cm^2 • Table 9-1: thickness of PVC tiling changed to 0.3 cm, and correspondingly corrected weight-to-surface area from 40 to 390 mg/cm^2. • Table 9-2: corrected 40 mg/cm^2 to 390 mg/cm^2 based on edit to PVC tiling thickness. • Table 10-2: corrected airless sprayer amount handled to "3 five gallon cans" • Table 10-3: corrected paint can amount handled to "3 five gallon cans" for airless sprayer

Date	Documentation of Revisions (as of October 2012)
	• Equation 10.2: corrected units mg/kg-day to mg/day • Added new equation 6.2 describing calculation of application rate (lb ai/day) • Table 6-2: removed gray fill from 3rd row • Added "Documentation of Revisions" to preamble
Oct2012	• Section 5 ("Outdoor Foggers"): Transfer coefficient cross-references to other sections corrected to properly match age-groups. • Section 6 ("Insect Repellents"): Revised calculations to avoid possibility of exposure to less than 1 application per day, as well as rounding to the nearest whole number – text also changed to characterize this issue. • Spreadsheet calculator updates: o All filenames changed to "USEPA-OPP-HED_..." o Residential Handler ▪ Corrected various inconsistencies and typos ▪ Deleted "zeros" in application rate cells o Lawn/Turf SOP ▪ Corrected soil ingestion weight unit conversion units to "g/ug" ▪ Increased decimal places in some cells o Insect Repellents SOP ▪ Dermal and incidental oral calculations edited to calculate "#Apps", including a function to select the maximum of either "1 application" or the product of "Exposure Time (hrs/day)" and "Application Frequency (#apps/hr)" rounded down to the nearest whole number o Indoor Environments SOP ▪ In "Deposited residue" tab, deleted cells C19:C22 due to unnecessary user confusion (no quantitative effect on calculations). o Treated Pets SOP ▪ Corrected dermal dose calculation for children 1 < 2 years old, which was incorrectly referencing adult bodyweight o Treated Paints/Preservatives ▪ Corrected hand-to-mouth risk calculation to select proper toxicity value ▪ Corrected conditional formatting for hand-to-mouth risk estimate to properly reflect values less than the target level of concern

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Section 1 Introduction

The Standard Operating Procedures for Residential Pesticide Exposure Assessment (hereafter referred to as "the SOPs" or "Residential SOPs") provide methods for assessment of pesticide exposures unrelated to employment or dietary intake of food or water. These types of exposures include two major scenarios: residential handler and post-application exposures. The term "handler" refers to an individual who mixes, loads, and/or applies a pesticide. The term "post-application" refers to exposure as a result of contact with pesticide residues in previously treated areas.

The exposure assessment methods in this document are scenario-based and reflect homeowners who purchase pesticides and complete their own applications as well as post-application exposures resulting from both homeowner and professional or commercial applications in areas that can be frequented by the general population. Prior to outlining exposure assessment methodologies for specific scenarios (Sections 3.0 – 10.0), this document provides general information, including:

- Section 1.1: General Principles of Exposure Assessment;
- Section 1.2: Guidance on Residential Pesticide Usage;
- Section 1.3: Residential Exposure Assessment Guidance; and
- Section 2.0: Universal Exposure Factors.

Exposure assessment methodologies are then outlined for the following major residential scenarios:

- Section 3.0: Lawns and Turf;
- Section 4.0: Gardens and Trees;
- Section 5.0: Outdoor Fogging/Misting Systems;
- Section 6.0: Insect Repellents;
- Section 7.0: Indoor Environments;
- Section 8.0: Treated Pets;
- Section 9.0: Impregnated Materials; and
- Section 10.0: Treated Paints and Preservatives.

1.1 General Principles of Exposure Assessment

Exposure assessment is the process by which: (1) potentially exposed populations are identified; (2) potential pathways of exposure are identified; and (3) potential doses are quantified. As indicated above, the populations considered in these SOPs are those individuals who are potentially exposed to pesticides in non-occupational or residential settings (e.g., homes, parks, schools, athletic fields or any other area frequented by the general public). Exposures to pesticides may occur from applying pesticides or from being in areas previously treated with pesticides and contacting residues through oral, inhalation, or dermal routes.

Planning, Scoping, and Problem Formulation

It is important to adequately prepare prior to the initiation of a risk assessment and to clearly define the limitations of an assessment as recently described by the National Academy of Science (NRC, 2009). In *Science and Decisions*, much more detailed information is available that describes these processes in detail. For assessments completed using these SOPs planning and scoping are important because it ensures that assessors clearly identify the information that will be used as the basis for an assessment, what specific types of exposure patterns will be considered, what durations of exposure will be considered, and what potentially impacted populations will be evaluated. A problem formulation exercise is important for assessors using these SOPs because it will clearly assist them in defining which methods will be used to evaluate particular exposure patterns and how data, if available, should be incorporated into the process. It will also help in the ultimate characterization of the resulting risk estimates because the process will aid in developing a more thorough understanding of the issues that should be considered with the interpretation of the data, methods, and results of a particular assessment.

Calculation of Exposure

Exposure is commonly defined as contact of visible external physical boundaries (i.e., mouth, nostrils, and skin) with a chemical agent (U.S. EPA, 1992). As described in the *Guidelines for Exposure Assessment* (U.S. EPA, 1992), exposure is dependent upon the intensity, frequency, and duration of contact. The intensity of contact is typically expressed in terms of the concentration of contaminant per unit mass or volume (i.e., µg/g, µg/L, mg/m^3, ppm, etc.) in the medium to which humans are exposed (U.S. EPA, 1992). Exposure can be calculated as follows:

$$E = C * CR \tag{1.1}$$

where:

E = exposure (mg/day);
C = contaminant concentration in the media (mg/cm^2; mg/m^3, mg/g); and
CR = contact rate with that media (cm^2/day; m^3/day; gm/day).

Calculation of Absorbed Dose

Dose refers to the amount of chemical to which individuals are exposed that crosses the external boundary. Dose is dependent upon contaminant concentration and the rate of intake (i.e., inhalation or ingestion) or uptake (i.e., dermal absorption) and may be normalized to body

weight as a function of time (i.e., mg/kg-day). Daily dose is the amount of chemical that could be ingested, inhaled, or deposited upon the skin per day (U.S. EPA, 1992) and can be calculated as follows:

$$D = \frac{E * AF}{BW} \tag{1.2}$$

where:

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

Exposure/Dose Amortization

An accurate estimate of exposure over the course of weeks, years or a lifetime is difficult to predict as exposure likely differs from one day to the next due to product-specific application regimens, residue dissipation, human behavior and activity patterns, and the extent to which an individual's exposure varies due to behavior changes. Approaches for amortizing dose over various exposure durations are explained in more detail in *Section 1.3*; however an example would be amortization of an individual's daily dose over their lifetime necessary for calculating exposures for cancer risk assessments. This amortized dose is known as the lifetime average daily dose (LADD) and it can be calculated as follows:

$$\text{LADD} = \frac{\text{D} * \text{EF} * \text{ET}}{\text{AT} * \text{CF}} \tag{1.3}$$

where:

LADD = lifetime average daily dose (mg/kg-day);
D = dose (mg/kg-day);
EF = exposure frequency (i.e., frequency of product use) (days/year);
ET = exposure time (years);
AT = averaging time (i.e., life expectancy) (years); and
CF = conversion factor (365 days/year).

1.2 Guidance on Residential Pesticide Usage

Prior to conducting a residential exposure assessment, all end-use product labels for the active ingredient under consideration should be researched to capture the information discussed below in order to define the overall scope of the assessment as well as specific exposure scenarios to consider. Additional information such as sales information or pest control extension agents can be considered as well.

Potential Use in Residential Settings

Assessors should assume that a product may be used at residential sites or used by homeowners unless specific labeling statements indicate otherwise. Each SOP section provides examples of such labeling language. Additionally, restricted-use product (RUP) classification indicates that the product cannot be bought or applied by homeowners (i.e., no residential handler exposure/risk assessment required), but it may be applied by commercial applicators to residential sites; therefore, a post-application risk assessment may be required.

Formulation Type

The label will list the type of formulation as part of, or associated with, the brand name. Formulation type is important in an exposure assessment because different formulations can lead to higher or lower exposures for handlers as well as having different levels of surface residue transfer in post-application exposure scenarios. Examples of common residential formulations are as follows:

- Liquid formulations (liquid formulations typically have a statement listing the number of pounds active ingredient contained in a gallon of the liquid formulated product)
    - Emulsifiable concentrates (EC)
    - Soluble concentrates (SC)
    - Liquids (L)
    - Microencapsulated (ME)
- Solid Formulations
    - Dusts
    - Granules (G)
    - Water dispersible granules/dry flowable (WDG/DF)
    - Wettable Powder (WP)
- Other
    - Bait stations
    - Water soluble bags (WSB)
    - Aerosol cans
    - Trigger-pump sprayers

Use directions such as mixing/loading instructions, application equipment and application rate terminology may also indicate the formulation if it is not explicitly stated on the label. For example, solid products are typically measured in dry volume (e.g., ounces) and liquid products are typically measured in wet volume (e.g., pints, quarts, gallons, etc.).

Possible Methods of Application

Use directions often specify the methods of application for a product either by prohibiting specific application techniques (e.g., "do not apply in any type of irrigation equipment" or "spot treatment only") or by listing the application equipment to be used. Handler assessments should be performed for all equipment types applicable to the product and its application sites unless a specific piece of equipment is prohibited on the labeling or is obviously incompatible with the formulation, use directions, or the intended setting where the pesticide is to be used.

Maximum Application Rates

Determine the maximum label-permitted application rate for each use site by comparing the directions for each use listed on the label. This is important because exposure assessments must consider the legal maximum application rates in order to account for those individuals who use pesticides at the highest rates allowable under the law. Label-specified lower rates or pest-specific rates should be noted as well if used in the assessment, and can provide valuable information for risk managers to consider during the regulatory decision-making process. Often there are multiple instructions with widely varying use rates because there are many uses associated with one label (e.g., indoor/outdoor use, types of pests, application timing, etc.) – these broad ranges of use should be addressed. Maximum rates also may vary by formulation, so the maximum rate for each formulation must be determined.

Use Frequency

Determine the number of applications per year or season and the re-treatment interval, typically estimated based on label directions for frequency of product application. Typical statements include "apply at 7-day intervals while pests are present," "apply in early spring before first mowing," or "apply a second spray in 3 to 5 days." Depending on the specific product, this can inform the expected duration of exposure as well as yearly exposure frequency for estimating lifetime exposure for cancer risk assessments. Often times, extension guidance or other information related to pest lifecycles can inform this process.

1.3 Residential Exposure Assessment Guidance

Prior to conducting a residential pesticide exposure assessment, the following should be considered:

(1) various products containing the pesticide,
(2) products' use patterns,
(3) application methods and equipment,
(4) expected exposed populations (e.g., adults for handler activities and adults and children for post-application activities),
(5) expected routes of exposure (e.g., dermal, inhalation, oral), and
(6) expected durations of exposure for the pesticide being assessed.

This section builds on the general exposure assessment concepts and basic use information presented in *Section 1.1* and *1.2* above. The intent is to provide more specific guidance on the issues that should be addressed in the development of a residential pesticide exposure assessment. **Section 1.3.1: Potentially Exposed and Index Lifestages** describes the various populations potentially exposed to pesticides in residential settings and how to select index lifestages used in exposure assessment to encompass exposure and risks for all potentially exposed populations. **Section 1.3.2: Durations of Exposure** addresses issues related to how exposure patterns associated with the use of a pesticide, which can range from a single exposure event through a lifetime, should be reconciled with its toxicological characteristics. **Section 1.3.3: Handler Exposure** and **Section 1.3.4: Post-application Exposure** describe special considerations for homeowners that apply pesticides and for those exposed while engaging in

activities in areas previously treated with pesticides. **Section 1.3.5: Combining Exposure Scenarios** discusses the issues associated with the development of exposure patterns which account for combinations of behaviors which contribute to overall exposure to a pesticide. **Section 1.3.6: Exposure Uncertainty and Characterization** introduces the concept of uncertainty and how to interpret its effect on residential exposure estimates. **Section 1.3.7: Considerations for Use of Exposure Data** describes issues surrounding Agency regulations with respect to research with human subjects. **Section 1.3.8: Deterministic Exposure Assessment Methodology** describes the Agency's approach of using point estimate inputs in exposure algorithms as well as inclusion of distributional data analysis for use in more complex probabilistic methods should they be warranted.

1.3.1 Potentially Exposed and Index Lifestages

In the beginning phase of an exposure and risk assessment, exposure assessors must first identify the relevant lifestages for each exposure scenario (i.e., adults, children 1 < 2 years old, children 3 < 6 years old, etc.). A lifestage can be thought of as a distinct period during development of a child, for example, where they have certain physical characteristics and also display discrete behaviors and cognitive abilities. In most cases, individuals in multiple lifestages could be potentially exposed within a particular exposure scenario. To simplify the exposure and risk assessment process, an exposure assessor generally focuses the exposure assessment towards the lifestage (or lifestages) of highest concern due to unique behavioral characteristics that may lead to higher levels of exposure. This "index lifestage" approach utilizes quantitative assessments of the index lifestage to protect for the exposures and risks for all potentially exposed lifestages. This approach simplifies and streamlines the assessment process and allows risk managers to focus on the area(s) of highest concern.

The Agency has analyzed the index lifestage issue using both quantitative (e.g., exposure assessments) and qualitative (e.g., exposure and activity data) considerations. The analysis focuses on four specific child lifestages as defined in the Agency's *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures for Environmental Contaminants*[5]: children 6 < 12 months old, children 1 < 2 years old, children 2 < 3 years old, and children 3 < 6 years old. While children younger than 6 months may potentially have exposure in the residential setting, it is believed that exposure for children older than 6 months will be equivalent, if not greater, due to behavioral and anatomical/physiological development; therefore, the focus of the quantitative assessment was on children older than 6 months. This analysis is presented in full in *Appendix A.*

Based on the combined quantitative and qualitative analysis of the index lifestage issue, the Agency has determined that the children 1 < 2 years old lifestage represents the most appropriate index lifestage for children for most of the individual SOPs. There are some exceptions to this selection within this document. For example, in some of the individual SOPs, selecting some of the younger lifestages (e.g., the 1 < 2 year old lifestage in animal barns) is inappropriate because children in that age range are not expected to engage in the activities represented in the scenario.

[5] http://www.epa.gov/raf/publications/guidance-on-selecting-age-groups.htm

Any exceptions with regards to the index lifestage will be clearly presented and explained in the individual SOP.

In addition to the children 1 < 2 years old lifestage, the adult lifestage should also be consistently assessed for all SOPs and exposure routes with the exception of non-dietary ingestion exposure. Adults typically do not have the highest calculated body burden, but the adult lifestage does represent a major proportion of the exposed population and some exposure patterns, like pesticide applications, are uniquely associated with adult behaviors.

1.3.2 Durations of Exposure

Depending on the type of pesticide (i.e., insecticide, fungicide, etc.) and its use profile (i.e., application regimen) as well as behavioral/activity patterns and exposure pathways, the potential exists for individuals to experience exposure over a variety of exposure durations. Exposure can be on the order of one day, intermittently over multiple days, months, years or a lifetime, or continually over multiple days, months, years or a lifetime. The following should be considered in conjunction with the duration of exposure for a particular pesticide:

- **Use Pattern:** The application frequency, pests of concern, and regional differences impact use patterns. For example, more routine (i.e., repeated) treatments might occur in consistently warmer, southern areas of the country where there is more constant pest pressure over the course of a year.
- **Environmental Persistence:** The extent to which pesticide residues persist in the environment can determine the frequency and extent of exposure. For example, if a lawn is treated and the pesticide dissipates rapidly there is less chance of a sustained exposure for children playing on that lawn compared to a pesticide where residues slowly dissipate.
- **Biological Persistence:** The route of exposure, distribution, metabolism, and excretion of a pesticide should also be considered in conjunction with the available toxicological database. For example, if exposure is frequent but the pesticide is rapidly excreted and exposed individuals recover quickly from the toxicological effect continual exposure durations may not be germaine to risk assessment. Conversely, if applications are infrequent but the pesticide is slowly eliminated from the body then continual exposure would likely need further or more detailed consideration**.**
- **Toxicity Endpoint Reconciliation:** Toxicology studies are conducted using protocols which are designed to mimic various exposure patterns that can range from a one-time exposure event to a lifetime of expected exposures. It is important that the selection of a toxic endpoint be closely matched with an expected pesticide exposure pattern to yield more accurate estimates of risk. In cases where this is not possible, assessors should acknowledge the issue and describe how this can impact the interpretation of calculated risk estimates.

Due to standard pesticide use patterns and toxicity information typically available, exposure durations are summarized as short-term (i.e., up to 30 days), intermediate-term (i.e., 1-6 months), long-term (i.e., greater than 6 months), and lifetime (for assessing cancer risk). For the purposes of residential pesticide exposure assessment, the following is a general description of each category.

Short-term Exposure (up to 30 days)

Exposure up to one month can range from continual pesticide exposure or a series of intermittent exposures over the course of one month. Though most residential handlers are not expected to re-treat the same sites repeatedly day after day, a short-term average exposure should be estimated in a residential handler assessment. Post-application exposure can be reasonably characterized as short-term as well. For example, it is not unreasonable to assume a child would play on a treated home lawn for a number of consecutive days and thus could be continually exposed to residues resulting from a previous pesticide treatment. Short-term post-application exposures can be refined by accounting for residue dissipation and re-treatment intervals. For instance, if a product can be applied to residential lawns twice a year at 14 day intervals, this could be accounted for in the calculation of transferable residues for short-term post-application assessments. If residential handler or post-application exposure fits this pattern, exposure over this time period should be compared with toxicity studies of comparable duration to assess risk.

Intermediate-term Exposure (1-6 months)

Exposure over the course of 1-6 months can range from continual pesticide exposure or a series of intermittent exposures over the course of 1-6 months. Intermediate-term residential handler assessments are generally not required because individuals are not expected to re-treat the same sites repeatedly day after day for this duration, nor are a large number of pesticide applications resulting in intermittent exposures expected over this duration. Residential post-application exposure could, however, be characterized as intermediate-term. Additionally, as in short-term assessments, residue dissipation and re-treatment intervals should be considered in a refined assessment. If residential handler or post-application exposure fits this pattern, exposure over this time period should be compared with toxicity studies of comparable duration to assess risk.

Long-term Exposure (greater than 6 months)

Exposure for more than 6 months can range from continual pesticide exposure or a series of intermittent exposures for more than 6 months. Long-term residential handler assessments are not required because individuals are not expected to re-treat the same sites repeatedly day after day for this duration, nor are a large number of pesticide applications resulting in intermittent exposures expected over this duration. For a limited number of situations, however, post-application exposure could be characterized as long-term (e.g., post-application indoor inhalation following structural termiticide applications). Additionally, as in short- and intermediate-term assessments, residue dissipation and re-treatment intervals should be considered in a refined assessment. If residential handler or post-application exposure fits this pattern, an average exposure estimate over this time period should be compared with toxicity studies of comparable duration to assess risk.

Lifetime Exposure

Calculation of pesticide exposure over an individual's lifetime is applicable only when the active ingredient under consideration is a carcinogen and is calculated by considering multiple days of exposure over many years. Cancer risk depends on the extent to which a person might be exposed (i.e., over a certain duration and to a certain quantity of the pesticide) over the course of their lifetime. Lifetime exposure is calculated using the lifetime average daily dose equation

shown in *Equation 1.3* of *Section 1.1* and includes two factors that are generic (i.e., non-chemical specific) to cancer assessments: (1) the averaging time or lifetime and (2) the exposure time.

Residential handler cancer assessments should include typical application rates, if available (if not, available maximum rates should be used) and amounts handled. Additionally, absent reliable information, an assumption must be made as to the yearly exposure frequency (i.e., the number of times that an individual applies the pesticide per year. The exposure frequency will typically differ depending on the type of pesticide (e.g., fungicide, herbicide, insecticide) and could potentially differ across formulations.

In the past, cancer risk assessments have assumed that children are no more sensitive than adults to carcinogens (i.e., no adjustment was made to children's exposure estimates in calculating a cumulative lifetime exposure). More recently, the Agency's "Guidelines for Carcinogen Risk Assessment" (U.S. EPA, 2005) and “Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens” (U.S. EPA, 2005) proposed age-dependent adjustment factors to be applied to children's exposure. A 10x factor (exposure multiplier) is applied to exposure incurred from birth to 2 years and a 3x factor is applied to exposure incurred from 2 years to 16 years. No factor is applied to children age 16 years and beyond. These age-dependent factors are applied only to carcinogens shown to have a mutagenic mode of action. In general, most carcinogenic pesticides have not been shown to act through a mutagenic mode of action and thus this SOP document does not include further discussion of these adjustment factors. Any pesticide found to be a carcinogen acting through a mutagenic mode of action will be evaluated on a case by case basis and such an assessment should follow the Agency’s 2005 guidance.

1.3.3 Handler Exposure

Handler exposure refers to an exposure scenario in which an adult is exposed during mixing, loading, and applying a pesticide. Residential handler exposure assessments estimate dermal and inhalation exposures for individuals using pesticides in and around their homes. Some key assumptions for residential handler assessments include:

- Residential handlers are assumed to be wearing shorts and short-sleeve shirts, shoes, and socks. This assumption differs from occupational handler assessments which assume handlers are wearing at least long pants, long-sleeved shirts, shoes, and socks.
- Personal protective equipment (PPE) is not considered a mitigation option for residential handlers because users are not trained and compliance would not be expected.
- Pesticides are assumed to be applied only by adults. The assessment methods account for children 16 years and older who may also perform applications, thus for the purposes of this document 16 year olds may be grouped with adults.
- All applicable application methods should be assessed unless prohibited by the product label.

Handler exposure can be estimated in the absence of chemical-specific exposure monitoring data with the following information:

- Application site (e.g., lawns, gardens, kitchen baseboards, etc.);
- Formulation type (e.g., liquid, granule, etc.);
- Application equipment (e.g., aerosol can, sprinkler can, hose-end sprayer, etc.); and
- Application rate (e.g., lb ai/ft^2, lb ai/gal).

Given the information described above – application equipment, formulation, etc. – dermal and inhalation handler exposure can be predicted using a factor known as the unit exposure. Unit exposure is the ratio, for a given formulation and application equipment, of an individual's exposure to the amount of active ingredient handled (AaiH), expressed as mass active ingredient exposure per mass active ingredient handled (e.g., mg/lb ai). More specifically, this means that an individual's exposure will increase by a given (and constant) amount for every "unit" increase in the amount of active ingredient handled. It follows that the use of unit exposures assumes proportionality between exposure and the amount of active ingredient handled, such that if one doubles the amount handled, the resulting exposure would be doubled as well.

Exposure monitoring data for individuals mixing, loading, and applying pesticides enables derivation of unit exposure distributions for various pesticide formulations used in various application scenarios (e.g., granule formulations applied using a rotary spreader or liquid formulations applied via a handheld pump sprayer). These unit exposures can then be applied generically for use in estimating dermal or inhalation exposure for any active ingredient by estimating how much active ingredient an individual will handle using a particular piece of application equipment.[6] *Appendix C* references and summarizes all available handler exposure studies from which unit exposures are derived for use in residential exposure assessment.

Each SOP section provides information for two inputs that are necessary for calculating residential handler exposure: (1) unit exposures for each possible formulation/application equipment combination and (2) factors for deriving the amount of active ingredient handled such as area treated or volume used for each formulation/application equipment combination. Dermal and/or inhalation handler exposure calculations follow the general form shown below.

$$E = UE * AR * A \tag{1.4}$$

where:

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

Dermal and/or inhalation absorbed doses are calculated as:

$$D = \frac{E * AF}{BW} \tag{1.5}$$

[6] This topic was discussed during a 2007 FIFRA SAP. See: http://www.epa.gov/scipoly/sap/meetings/2007/010907_mtg.htm

where:

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

As described in *Section 1.3.2* residential handlers are expected to generally experience only short-term exposures. Intermediate- and long-term exposures are not typically expected but should be considered with respect to regional differences and product label use directions. Additionally, selection of exposure factor inputs is dependent on various considerations related to the exposure duration. For residential handler exposure assessment, these considerations include product application regimens and the extent to which an individual's exposure varies from day-to-day.

1.3.4 Post-application Exposure

Post-application exposure refers to an exposure scenario in which an individual is exposed through dermal, inhalation, and/or incidental oral (non-dietary ingestion) routes as a result of being in an environment that has been previously treated with a pesticide. Post-application dermal exposure pathways can be evaluated using estimates for surface residue (e.g., carpets, foliage, turf, etc.), surface-to-skin residue transfer for individuals contacting treated surfaces during certain activities, and exposure time. The measure of surface-to-skin residue transfer for a given treated area and activity is known as the transfer coefficient (TC). Transfer coefficients are derived from concurrent measurements of exposure and surface residue, and is the ratio of exposure rate, measured in mass of chemical per time (e.g., µg/hr), to residue, measured in mass of chemical per foliar surface area (e.g., $\mu g/cm^2$). In other words, transfer coefficients are exposure rates (e.g., mg/hr) normalized to residue (e.g., mg/cm^2), with resulting units of cm^2/hr. It follows that exposure rate for a given treated area and activity can then be predicted from a given residue using the transfer coefficient. Additionally, transfer coefficients are typically applied generically – that is, for any given chemical, treated area-activity transfer coefficients (e.g., apple harvesting, playing on lawns or carpets) can be used.

Post-application inhalation exposure depends on concentrations in the air after treatment and inhalation rates. Post-application oral exposures are based on the ingestion of residues that can result from transfer of residues from hand-to-mouth or object-to-mouth or via direct ingestion of residues through soil ingestion, dust ingestion, or ingestion of pesticide granules or baits.

Post-application dermal and inhalation assessments are typically conducted for a number of lifestages (ranging from children 1 < 2 years old through adulthood) while non-dietary oral post-application exposure assessments are typically only conducted for younger lifestages. Non-dietary oral exposure generally consists of two "incidental" exposure pathways – exposure resulting from children contacting treated surfaces and putting their hands in their mouth (i.e., "hand-to-mouth" exposure) and exposure resulting from children putting objects or other toys in their mouth that had been in contact with treated surfaces (i.e., "object-to-mouth" exposure). Exposure via these pathways are dependent upon the surface loading of the pesticide, transfer of the pesticide to children's hands or objects from the treated surface, and the number of times a

child places their hands or an object in their mouth. While the basic input variables remain unchanged, the overall methodology/algorithm to assess this exposure has been revised since previous versions of the Residential SOPs. Working collaboratively with the Agency's Office of Research and Development (ORD), the Residential SOPs incorporate a modified version of the algorithm utilized in the Stochastic Human Exposure Dose Simulation (SHEDS) – Multimedia model. Previous SOP versions assumed complete removal of hand/object residue per mouthing contact and complete residue replenishment of the hand/object per contact with the treated surface. The revised algorithm follows a more realistic removal/replenishment mechanism between hand/object mouthing events, establishing a maximum amount of residue which can be on the hand, or a maximum dermal hand loading, based on the post-application dermal exposure estimate.[7]

Like residential handler assessments, residential post-application assessments differ from occupational post-application assessments in that they assume individuals are wearing typical clothing such as shorts and short-sleeved shirts, shoes, and socks. Additionally, when managing occupational post-application risks the Agency typically uses an administrative control known as a Restricted Entry Interval (REI) which precludes worker activities in a treated area until residues dissipate to certain levels. This is not feasible in residential settings because excluding individuals from contact with their treated lawns or pets is not practical. Therefore, residential post-application exposure assessments need to address the potential for exposure on the day of application (i.e., "day 0") because there is not a viable means of mitigating that type of scenario.

If applicable, each SOP section provides separate algorithms for assessing dermal, inhalation, and oral non-dietary post-application exposures. Because both residues and their transfer to the body are likely dependent on both the chemical and scenario (e.g., indoors vs. outdoors; smooth surfaces vs. textured surfaces; etc.), chemical- and scenario-specific data are most reliable when performing post-application exposure assessments. However, in the absence of such data, generic exposure factors outlined in the scenario-specific SOPs are provided and should be used to estimate exposure.

As described in *Section 1.3.2*, individuals can experience post-application exposures for all possible exposure durations and selection of exposure factor inputs is dependent on various considerations related to the exposure duration. For post-application exposure assessment, these considerations include product application regimens, residue dissipation, longitudinal activity patterns, and the extent to which exposure is expected to vary from day-to-day.

1.3.5 Combining Exposure Scenarios

Each SOP provides methods for estimating daily exposures for a number of potential scenarios with the focus on assessment of single routes of exposure (i.e., dermal, inhalation, and non-dietary oral exposure). However, in reality, exposures to pesticides do not impact individuals through only dermal or oral contact and do not occur as single, isolated events, but rather as a series of sequential or concurrent events that may overlap or be linked in time and space. Based

[7] The revised incidental oral exposure algorithm was first utilized in the Agency's N-Methyl Carbamate cumulative risk assessment.

on this, risk estimates resulting from different exposure routes are combined when it is likely that they can occur simultaneously based on the use pattern and when the toxicological effects across different routes of exposure are the same.

There are several methods of measuring and aggregating risk. Two aggregation methods used include the Total MOE and the Aggregate Risk Index (ARI). Arithmetically, the two approaches are the same when the uncertainty factors (UF) are the same for all routes of exposure. When the UF's differ by route, however, the ARI is required. Further discussion of these two approaches and the corresponding algorithms can be found in the Agency's *General Principles for Performing Aggregate Exposure and Risk Assessments*[8].

To the extent that information is available, it is important for the assessor to characterize the potential for co-occurrence as well as to characterize the assessment inputs when combining risks from multiple scenarios. For example, it is likely that a child could experience dermal and hand-to-mouth exposures intermittently over a particular period of time while playing on previously treated turf. If each of those exposure scenarios is assessed using health-protective inputs, one must consider the likelihood when combining them that those individual health-protective exposures could reasonably co-occur at those same levels. Each scenario-specific SOP contains a more specific discussion and explanation of what routes of exposure should be combined.

1.3.6 Exposure Uncertainty and Characterization

A number of different types of uncertainty are present in these SOPs. Uncertainty may occur as a result of the techniques used to estimate environmental concentrations (i.e., analytical uncertainty), the underlying models and relationships assumed for certain types of data (e.g., exponential decay for surface residues), and the application of surrogate information or data for exposure scenarios and exposure factors lacking specific information. Expected but unquantifiable variation in daily and longitudinal exposure also introduces uncertainty. Each scenario-specific SOP includes an exposure characterization and data quality section which describes the uncertainties associated with that particular scenario. While these uncertainties exist they should be addressed in the exposure assessment process to ensure that resulting risk assessments are developed in a manner that can be considered health protective for the particular situations being evaluated (U.S. EPA, 2002). The following discussion outlines general or universal uncertainties that should be considered in the interpretation of all the SOPs presented in this document.

Surrogate Exposure Data

For many scenarios, specific information is lacking and available information for another exposure scenario is considered appropriate to use. Examples include using exposure data for individuals applying powder formulations to assess exposure for individuals applying liquid products or using post-application occupational field worker exposure data for home gardening activities. Though reasonable when exposure information is unavailable, the assessment should characterize the uncertainty and identify the data gap.

[8] http://www.epa.gov/opp00001/trac/science/aggregate.pdf

Exposure Data Analysis

The exposure data utilized across residential exposure assessments (e.g., handler exposure data, post-application exposure data, etc.) are considered reasonable for the purposes of establishing distributions and estimating exposure. The data are from actual applications using standardized exposure sampling methodologies and laboratory analyses.

Additionally, the use of exposure data in certain ways requires assumptions with regard to correlations or relationships between variables. For example, the underlying assumption of the use of exposure data as unit exposures – proportionality between the amount of active ingredient handled and exposure – is uncertain, though potentially conservative. However, as a prediction mechanism, it is considered practical and useful for the purposes of handler exposure assessment in a regulatory context. It provides a straightforward handler exposure calculation method and enables risk mitigation via formulation comparisons or decreased application rates. Where assumptions such as this are implicit, the assessment should characterize the associated uncertainty.

Longitudinal Exposure Variation

Information detailing the extent to which various residential pesticide exposure factors vary from day-to-day or application-to-application is largely unavailable. Therefore, if day-to-day or application-to-application variation is not assumed to occur for short-, intermediate-, long-term or lifetime assessments, the likelihood of this pattern should be characterized.

1.3.7 Ethical Considerations of Human Exposure Data

As described in the preamble of this document, the Residential SOPs are based on a number of monitoring studies that involved the intentional exposure of humans to pesticides (e.g., scripted activities by human volunteers). These studies can only be used for regulatory purposes by the Agency if they are compliant with the requirements of 40 CFR 26. Each of the studies used in the development of this document has been found to be compliant with these requirements.

In some cases, however, research considered throughout the process of revising the SOPs, though germane to a particular scenario under consideration, had to be excluded from consideration because they are not compliant with 40 CFR 26. For example, for the Lawns/Turf SOP, there is a section (Section 3.2.8) that describes how the exposure of golfers is estimated based on monitoring data for workers at a golf course. In this case, one of the available golfer exposure studies (Putnam et al., 2008) did not meet 40 CFR 26 requirements and, therefore, the data from that study were not included in the final analysis. As the Agency considers the Residential SOPs a "living" document, if additional applicable research is identified that should be considered, it would also be subject to review under the criteria stipulated in 40 CFR 26.

1.3.8 Deterministic Exposure Assessment Methodology

Deterministic methods are most commonly used for residential exposure assessments. In a deterministic exposure assessment, each algorithm input is represented by a single numeric value called a point estimate. The output of a deterministic exposure assessment, therefore, is also a single point estimate. Exposure estimates are easily calculated using deterministic methods and can be relatively straightforward to communicate to risk managers. As described in *Section 1.3.2*, due to both expected exposure patterns and available toxicity information, routine residential exposure assessments include short-term exposures, and sometimes intermediate- and long-term exposures. For these assessments, the Agency typically utilizes arithmetic mean inputs coupled with chemical-specific inputs such as maximum application rates or minimum retreatment intervals in order to yield reasonably health-protective estimates of exposure.

Even though deterministic methods are straightforward and provide a health protective estimate of exposure, they do not provide information on the variability and uncertainty inherent in the algorithm inputs. As a result, deterministic assessment may not provide sufficient detail on the range of possible exposures or the level of confidence in the estimate of exposure used in risk assessment. Probabilistic assessment is a more complex methodology that accounts for the variability of each algorithm input. Additionally, probabilistic methods can be incorporated into more robust sensitivity analyses, based on each algorithm input's probability distribution. These sensitivity analyses can be useful at identifying the inputs that are the main contributors of exposure and can be used to prioritize additional research efforts (U.S. EPA, 2001).

As the main focus for the Residential SOPs is to provide a simple, yet health protective, approach for assessing residential exposures in the form of a deterministic method using appropriate default point estimates, each section presents summary tables and algorithms which correspond to this goal. The appendices for each section, however, analyze and characterize the data for each algorithm input in the form of probability distributions, so that users can conduct a probabilistic exposure assessment, if necessary. Other than presenting datasets in a format useful for probabilistic methods, this document does not provide any other guidance, nor should it be viewed as recommending probabilistic assessment as a routine approach. As described above, for routine use by the Agency, deterministic assessments yield understandable and health-protective exposure estimates.

Section 2 Universal Exposure Factors

Many of the algorithm inputs discussed in this document are specific to a particular scenario. However, some factors are common across the SOPs. These factors include: body weight, inhalation rate, body surface area, hand surface area mouthed, object surface area mouthed, and saliva extraction factor. Where applicable, each SOP refers to this section for discussion of these universal exposure factors.

Where appropriate and when data are available, the recommended distributions are presented for lifestages that are potentially exposed during residential pesticide use. These are represented by the following lifestages: adults 16 < 80 years (male and female combined), children 11 < 16 years old (male and female combined), children 6 < 11 years old (male and female combined), children 3 < 6 years old (male and female combined), children 2 < 3 years old (male and female combined), and children 1 < 2 years old (male and female combined) respectively. The selection of these lifestages is based, in part, on discussions presented in *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005). Distributions for different lifestages can be used if there is a need to assess a more specific lifestage. The following sections provide summary descriptions and recommended exposure assessment inputs for each factor.

2.1 Body Weight

In order to estimate risk, toxicological points of departure (POD) are compared with exposure estimates. These PODs are typically dose values calculated by normalizing by body weight (e.g., mg/kg). Therefore, to make an appropriate comparison to estimate risk, exposure estimates must be expressed in a similar fashion. *Table 2-1* below provides body weights for use in residential pesticide exposure assessment taken from the EPA Exposure Factors Handbook 2011 Edition (U.S. EPA, 2011; Tables 8-3 through 8-5). Adult body weights are provided for various lifestages in the Exposure Factors Handbook 2011 Edition and have been averaged across lifestages for both the percentiles and mean body weight values in the table below.

Table 2-1: Recommended Estimates for Body Weight (kg)

Lifestage	Percentiles									
	5	**10**	**15**	**25**	**50**	**75**	**85**	**90**	**95**	**Mean**
Combined Adults 16 < 80 years old	53	57	60	66	77	90	99	110	120	80
Male Adults 16 < 80 years old	61	65	69	73	83	96	100	110	120	86
Female Adults 13 < 49 years old[a]	46	50	52	56	63	78	87	95	110	69
Children 11 < 16 years old	34	37	41	45	54	65	73	79	89	57
Children 6 < 11 years old	20	21	22	24	29	37	42	46	53	32

Table 2-1: Recommended Estimates for Body Weight (kg)										
Lifestage	**Percentiles**									
	5	**10**	**15**	**25**	**50**	**75**	**85**	**90**	**95**	**Mean**
Children 3 < 6 years old	14	14	15	16	18	20	22	24	26	19
Children 2 < 3 years old	11	12	12	12	14	15	16	16	17	14
Children 1 < 2 years old	8.9	9.3	9.7	10	11	12	13	13	14	11
Children 6 < 12 months old	7.1	7.5	7.9	8.3	9.1	10	11	11	11	9.2

a. Female body weight is meant to represent average body weight of women of child-bearing age, assumed to be ages 13 through 49. Data provided in the EFH for ages 11 through <50 were averaged to represent this lifestage.

2.2 Inhalation Rates

Inhalation rates are utilized in a number of the SOPs in this document. The inhalation rates presented in this section are based on recommendations from the Exposure Factors Handbook 2011 Edition (U.S. EPA, 2011; Table 6-1). The values provided in the Exposure Factors Handbook 2011 Edition are derived from multiple studies and represent average daily inhalation rates in units of m^3/day. For the purposes of this SOP, the rates were converted to m^3/hr and the adult rates were averaged across the lifestages provided in the Exposure Factors Handbook 2011 Edition. *Table 2-2* provides inhalation rates on a per hour basis for adults and children.

Table 2-2: Recommended Estimates for Daily Average Inhalation Rates (m^3/hr)	
Lifestage	**Mean**
Children 6 < 12 months old	0.23
Children 1 < 2 years old	0.33
Children 2 < 3 years old	0.37
Children 3 < 6 years old	0.42
Children 6 < 11 years old	0.50
Children 11 < 16 years old	0.63
Adults 16 < 81 years old	0.64

2.3 Body Surface Area

Body Surface Area

Body surface area is utilized in a number of the SOPs. *Table 2-3* below provides total body surface areas taken from the Exposure Factors Handbook 2011 Edition (U.S. EPA, 2011; Tables 7-9 through 7-11). Adult surface areas are provided for various lifestages in the Exposure Factors Handbook 2011 Edition and have been averaged across lifestages for both the percentiles and mean surface area values in the table below.

Table 2-3: Recommended Estimates for Body Surface Area (m^2)										
Lifestage	**Percentiles**									
	5	**10**	**15**	**25**	**50**	**75**	**85**	**90**	**95**	**Mean**
Combined Males/Females 16 < 80 years old	1.54	1.6	1.66	1.75	1.93	2.12	2.23	2.3	2.42	1.95
Males 16 < 80 years old	1.71	1.78	1.83	1.9	2.05	2.21	2.31	2.38	2.49	2.07
Female Adults 13 < 49 years old[a]	1.42	1.48	1.53	1.59	1.74	1.90	2.04	2.12	2.22	1.77
Children 11 < 16 years old	1.19	1.25	1.31	1.40	1.57	1.75	1.86	1.94	2.06	1.59
Children 6 < 11 years old	0.81	0.85	0.88	0.93	1.05	1.21	1.31	1.36	1.48	1.08
Children 3 < 6 years old	0.61	0.64	0.66	0.68	0.74	0.81	0.85	0.89	0.95	0.76
Children 2 < 3 years old	0.52	0.54	0.55	0.57	0.61	0.64	0.67	0.68	0.70	0.61
Children 1 < 2 years old	0.45	0.46	0.47	0.49	0.53	0.56	0.58	0.59	0.61	0.53
Children 6 < 12 months old	0.39	0.4	0.41	0.43	0.46	0.48	0.49	0.5	0.51	0.45

a. Female body weight is meant to represent average body weight of women of child-bearing age, assumed to be ages 13 through 49. Data provided in the EFH for ages 11 through <50 were averaged to represent this lifestage.

Adjustments to Transfer Coefficients for Children

One of the factors used in dermal post-application assessments, the transfer coefficient, is typically derived from studies which utilize adult volunteers. In order to translate these transfer coefficients to children, an adjustment factor is needed based on body surface area. Children have a lower body surface area than adults and consequently they have lower absolute exposures than adults, all other factors being equal. This translation is performed using a number of simple surface area ratios depending on the lifestage under consideration.

For the adult component of this ratio, the combined (males and females) mean surface area is used (i.e., 1.95 m^2, average of the mean surface areas for ages 16 < 80 years) (U.S. EPA, 2011; Table 7-9). Then the corresponding combined male and female mean for the lifestage under consideration is used to derive the adjustment factor. A summary of adjustment factors for relevant lifestages, representing the respective ratios of mean body surface area to mean adult body surface area is provided in *Table 2-4* below.

Table 2-4: Transfer Coefficient Surface Area Adjustment Factor		
Lifestage	**Surface Area (m^2) [Mean: Combined Males and Females[1]]**	**Adjustment Factor[2]**
6 < 12 months	0.45	0.23
1 < 2 years	0.53	0.27
2 < 3 years	0.61	0.31
3 < 6 years	0.76	0.39
6 < 11 years	1.08	0.55
11 < 16 years	1.59	0.82

[1] U.S. EPA, 2011; Table 7-9

[2] Derived as ratio of the combined male and female mean surface area for specified lifestage to adult surface area

Table 2-4: Transfer Coefficient Surface Area Adjustment Factor		
Lifestage	**Surface Area (m^2) [Mean: Combined Males and Females[1]]**	**Adjustment Factor[2]**
($1.95\ m^2$; average of male and female means) (e.g., 3 < 6 years old: $0.76\ m^2 \div 1.95\ m^2 = 0.39$)		

2.4 Fraction Hand Surface Area Mouthed (F_M)

An important factor used in hand-to-mouth post-application assessments is the fraction of a hand's surface area that is mouthed by a child. This value is used in a number of the SOPs. The fraction hand surface area mouthed values are from the Zartarian et al. (2005) analysis of data originally presented in Leckie et al. (2000). The Leckie et al. (2000) study consisted of a data set of 20 suburban children videotaped outdoors. Part of the videotape analysis performed by Leckie was to determine the amount of the hand that was mouthed by each child every time a mouthing event occurred. This was broken up into five categories, including:

- Outside mouth contact – defined as finger(s)/hand touching lips but no immersion in mouth
- Partial finger – defined as less than half the finger(s) are inside mouth
- Full finger – defined as more than half the finger(s) are inside mouth
- Partial palm with fingers – defined as fingers in mouth as well as part of the palm area
- Partial palm without fingers – defined as fingers in mouth as well as part of the palm area

The analysis in Zartarian et al. (2005) consisted of assigning numerical values to each of the five scenarios discussed above. It was assumed that each finger is 10% of the hand, and that the surface area of palm that can be mouthed is 25% of the hand. For 1 "partial finger" inserted into the mouth a value of 5% of the hand was selected, 2 partial fingers 10%, *et cetera*. Based on an analysis of the data, it was determined that a beta distribution (α=3.7, β=25) best fits the observed data. *Table 2-5* provides distributions and point estimates of fraction hand surface area mouthed for use in residential pesticide exposure assessment. The data used to derive fraction of hand surface area mouthed is provided in *Section B.1* of *Appendix B.*

Table 2-5: Fraction Hand Surface Area Mouthed	
Statistic	**Fraction**
50^{th} percentile	0.118
75^{th} percentile	0.164
95^{th} percentile	0.243
AM (SD)	0.127 (0.0614)
GM (GSD)	0.114 (1.58)
Range	0.05 – 0.4
N	220
AM (SD) = arithmetic mean (standard deviation) GM (GSD) = geometric mean (geometric standard deviation)	

2.5 Surface Area of Object Mouthed (SAM_O)

One of the factors used in object-to-mouth post-application assessments is the surface area (expressed in cm^2) of the object that is mouthed by a child, and is used in a number of the SOPs. Based on the area of hand mouthed by 2-5 years old as reported by Leckie et al. , (2000), and the assumption that children mouth a smaller area of an object than their hand, an exponential distribution with a minimum of 1 cm^2, a mean of 10 cm^2, and a maximum of 50 cm^2 was chosen. The maximum is comparable to the surface area of a ping-pong ball. Additional details and analyses are provided in *Section B.2* of *Appendix B.*

2.6 Fraction of Pesticide Extracted by Saliva (SE)

One of the factors used in hand-to-mouth and object-to-mouth post-application assessments is the fraction of pesticide extracted from the hand/object via saliva. The values for fraction of pesticide extracted by saliva are based on analysis of data collected in a study by Camann et al. (1996). This study focused specifically on fraction of pesticide extracted by saliva from hands, not objects. However, there are currently no data available to address the removal of residues from objects by saliva during mouthing events so this study is being used for both hands and objects. The estimates of saliva extraction were derived using a beta distribution ($\alpha = 7.0$, $\beta = 7.6$). *Table 2-6* provides estimates of pesticide extracted by saliva for use in residential pesticide exposure assessment. Additional details and analyses are provided in *Section B.3* of *Appendix B.*

Table 2-6: Fraction of Pesticide Extracted by Saliva

Statistic	Fraction of Pesticide Extracted by Saliva
50^{th} percentile	0.50
75^{th} percentile	0.57
90^{th} percentile	0.64
95^{th} percentile	0.68
99^{th} percentile	0.80
AM (SD)	0.48 (0.13)
GM (GSD)	0.46 (1.35)
Range	0.22 – 0.71
N	27

AM (SD) = arithmetic mean (standard deviation)
GM (GSD) = geometric mean (geometric standard deviation)

2.7 Life Expectancy Averaging Time

An important factor to consider when evaluating cancer risk is life expectancy because it is used to derive the lifetime average daily dose estimate. Life expectancy values are presented in the Exposure Factors Handbook 2011 Edition Table 18-1 (U.S. EPA, 2011). The table shows that the overall life expectancy is 78 years based on life expectancy data from 2007. In 2007, the average life expectancy for males was 75 years and 80 years for females. **Based on the available data, the recommended value for use in cancer risk assessments is 78 years.**

Section 3 Lawns/Turf

The residential lawns/turf SOP provides algorithms and inputs to assess a number of handler and post-application turf exposure scenarios. The populations considered in this SOP are those individuals who are potentially exposed to pesticides from either treating turf with a product available for sale to the general public or after contact with treated turf in many settings, including residential lawns, playgrounds, parks, recreation areas, schools, and golf courses. Another potential source of exposure addressed by this section, where professional applications could potentially lead to exposure by the general population, if applicable to the pesticide and its label under consideration, is treated sod purchased at retail locations.

Before the development of an exposure assessment for a turf scenario, the assessor should review the pesticide label to determine whether the scenario is appropriate based on the usage of the product. Specific labeling statements that indicate an assessment for residential lawns is needed are as follows:

- **Registered for Use on Turfgrass**: Determine whether the labeling contains directions for use on "turfgrass," "lawns," or "ornamental turf," or on specific species of turfgrasses, such as "bluegrass," "zoysia," "bentgrass," etc.

- **Limitation and Descriptive Statements**: Assume that a product registered for use on turfgrass is used on home lawns or by homeowners, unless a specific statement on the label indicates the product is only used in non-residential settings. Examples include:

    - For golf course use only;
    - For commercial sod farm use only;
    - For professional athletic field use only; and
    - For industrial/commercial turf use only.

    Additionally, “Restricted Use Pesticide” classification indicates that the product cannot be bought or applied by homeowners (i.e., no residential handler exposure/risk assessment required), but it may be applied by commercial applicators to residential sites; therefore, a post-application risk assessment may be required.

- Post-application assessments do not need to be performed if label directions indicate the turf use is an edging use (e.g., along fence rows), a foundation perimeter treatment (e.g., 3 foot band around the perimeter of a house), or a specific spot treatment (e.g., ant mounds). These types of uses can result in residues on turf but residential exposure is expected to be low. Post-application assessments should be conducted for all other turf application scenarios.

If a turf use is possible, the assessment should then characterize and estimate the potential for exposure by route (e.g., dermal, non-dietary ingestion, inhalation) following the methodology outlined in this SOP. The assessor should also consider the durations of exposure for each route.

Much of the data contained within this SOP is the result of the Outdoor Residential Data-Call-In (OREDCI) that was issued to pesticide registrants in 1995 (U.S. EPA, 1995) under the authority of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). This DCI required additional data, which would allow for more refined turf handler and post-application exposure assessments. It impacted all pesticide registrants who produced products that could lead to handler and post-application exposure on turf. In anticipation of the need to provide these data to the Agency, the industry-based Occupational and Residential Exposure Task Force (ORETF) was formed prior to the time that the DCI was issued.

3.1 Handler Exposure Assessment

This residential turf handler SOP provides a standard method for estimating potential dermal and inhalation doses resulting from applying pesticides to residential turf. Such exposure is assumed to occur only to adults (i.e., individuals 16 years old or older).

Dermal and Inhalation Handler Exposure Algorithm

As described in *Section 1.3.3*, 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:

$$E = UE * AR * A \quad (3.1)$$

where:

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

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

$$D = \frac{E * AF}{BW} \quad (3.2)$$

where:

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

Handler exposure for applications to lawns and turf is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.3* such as the product-specific application regimen.

Dermal and Inhalation Handler Exposure Algorithm Inputs and Assumptions

Recommended values for handler exposure (inhalation and dermal) assessments are provided in *Table 3-1* and *Table 3-2*. Following these tables, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 3-1: Turf – Recommended Unit Exposure (mg/lb ai) Point Estimates

Formulation	Equipment/ Application Method	Dermal	Inhalation	Appendix Page Reference
		Point Estimate	Point Estimate	
Granules	Push-type spreaders	0.81	0.0026	C-4
	Belly grinders	360	0.039	C-11
	Spoon	6.2	0.087	C-20
	Cup	0.11	0.013	C-24
	Hand dispersal	160	0.38	B-39
	Shaker can	No exposure data available for this application scenario. Exposure data for granule applications using a cup recommended as surrogate data.		
Liquid concentrates	Manually-pressurized handwand	63	0.018	C-56
	Hose-end sprayer	13.4	0.022	C-79
	Backpack	130	0.14	C-91
	Sprinkler can	No exposure data available for this application scenario. Exposure data for hose-end sprayer applications of liquid concentrates recommended as surrogate data.		
Ready-to-Use (RTU)	Hose-end sprayer	6.26	0.034	C-107
	Trigger-pump sprayers	85.1	0.061	C-113
	Aerosol can	370	3.0	C-134
Wettable Powder	Manually-pressurized handwand	69	1.1	C-141
	Hose-end sprayer	No exposure data available for this application scenario. Exposure data for hose-end sprayer applications of liquid concentrates recommended as surrogate data.		
	Backpack	No exposure data available for this application scenario. Exposure data for manually-pressurized handwand applications of wettable powders recommended as surrogate data.		
	Sprinkler can	No exposure data available for this application scenario. Exposure data for hose-end sprayer applications of liquid concentrates recommended as surrogate data.		
Wettable Powder in Water-soluble Packaging	Manually-pressurized handwand	No exposure data available for this scenario. Exposure data for manually-pressurized handwand applications of liquid concentrates recommended as surrogate data.		

Table 3-1: Turf – Recommended Unit Exposure (mg/lb ai) Point Estimates				
Formulation	**Equipment/ Application Method**	**Dermal**	**Inhalation**	**Appendix Page Reference**
		Point Estimate	**Point Estimate**	
	Hose-end sprayer	No exposure data available for this scenario. Exposure data for RTU hose-end sprayers recommended as surrogate data.		
	Backpack	No exposure data available for this scenario. Exposure data for manually-pressurized handwand applications of liquid concentrates recommended as surrogate data.		
	Sprinkler can	No exposure data available for this scenario. Exposure data for RTU hose-end sprayers recommended as surrogate data.		
Dry Flowable / Water-dispersible Granule	Manually-pressurized handwand	No exposure data available for this scenario. Application method-specific exposure data for wettable powders recommended as surrogate data.		
	Hose-end sprayer			
	Backpack			
	Sprinkler can			
Micro-encapsulates	Manually-pressurized handwand	No exposure data available for this scenario. Application method-specific exposure data for liquid concentrates recommended as surrogate data.		
	Hose-end sprayer			
	Backpack			
	Sprinkler can			

Table 3-2: Turf – Recommended Handler Exposure Factor Point Estimates		
Exposure Factor (units)		**Point Estimate(s)**
Application Rate (mass ai per unit area)		Maximum labeled rate
Area Treated/Amount Handled	Push-type spreader (acres)	0.5
	Belly grinder (ft^2)	1,000
	Cup, Spoon, Hand (ft^2)	100
	Manually-pressurized handwand (gallons)	5
	Backpack sprayer (gallons)	5
	Hose-end sprayer (acres)	0.5
	Sprinkler can (ft^2)	1,000
	Trigger-sprayer (# bottles)	1
	Aerosol Can (# cans)	1
	Any equipment, fire ant mounds (# mounds)	5
Body Weight	Adult (kg)	80

Unit Exposures

As described in *Section 1.3.3*, the unit exposure is the ratio, for a given formulation/application method combination, between exposure and the amount of active ingredient handled, with units

mass exposure per mass active ingredient handled (e.g., mg ai exposure/lb ai handled). **The recommended point estimates for individual handler scenarios are shown in *Table 3-1*.** Data summaries can be found in *Appendix C*.

Amount of Active Ingredient Handled

The algorithm for estimating handler exposure requires some estimate of the amount of active ingredient handled per day. This factor varies based on the type of equipment or application method used and is estimated based on the application rate specified on the product label. First, the assessor should assemble application rate information in terms of active ingredient per area treated (e.g., lb ai/acre, lb ai/1000 ft^2) and active ingredient per volume of spray (e.g., lb ai/gallon solution). For example, instructions for a granule formulation might direct application of 2 lbs of product per 100 square feet or a spray application might say to apply 2 gallons of solution per 100 square feet.

Data on the amount of active ingredient handled are limited and difficult to collect. The amounts of active ingredient handled presented in this SOP are reasonable high-end assumptions for typical residential turf application equipment. These values and the supporting data (where applicable) are discussed below.

- Push-type spreader: ½ an acre for broadcast applications. This value is supported by data from the Outdoor Residential Pesticide Use and Usage Survey and National Gardening Association Survey (Johnson, et al., 1999), which showed that 73% of the people surveyed had lawns smaller than ½ acre.
- Belly grinder: 1,000 ft^2 for spot treatments. Belly grinders are not practical for broadcast lawn treatments.
- Cup, Spoon, or Hand: 100 ft^2 for spot treatments. Applications of granule pesticides with a cup, spoon, or by hand are not practical for broadcast lawn treatments, but are more appropriate for treating ant mounds, yellow jacket nests or dandelions (check label for pest directions).
- Manually-pressurized handwand sprayer: 5 gallons for spot treatments, which assumes mixing/loading/applying two 2.5-gallon sprayers. Manually-pressurized hand sprayers are not practical for broadcast lawn treatments due to the numbers of gallons generally required for broadcast sprays (e.g., 15 gallons/1000 sq ft).
- Backpack sprayer: 5 gallons for spot treatments, which assumes mixing/loading/applying two 2.5-gallon sprayers. Backpack sprayers are not practical for broadcast lawn treatments due to the numbers of gallons generally required for broadcast sprays (e.g., 15 gallons/1000 sq ft).
- Hose-end sprayer: ½ an acre for broadcast applications. This value is further supported by data from the Outdoor Residential Pesticide Use and Usage Survey and National Gardening Association Survey (Johnson, et al., 1999), which showed that 73% of the people surveyed had lawns smaller than ½ acre.
- Sprinkler can: 1,000 ft^2 for spot treatments. Sprinkler cans are not practical for broadcast lawn treatments due to the numbers of gallons generally required for broadcast sprays (e.g., 15 gallons/1000 sq ft).

- Trigger sprayer: 1 bottle. Trigger sprayers are not practical for broadcast lawn treatments but are more appropriate for treating ant mounts, yellow jacket nests or dandelions (check label for pest directions).
- Aerosol can: 1 can. Aerosol cans are not practical for broadcast lawn treatments but are more appropriate for treating ant mounts, yellow jacket nests or dandelions (check label for pest directions).
- Fire ant mound treatments (any equipment): 5 individual mounds. Note: some labels have directions for broadcast applications to prevent invasion of fire ants of areas widely infested.

Future Research/Data Needs

Unavailable information that would refine handler exposure assessments for pesticide applications to turf include:

- Application intervals (i.e., how often chemicals are applied to turf) – either chemical-specific or generic intervals by pesticide-type (e.g., fungicides, insecticides, etc.).
- Survey information (preferably longitudinal) detailing:
    - General pesticide use to obtain, on a per capita basis, the probability of treating turf with pesticides;
    - Amount of product or formulation used or area treated per application; and,
    - Product-specific application rates to obtain the likelihood that the maximum rate is used.
- Handler exposure data:
    - Specific for turf applications as well as for those formulations and/or application methods currently unavailable as shown in *Table 3-1*;
    - Describing the extent to which an individual's exposure for a given formulation and application method varies from application-to-application.

Exposure Characterization and Data Quality

<u>Unit Exposures</u>

- The exposure data underlying unit exposures are considered reasonable for the purposes of estimating exposure. The data are from actual applications using standardized exposure sampling methodologies and laboratory analyses.
- The underlying assumption of the use of exposure data as unit exposures – proportionality between the amount of active ingredient handled and exposure – is uncertain, though potentially conservative. However, as a prediction mechanism, it is considered practical and useful for the purposes of handler exposure assessment in a regulatory context. It provides a straightforward handler exposure calculation method and enables risk mitigation in the form of formulation comparison and decreased application rates.
- The extent to which an individual's exposure (expressed via unit exposures) varies day-to-day or application-to-application is unknown; therefore, the assumption that there is no variation when assessing longer-term exposure durations is considered conservative.

Amount of active ingredient handled

- Information on the amounts of active ingredient handled for typical residential turf application equipment is largely unavailable. The estimates used however, are believed to result in health protective exposure estimates.
- The extent to which the amount an individual will handle per application varies from day-to-day or application-to-application is unknown; therefore, the assumption that there is no variation when assessing longer-term exposure durations is considered conservative.

3.2 Post-application Exposure Assessment

Post-application exposure can result from a number of activities following pesticide applications on turf. While exposure may occur for people of all ages, adults, children 11 < 16 years old, children 6 < 11 years old, and children 1 < 2 years old are considered the index lifestages for lawns and turf depending on the exposure scenario.

The Agency has derived standard methods for estimating exposure and dose for eight scenarios resulting from contact with turf that has previously been treated with pesticides:

- Section 3.2.1 - adult/children 1 < 2 years old inhalation exposure resulting from activities on turf;
- Section 3.2.2 - adult/children 1 < 2 years old dermal exposure resulting from activities on turf;
- Section 3.2.3 - children 1 < 2 years old non-dietary ingestion via hand-to-mouth activity;
- Section 3.2.4 - children 1 < 2 years old non-dietary ingestion via object-to-mouth activity;
- Section 3.2.5 - children 1 < 2 years old non-dietary ingestion via soil ingestion;
- Section 3.2.6 - children 1 < 2 years old non-dietary ingestion via episodic granular ingestion;
- Section 3.2.7 - adult/children 11 < 16 years old dermal exposure resulting from mowing; and
- Section 3.2.8 – adult/children 11 < 16 years old/children 6 < 11 years old dermal exposure resulting from golfing.

3.2.1 Post-application Inhalation Exposure Assessment

Post-application inhalation exposure while engaged in activities on or around previously treated turf is generally not assessed and should be handled on a case-by-case basis. The combination of low vapor pressure for chemicals typically used as active ingredients in outdoor residential pesticide products and dilution in outdoor air is likely to result in minimal inhalation exposure.

3.2.2 Post-application Dermal Exposure Assessment: Physical Activities on Turf

The residential turf post-application SOP provides a standard method for estimating potential dermal doses among adults and/or children 1 < 2 years old from dermal contact with turf that has previously been treated with pesticides. This scenario assumes that pesticide residues are transferred to the skin of adults/children who enter treated lawns for play, recreation, yardwork, or other homeowner activities. Considering the strengths and limitations of available data and behavioral characteristics of potentially exposed lifestages (see *Appendix A* for more details); post-application dermal exposure is only calculated for adults and children 1 < 2 years old.

It is assumed that individuals contact previously treated turf on the same day a pesticide is applied. However, the assessment can be refined to more accurately reflect exposure over a longer period of time (e.g., a week or month) if toxicological or activity information indicate the need for such estimates.

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. As discussed in *Section 1.3.4* 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.

$$E = TTR_t * CF1 * TC * ET \quad (3.3)$$

where:

E	= exposure (mg/day);
TTR_t	= turf transferable residue on day t (µg/cm^2);
CF1	= weight unit conversion factor (0.001 mg/µg);
TC	= transfer coefficient (cm^2/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_t can be calculated using the following formula:

$$TTR_t = AR * F * (1-F_D)^t * CF2 * CF3 \quad (3.4)$$

where:

TTR_t	= turf transferable residue on day t (µg/cm^2);
AR	= application rate (lbs ai/ft^2 or lb ai/acre);
F	= fraction of ai as transferable residue following application (unitless);
F_D	= 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 10^8 µg/lb); and
CF3	= area unit conversion factor (1.08 x 10^{-3} ft^2/ cm^2 or 2.47 x 10^{-8} acre/cm^2).

Dermal absorbed doses are calculated as:

$$D = \frac{E * AF}{BW} \quad (3.5)$$

where:

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

Post-application dermal exposure following applications to lawns and turf is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4* such as residue dissipation, product-specific re-treatment intervals, and activity patterns. If longer-term assessments (i.e., intermediate-, long-term, or lifetime exposures) are deemed necessary, similar refinements to more accurately reflect the exposure profile are recommended.

Post-application Dermal Exposure Algorithm Inputs and Assumptions – Physical Activities on Turf

Recommended values for post-application dermal (physical activities on turf) exposure assessments are provided in *Table 3-3*. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 3-3: Turf (Physical Activities) – Recommended Point Estimates for Post-Application Dermal Exposure Factors

Algorithm Notation	Exposure Factor (units)			Point Estimate(s)
AR	Application rate (mass active ingredient per unit area)			Maximum labeled application rate
F	Fraction of AR as TTR following application (if chemical-specific data is unavailable)		L/WP/WDG	0.01
			Granules	0.002
F_D	Daily residue dissipation (if chemical-specific data is unavailable) (fraction)		L/WP/WDG	0.1
			Granules	0.1
TC	Transfer Coefficient (cm^2/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

Table 3-3: Turf (Physical Activities) – Recommended Point Estimates for Post-Application Dermal Exposure Factors		
Algorithm Notation	**Exposure Factor (units)**	**Point Estimate(s)**
L/WP/WDG = Liquids/Wettable Powders/Water-dispersible Granules		

Turf Transferable Residue (TTR)

Following an application, some pesticide residue remains on turf for an individual to contact and remove. This is referred to as turf transferable residue (TTR) and is assumed to be the most significant source for dermal exposure in this scenario. The industry-based ORETF tested five TTR collection techniques in 1996: the California roller method, the shoe method, the polyurethane foam (PUF) roller method, the drag sled method, and the foliar wash method. A follow-up study was conducted on a turf farm in 1997 using three modified techniques: the modified California roller method, the modified shoe method, and the ORETF roller method. The data from both of these studies are summarized and analyzed in a 1999 ORETF report (Cowell, J. and Johnson, D., 1999; EPA MRID 44972203). Ultimately – based on the information provided by ORETF and working in conjunction with the California Department of Pesticide Regulation (DPR) and Canada's Pest Management Regulatory Agency (PMRA) – a TTR collection method (the Modified California Roller Method) was agreed upon for all future TTR studies. The Modified California Roller was selected because it produced the most consistent results across individuals, active ingredients, formulation types, and time than the other techniques. It also was sensitive enough to detect low levels of residues and was one of the easier techniques to use.

TTR studies using the Modified California Roller Method were required for all pesticide active ingredients that had turf uses as part of the 1995 OREDCI (U.S. EPA, 1995), which was amended in 1998. Subsequently, in October of 2007, the Agency revised the data requirements that pertain to conventional pesticides. As part of these revisions, TTR studies were classified as required for all occupational (e.g., sod farms, golf courses, parks, and recreational areas) or residential turf uses under 40 CFR 158, subpart K (158.1070; post-application exposure data requirements table).

If no chemical-specific TTR data are available, an initial screening level assessment can be performed using the maximum labeled turf application rate.

Chemical-specific data

When chemical-specific data are available, the TTR is the surface residue on Day 0, which assumes an individual could be exposed to residues immediately after application.

Calculating from Application Rate

When the application rate is in terms of mass active ingredient per area (e.g., lbs ai/ft^2 or lb ai/acre), the total deposited residue is assumed to be equivalent to the application rate.

Fraction of Application Rate Available For Transfer (F)

If chemical-specific TTR measurements are not available, a screening value for the fraction of application rate available for transfer should be used to perform the assessment. For the purpose

of this SOP, 59 studies that collected turf transferable residues using the Modified California Roller Method (36 studies using liquids, 11 studies using wettable powders/water dispersible granules, and 12 studies using granules) were analyzed. Only TTR data collected with the Modified California Roller Method were used in this analysis because this was the turf residue collection method agreed upon by the Agency in the 1995 OREDCI (U.S. EPA, 1995). During the analysis of these studies, it was determined that there was no statistical difference between residues resulting from liquid, wettable powder (applied as a spray), or water dispersible granular (applied as a spray) applications; as a result, these data were combined for analysis. Granular data were analyzed separately. These analyses are presented in *Section D.6* of *Appendix D*.

For liquid applications (including wettable powders/water dispersible granules applied as sprays), the recommended screening level point estimate for use in post-application dermal exposure assessment is 0.01 (equivalent to 1%). For granular applications, the recommended screening level point estimate for use in post-application dermal exposure assessment is 0.002 (equivalent to 0.2%).

Daily Residue Dissipation (F_D)

Post-application exposures must be assessed on the same day the pesticide is applied because it is assumed that individuals could be exposed to turfgrass immediately after application. Therefore, post-application exposures are based on residues found on the day of application (i.e., referred to as day 0). For subsequent days after application it is also important to estimate exposure based on pesticide dissipation rates because of possible concerns over longer term exposures (i.e., using an amortized dose) and possible re-treatment intervals. If no chemical-specific TTR data are available, then a **10 percent dissipation rate per day** should be assumed.

Transfer Coefficient (TC)

The transfer coefficients used for turf dermal scenarios were derived from data gathered while adult human volunteers performed an approximate 2-hour composite routine consisting of 12 sequential activities which children and adults routinely engage on residential turf (D. Klonne and D. Johnson, MRID 47292001). These activities represent behaviors that are reported in the National Human Activity Pattern Survey (NHAPS) for children aged 1 to 12 years (Klepeis, et. al., 2001). The two-hour duration of the routine was chosen because NHAPS indicated that a high-bound estimate of time children spend playing on turf is two hours per day. Two turf sites were treated during the study; one with a liquid formulation and the other with a granular formulation. A total of 40 participants performed the composite routine during the study; 10 participants each during two separate sessions at the two treated turf sites. The potential dermal exposure to each study participant was measured by using whole-body dosimetry (inner and outer dosimeters), foot washes, hand washes, and face/neck wipes. TTR was collected at both sites using the Modified California Roller Method. All of these measurements were then used in the transfer coefficient calculations.

An analysis was performed to assess the statistical differences between the TCs calculated using the liquid data vs. the granular data. It was determined that these two distributions should not be combined because the upper percentile values are higher for the granular TCs vs. the liquid TCs even though the central tendency values of the two distributions are similar (*See Section D.7.1* of *Appendix D*). For children 1 < 2 years old, the transfer coefficient is adjusted for body surface

area by a factor of 0.27 (i.e., a 73% reduction in the TC) as outlined in *Section 2.3*. *Table 3-4* provides some summary statistical information about the turf dermal transfer coefficient distribution.

For liquid applications to lawns/turf, the recommended point estimates for use in post-application adult and children 1 < 2 years old dermal exposure assessments are 180,000 and 49,000 cm^2/hr, respectively.

For granular applications, the recommended point estimates for use in post-application adult and children 1 < 2 years old dermal exposure assessment are 200,000 and 54,000 cm^2/hr, respectively.

Table 3-4: Dermal Exposure Transfer Coefficients (T-shirt and Shorts) for Individuals Performing NHAPS Activities

Statistic	Liquid Transfer Coefficient (cm^2/hr)		Granular Transfer Coefficient (cm^2/hr)	
	Children 1 < 2 years old [1]	Adult	Children 1 < 2 years old [1]	Adult
50th percentile	48,000	180,000	52,000	190,000
75th percentile	56,000	210,000	61,000	230,000
95th percentile	71,000	260,000	77,000	290,000
99th percentile	83,000	310,000	91,000	340,000
AM (SD)	49,000 (NA)	180,000 (41,000)	54,000 (NA)	200,000 (45,000)
GM (GSD)	48,000 (NA)	180,000 (1.26)	52,000 (NA)	190,000 (1.26)
Range	NA	110,000–260,000	NA	110,000–300,000
N	NA	20	NA	20

[1] A 73% reduction in the adult transfer coefficient is recommended because of the differences of body surface areas between adults and children 1 < 2 years old.
AM (SD) = arithmetic mean (standard deviation)
GM (GSD) = geometric mean (geometric standard deviation)

Exposure Time (ET)

Another important variable for addressing post-application exposure from treated turf is the duration of time spent on turf. Empirical distributions were selected for adults and children (expressed as cumulative distributions) from the Exposure Factors Handbook 2011 Edition (U.S. EPA, 2011; Table 16-20). These distributions represent the amount of time spent at home in the yard or other areas outside the house rather than just on lawns (see *Table 3-5*) as the available data for time spent on lawns is not of sufficient quality for use in this SOP. The children's exposure time distribution reflects children ages 1 to 4 years old as lifestage-specific data are not currently available. Both the adult and children distributions taken from Exposure Factors Handbook 2011 Edition Table 16-20 were bounded at the 90th percentile as use of the upper percentiles of these distributions would likely overestimate time spent on lawns. **Based on these data, the recommended point estimate for use in post-application dermal exposure assessment for adults and children is 1.5 hrs/day.**

Table 3-5: Time Spent on Turf for Adults and Children

Statistic	Hours per Day	
	Adults	Children 1 < 2 years old [1]
5th percentile	0.08	0.42
25th percentile	0.5	1.0
50th percentile	1.5	1.5
75th percentile	3.0	3.0
90th percentile	5.5	5.1
100th percentile	5.5	5.1
[1] Data represents 1 to 4 years old.		

Future Research/Data Needs

Unavailable information that would refine post-application dermal exposure assessments for pesticide applications to turf include:

- Application intervals (i.e., how often chemicals are applied to turf) – either chemical-specific or generic intervals by pesticide-type (e.g., fungicides, insecticides, etc.).
- Survey information (preferably longitudinal) detailing:
  - General pesticide use to obtain, on a per capita basis, the probability of treating turf with pesticides;
  - Product-specific application rates to obtain the likelihood that the maximum rate is used; and,
  - Lifestage-specific daily activity patterns for turf.
- Post-application exposure data:
  - Describing the extent to which an individual's exposure for a given activity varies.

Exposure Characterization and Data Quality

Turf Transferable Residue

- The Modified California Roller Method was used in the selected turf dermal transfer coefficient study to collect TTR. This TTR collection method was agreed upon by the ORETF, CDPR, PMRA, and the Agency. For all assessments, transfer coefficients from this study should only be used with TTR studies that utilize the Modified California Roller Method. If chemical-specific TTR data collected via the Modified California Roller Method are not available, then the screening level TTR value (i.e., based on application rate) should be used.
- Absent chemical-specific data, estimates of turf transferable residue factors such as the amount available following application and dissipation are used generically based on existing data for a wide variety of chemicals. Use of the data generically, including using high-end estimates, may overestimate exposure for some chemicals.
- Assessors should recognize that factors such as rainfall/irrigation, grass growth, and grass mowing can greatly impact the dissipation rate of pesticides on turf when conducting turf post-application exposure assessments.

Exposure Time

- The extent to which the amount of time spent conducting certain activities varies over an extended period of time is unknown; therefore, the assumption that there is no variation when assessing longer-term exposure times is considered conservative.

3.2.3 Post-application Non-Dietary Ingestion Exposure Assessment: Hand-to-Mouth

This SOP provides a standard method for estimating the dose from incidental ingestion of pesticide residues from previously treated turf. Considering the strengths and limitations of available data and behavioral characteristics of potentially exposed lifestages (see *Appendix A* for more details), exposure for children 1 < 2 years old is calculated in this scenario. It assumed that pesticide residues are transferred to the skin of children playing on treated turf and are subsequently ingested as a result of hand-to-mouth transfer. It does not include residues ingested as a result of mouthing an object or via soil ingestion (*See Sections 3.2.4* and *3.2.5*).

Post-application Hand-to-Mouth Exposure Algorithm

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

$$E = \left[HR * \left(F_M * SA_H\right) * \left(ET * N_Replen\right) * \left(1 - \left(1 - SE\right)^{\frac{Freq_HtM}{N_Replen}}\right)\right] \quad (3.6)$$

where:

E	= exposure (mg/day);
HR	= hand residue loading (mg/cm^2);
F_M	= fraction hand surface area mouthed / event (fraction/event);
SA_H	= typical surface area of one hand (cm^2);
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

$$HR = \frac{Fai_{hands} * DE}{SA_H * 2} \quad (3.7)$$

where:

HR	= hand residue loading (mg/cm^2);
Fai_{hands}	= fraction ai on hands compared to total surface residue from dermal transfer coefficient study (unitless);
DE	= dermal exposure (mg); and
SA_H	= typical surface area of one hand (cm^2).

Dose, normalized to body weight, is calculated as:

$$D = \frac{E}{BW} \quad (3.8)$$

where:

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

Post-application hand-to-mouth exposure following applications to lawns and turf is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2*and *1.3.4* such as residue dissipation, product-specific re-treatment intervals, and activity patterns. If longer-term assessments (i.e., intermediate-, long-term, or lifetime exposures) are deemed necessary, similar refinements to more accurately reflect the exposure profile are recommended.

Post-application Hand-to-Mouth Algorithm Inputs and Assumptions

Recommended values for post-application hand-to-mouth exposure assessments are provided in *Table 3-6*. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 3-6: Turf - Recommended Point Estimates for Post-Application Hand-to-Mouth Exposure Factors

Algorithm Notation	Exposure Factor (units)		Point Estimate(s)
Fai_{hands}	Fraction of ai on hands from dermal transfer coefficient study (unitless)	Liquid formulations	0.06
		Granular formulations	0.027
DE	Dermal exposure (mg)		As calculated from Section 3.2.2
SA_H	Typical surface area of one hand (cm^2), children 1 < 2 years old		150
AR	Application rate (mass active ingredient per unit area)		Maximum labeled application rate
HR	Residue available on the hands (mg/cm^2)		Calculated via (DE * Fai_{hands})/SA_H
F_M	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	Children 1 < 2 years old	11.4

Table 3-6: Turf - Recommended Point Estimates for Post-Application Hand-to-Mouth Exposure Factors			
Algorithm Notation	**Exposure Factor (units)**		**Point Estimate(s)**
	(kg)		

Hand Residue Loading (HR)

Hand residue is linked to dermal exposure and it is assumed that the fraction of residue on the hands is equal to the fraction of the residue on the hands from the turf dermal transfer coefficient study.

Fraction Active Ingredient on the Hands (Fai_{hands})

The fraction of active ingredient available on the hands was based on the turf dermal transfer coefficient study (D. Klonne and D. Johnson, MRID 47292001). These values were determined for liquids and granules by taking the average fraction of active ingredient on the hands from all monitoring units and comparing that value to the average fraction of active ingredient on the entire body from all monitoring units assuming an individual is wearing a t-shirt and shorts. This analysis resulted in **values of 0.06 for liquids and 0.027 for granules**.

Fraction Hand Surface Area Mouthed (F_M)

See *Section 2.4* of this SOP for discussion of the fraction of hand surface area mouthed distribution. **The recommended point estimate for use in post-application hand-to-mouth exposure assessment is 0.127 per event.**

Hand Surface Area (SA_H)

The hand surface area for **children 1 < 2 years old of 150 cm^2**, for one hand, was based on values from the Exposure Factors Handbook 2011 Edition (U.S. EPA, 2011).

Exposure Time (ET)

See discussion of exposure time in *Section 3.2.2* above. **The recommended point estimate for use in post-application hand-to-mouth exposure assessment is 1.5 hrs/day.**

Replenishment Intervals per Hour (N_Replen)

This SOP assumes an estimate of 4 replenishment intervals per hour (i.e., residues on the hand will be replenished every 15 minutes). This value was selected as a conservative assumption based on the use of 30 minutes in the SHEDS model to coincide with the Consolidated Human Activity Database (CHAD) diaries.

Fraction of Pesticide Extracted by Saliva (SE)

See *Section 2.6* of this SOP for discussion of fraction of pesticide extracted by saliva distribution. **The recommended point estimate for use in post-application hand-to-mouth exposure assessment is 0.48.**

Hand-to-Mouth Events per Hour (Freq_HtM)

Frequency of hand-to-mouth events is an important variable for hand-to-mouth post-application exposure assessments. The estimates for frequency of hand-to-mouth events in outdoor environments are based on the Xue et al. (2007) meta-analysis. The turf SOP utilizes hand-to-mouth frequency data for the 1 < 2 year old lifestage. The estimates of hand mouthing frequency (events/hour) for 1 < 2 years old were derived from 4 studies representing 32 participants. Based on an analysis of the data by Xue et al., it was determined that a Weibull distribution (scale= 13.8, shape= 0.98) best fits the observed data. *Table 3-7* provides distributions and point estimates of hand-to-mouth events for use in residential pesticide exposure assessment and *Appendix D.9.1* provides additional analysis. **The recommended point estimate for use in post-application hand-to-mouth exposure assessment is 13.9 events/hr.**

Table 3-7: Frequency of Hand-to-Mouth Events (events/hour)

Statistic	Children 1 < 2 years old
50th percentile	8.0
75th percentile	19.2
95th percentile	42.2
AM (SD)	13.9 (13.6)
Range	1 - 46.7
N	32

AM (SD) = arithmetic mean (standard deviation)

Future Research/Data Needs

Unavailable information that would refine post-application hand-to-mouth exposure assessments for pesticide applications to turf include:

- Application intervals (i.e., how often chemicals are applied to turf) – either chemical-specific or generic intervals by pesticide-type (e.g., fungicides, insecticides, etc.).
- Survey information (preferably longitudinal) detailing:
  - General pesticide use to obtain, on a per capita basis, the probability of treating turf with pesticides;
  - Product-specific application rates to obtain the likelihood that the maximum rate is used; and,
  - Daily activity patterns specific to hand-to-mouth activities on turf (e.g., replenishment interval, hand-to-surface contacts).

Exposure Characterization and Data Quality

Turf Transferable Residue

- Absent chemical-specific data, estimates of turf transferable residue factors such as the amount available following application and dissipation are used generically based on existing data for a wide variety of chemicals. Use of the data generically, including using high-end estimates, may overestimate exposure for some chemicals.
- Assessors should recognize that factors such as rainfall/irrigation, grass growth, and grass mowing can greatly impact the dissipation rate of pesticides on turf.

Exposure Time

- The extent to which the amount of time spent conducting certain activities varies over an extended period of time is unknown; therefore, the assumption that there is no variation when assessing longer-term exposure times is considered conservative.

Fraction of Pesticide Extracted by Saliva

- Though based on limited data, the determination of the fraction of pesticide extracted by saliva from the hand is considered reasonable.

3.2.4 Post-application Non-Dietary Ingestion Exposure Assessment: Object-to-Mouth

This SOP provides a standard method for estimating the dose from incidental ingestion of pesticide residues from previously treated turf. Considering the strengths and limitations of available data and behavioral characteristics of potentially exposed lifestages (see *Appendix A* for more details), exposure for children 1 < 2 years old is calculated in this scenario. It assumes that pesticide residues are transferred to a child's toy and are subsequently ingested as a result of object-to-mouth transfer. It does not include residues ingested as a result of soil ingestion (see *Section 3.2.5*).

Post-application Object-to-Mouth Exposure Algorithm

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

$$E = \left[OR * CF1 * SAM_O * (ET * N_Replen) * \left(1 - (1 - SE)^{\frac{Freq_OtM}{N_Replen}}\right)\right] \quad (3.9)$$

where:

E	= exposure (mg/day);
OR	= chemical residue loading on the object on day "t" (ug/cm^2);
CF1	= weight unit conversion factor (0.001 mg/µg);
SAM_O	= area of the object surface that is mouthed (cm^2/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

$$OR = AR * F_O * CF2 * CF3 \quad (3.10)$$

where:

OR	= chemical residue loading on the object (µg/cm^2);
AR	= application rate (lbs ai/ft^2 or lb ai/acre);
F_O	= fraction of residue available on the object (unitless);
CF2	= weight unit conversion factor (4.54 x 10^8 µg/lb); and

CF3 = area unit conversion factor (1.08×10^{-3} ft^2/cm^2 or 2.47×10^{-8} $acre/cm^2$).

and

Dose, normalized to body weight, is calculated as:

$$D = \frac{E}{BW} \tag{3.11}$$

where:

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

Post-application object-to-mouth exposure following applications to lawns and turf is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4* such as residue dissipation, product-specific re-treatment intervals, and activity patterns. If longer-term assessments (i.e., intermediate-, long-term, or lifetime exposures) are deemed necessary, similar refinements to more accurately reflect the exposure profile are recommended.

Post-application Object-to-Mouth Algorithm Inputs and Assumptions

Recommended values for post-application object-to-mouth exposure assessments are provided in *Table 3-8*. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 3-8: Turf - Recommended Point Estimates for Post-Application Object-to-Mouth Exposure Factors

Algorithm Notation	Exposure Factor (units)		Point Estimate(s)
AR	Application rate (to turf) (mass active ingredient per unit area)		Maximum labeled application rate
F_O	Fraction of AR as OR following application [1]		0.01
SAM_O	Surface area of object mouthed (cm^2/event)		10
N_Replen	Replenishment intervals per hour (intervals/hour)		4
SE	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)	Children 1 < 2 years old	11.4

[1] 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).

Fraction of Residue Available on the Object (F_O)

Following an application, some pesticide residue remains on turf. Some of this residue may be transferred to a child's toy and subsequently ingested via object-to-mouth activities. For this SOP, it is assumed that the residue that could be transferred to the object is the same as what is available for dermal transfer. As a result, the fraction of total deposited residue available for transfer using the turf transferable residue data (see discussion above in *Section 3.2.2* for more detail) should be used as a conservative estimate for the fraction of residue available on the object. **Based on the available liquid TTR data, the recommended point estimate for use in post-application object-to-mouth exposure assessment is 0.01.**

Surface Area of Object Mouthed (SAM_O)

See *Section 2.5* of this SOP for discussion of surface area of object mouthed. **The recommended point estimate for use in post-application object-to-mouth exposure assessment is 10 cm^2.**

Exposure Time (ET)

See discussion of exposure time in *Section 3.2.2* above. **The recommended point estimate for use in post-application object-to-mouth exposure assessment is 1.5 hrs/day.**

Replenishment Intervals per Hour (N_Replen)

This SOP assumes an estimate of 4 replenishment intervals per hour (i.e., residues on the hand will be replenished every 15 minutes). This value was selected as a conservative assumption based on the use of 30 minutes in the SHEDS model to coincide with the CHAD diaries.

Fraction of Pesticide Extracted by Saliva (SE)

See *Section 2.6* of this SOP for discussion of fraction of pesticide extracted by saliva distribution. **The recommended point estimate for use in post-application object-to-mouth exposure assessment is 0.48.**

Object-to-Mouth Events per Hour (Freq_OtM)

Frequency of object-to-mouth events is an important variable for object-to-mouth post-application exposure assessments. The estimates for frequency of object-to-mouth events in outdoor environments are based on the Xue et al. (2010) meta-analysis. The turf SOP utilizes object-to-mouth frequency data for the 1 < 2 year old lifestage. The estimates of object mouthing frequency (events/hour) for 1 < 2 years old were derived from 2 studies representing 21 participants. Based on an analysis of the data by Xue et al. (2010), it was determined that a Weibull distribution (scale=8.58, shape= 0.93) best fits the observed data. *Table 3-9* provides distributions and point estimates of hand to mouth events for use in residential pesticide exposure assessment and *Appendix D.10.1* provides further detailed analysis. **Based on this analysis, the recommended point estimate for use in post-application object-to-mouth exposure assessment is 8.8 events/hr.**

Table 3-9: Frequency of Object-to-Mouth Events (events/hour)	
Statistic	**Children 1 < 2 years old**

Table 3-9: Frequency of Object-to-Mouth Events (events/hour)	
Statistic	**Children 1 < 2 years old**
50th percentile	6.0
75th percentile	10.8
95th percentile	21.3
AM (SD)	8.8 (8.8)
N	21
AM (SD) = arithmetic mean (standard deviation)	

Future Research/Data Needs

Unavailable information that would refine post-application object-to-mouth exposure assessments for pesticide applications to turf include:

- Application intervals (i.e., how often chemicals are applied to turf) – either chemical-specific or generic intervals by pesticide-type (e.g., fungicides, insecticides, etc.).
- Survey information (preferably longitudinal) detailing:
  - General pesticide use to obtain, on a per capita basis, the probability of treating turf with pesticides;
  - Product-specific application rates to obtain the likelihood that the maximum rate is used; and,
  - Daily activity patterns specific to object-to-mouth activities on turf (e.g., typical surface area of object that is mouthed).
- Data on the amount of residue transferred from treated turf to both hard and soft children's toys.

Exposure Characterization and Data Quality

Turf Transferable Residue

- The assumption that the entire available turf transferable residue is transferred to the object is considered conservative.
- Absent chemical-specific data, estimates of turf transferable residue factors such as the amount available following application and dissipation are used generically based on existing data for a wide variety of chemicals. Use of the data generically, including using high-end estimates, may overestimate exposure for some chemicals.
- Assessors should recognize that factors such as rainfall/irrigation, grass growth, and grass mowing can greatly impact the dissipation rate of pesticides.

Exposure Time

- The extent to which the amount of time spent conducting certain activities varies over an extended period of time is unknown; therefore, the assumption that there is no variation when assessing longer-term exposure times is considered conservative.

Fraction of Pesticide Extracted by Saliva

- There are no data with which to determine the fraction of pesticide extracted by saliva from an object. Use of the saliva extraction data for hands is considered a reasonable surrogate.

3.2.5 Post-application Non-Dietary Ingestion Exposure Assessment: Incidental Soil Ingestion

This SOP provides a standard method for estimating dose from incidental ingestion of soil containing pesticide residues. Considering the strengths and limitations of available data and behavioral characteristics of potentially exposed lifestages (see *Appendix A* for more details), exposure for children 1 < 2 years old is calculated in this scenario. It assumes that pesticide residues in soil are ingested by children who play on treated areas (e.g., lawns, gardens, playgrounds) as a result of normal mouthing activities (i.e., these estimates do not represent exposure among children who exhibit pica, an abnormal ingestion behavior).

Post-application Incidental Soil Ingestion Exposure Algorithm

Exposure from incidental soil ingestion is calculated as follows:

$$E = SR_t * SIgR * CF1 \quad (3.12)$$

where:

E = exposure (mg/day);
SR_t = soil residue on day "t" (µg/g);
SIgR = ingestion rate of soil (mg/day); and
CF1 = weight unit conversion factor (1×10^{-6} g/µg).

and

$$SR_t = AR * FS * (1-F_D)^t * CF2 * CF3 * CF4 \quad (3.13)$$

where:

SR_t = soil residue on day "t" (µg/g);
AR = application rate (lbs ai/ft^2 or lb ai/acre);
FS = fraction of ai available in uppermost cm of soil (fraction/cm);
F_D = fraction of residue that dissipates daily (unitless);
t = post-application day on which exposure is being assessed;
CF2 = weight unit conversion factor (4.54×10^8 µg/lb);
CF3 = area unit conversion factor (1.08×10^{-3} ft^2/cm^2 or 2.47×10^{-8} acre/cm^2); and
CF4 = soil volume to weight unit conversion factor (0.67 cm^3/g soil).

Dose, normalized to body weight, are calculated as:

$$D = \frac{E}{BW} \quad (3.14)$$

where:

D = dose (mg/kg-day);
E = exposure (mg/day); and

BW = body weight (kg).

Post-application soil ingestion exposure following applications to lawns and turf is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4* such as residue dissipation, product-specific re-treatment intervals, and activity patterns. If longer-term assessments (i.e., intermediate-, long-term, or lifetime exposures) are deemed necessary, similar refinements to more accurately reflect the exposure profile are recommended.

Post-application Incidental Soil Ingestion Algorithm Inputs and Assumptions

Recommended values for post-application incidental soil ingestion exposure assessments are provided in *Table 3-10*. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions, ii) data sources used to derive recommended input values, and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 3-10: Turf - Recommended Point Estimates for Post-Application Incidental Soil Ingestion Exposure Factors

Algorithm Notation	Exposure Factor (units)		Point Estimate(s)
AR	Application rate (mass active ingredient per unit area)		Maximum labeled application rate
FS	Fraction of AR available in uppermost 1 cm of soil (unitless)		1
F_D	Daily residue dissipation (fraction)		0.1
SIgR	Soil ingestion rate (mg/day)		50
BW	Body weight (kg)	Children 1 < 2 years old	11.4

Fraction of Residue Available in Soil (FS)

On the day of application, the Agency assumes a conservative assumption that **100 percent of the application rate is located within the soil's uppermost 1 cm**.

Daily Residue Dissipation (F_D)

Post-application exposures must be assessed on the same day the pesticide is applied because it is assumed that individuals could be exposed to turfgrass and soil immediately after application. Therefore, post-application exposures are based on residues found on the day of application (i.e., referred to as day 0). For subsequent days after application, an assumed pesticide **soil dissipation of 10%** should be used, unless chemical-specific data is available.

Soil Ingestion Rate (SIgR)

The assumed soil ingestion rate for **children 1 < 2 years old is 50 mg/day**. This is the central tendency value for ingestion rate of soil recommended in the Exposure Factors Handbook 2011 Edition (U.S. EPA, 2011; Table 5-1) for use in exposure/risk assessments. The data represents data on soil ingestion collected from children ranging from 1 to 6 years old.

Future Research/Data Needs

Unavailable information that would refine post-application exposure assessments for pesticide applications to turf include:

- Application intervals (i.e., how often chemicals are applied to turf) – either chemical-specific or generic intervals by pesticide-type (e.g., fungicides, insecticides, etc.).
- Data could be produced to examine the potential for a range of pesticides to stay in the uppermost 1 cm of soil over a period of time.

Exposure Characterization and Data Quality

Soil Residue

- The uncertainties associated with this assessment stem from the use of an assumed amount of pesticide available in the uppermost 1 cm of soil, and assumptions regarding dissipation of chemical residues in the soil and soil ingestion. However, the defaults used produce health protective exposure estimates.

3.2.6 Post-application Non-Dietary Ingestion Exposure Assessment: Episodic Granular Ingestion

This SOP provides a standard method for estimating post-application doses from incidental ingestion of pesticide pellets and granules that have been applied to lawns and gardens when adequate site-or chemical-specific field data are unavailable. Considering the strengths and limitations of available data and behavioral characteristics of potentially exposed lifestages (see *Appendix A* for more details), exposure for children 1 < 2 years old is calculated in this scenario. This scenario assumes that dry pesticide materials are ingested by children who play in treated areas (e.g., lawns, playgrounds).

Post-application Episodic Granular Ingestion Exposure Algorithm

Exposure from incidental ingestion of pesticide pellets or granules is calculated as follows:

$$E = GIgR^* FD * CF1 \quad (3.15)$$

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:

$$D = \frac{E}{BW} \quad (3.16)$$

where:

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

Post-application granular pesticide exposure following applications to lawns and turf would not occur as a result of routine behavior and is considered an episodic event related to poisoning. Thus, longer-term assessments are not conducted.

Post-application Episodic Granular Ingestion Algorithm Inputs and Assumptions

Recommended values for post-application episodic granular ingestion exposure assessments are provided in *Table 3-11*. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 3-11: Turf - Recommended Point Estimates for Post-Application Episodic Granular Ingestion Exposure Factors

Algorithm Notation	Exposure Factor (units)		Point Estimate(s)
F_D	Fraction of active ingredient in dry formulation		Product specific
AR	Application rate (lbs/A or lbs/1,000 ft^2)		Product specific
GIgR	Granule ingestion rate per day (g/day) [1]		0.3
BW	Body Weight (kg)	Children 1 < 2 years old	11.4

[1] See discussion below on how this value may be adjusted if product specific information is available.

Fraction of Active Ingredient in the Dry Formulation (F_D)

The fraction of active ingredient in the dry formulation should be determined by consulting the product label(s). In all cases, the formulation with the highest amount of active ingredient should be used to assess episodic granular ingestion.

Granular Product Application Rate (AR)

The amount of granule product applied per area of lawn should be indicated by the product label. The combination of this factor with the fraction of active ingredient in the product yields the application rate in terms of active ingredient per area.

Granular Ingestion Rate (GIgR)

The assumed ingestion rate for dry pesticide formulations (e.g., pellets and granules) is **0.3 gram/day for children 1 < 2 years old**. It is assumed that if 150 pounds of product were to be applied to a ½ acre lawn, the amount of product per square foot would be approximately 3 g/ft^2 and a child would consume one-tenth of the product available in a square foot.

If product-specific information is available, the granular ingestion rate may be adjusted to reflect the amount of product applied on a per area basis if it is less or more than 150 pounds to a ½ acre lawn. For instance, if 50 pounds of product is meant to treat a ½ acre lawn, then the ingestion rate should be reduced by a third to 0.1 grams/day.

Future Research/Data Needs

There are currently no data needs for the episodic granular ingestion scenario.

Exposure Characterization and Data Quality

Exposure assessments addressing non-dietary ingestion of granules should indicate this is considered to be an episodic event, and should be addressed as a single scenario (i.e., the exposure should not be combined with any other sources of exposure to the pesticide). Granule size, granular color, particle density, and instructions such as "soil incorporate" should also be considered.

An alternative assessment methodology for episodic granular ingestion can be done which examines the amount of granular product that a child could eat before any adverse effects occur. This alternative methodology can be used as characterization in support of the episodic granular ingestion assessment methodology discussed above.

3.2.7 Post-application Dermal Exposure Assessment: Mowing

This SOP provides a method for estimating potential dermal doses from contact with turf that has previously been treated with pesticides. Considering the strengths and limitations of available data and behavioral characteristics of potentially exposed lifestages (see *Appendix A* for more details), exposure for adults and children 11 < 16 years old is calculated in this scenario. This scenario assumes that pesticide residues are transferred to the skin of adults and children 11 < 16 years old that enter treated lawns for mowing.

It is assumed that individuals can be mowing previously treated turf on the same day a pesticide is applied even though this may be an unlikely scenario. However, the assessment can be refined to more accurately reflect exposure over a longer period of time (e.g., a week or month) if usage and activity information is available to allow for such calculations.

Post-application Dermal Exposure Algorithm – Mowing

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

$$E = TTR_t * CF1 * TC * ET \quad (3.17)$$

where:

E = exposure (mg/day);
TTR_t = turf transferable residue on day "t" (µg/cm^2);
CF1 = weight unit conversion factor (0.001 mg/µg);
TC = transfer coefficient (cm^2/hr); and

ET = exposure time (hr/day).

and

$$TTR_t = AR * F_{AR} * (1-F_D)^t * CF2 * CF3 \quad (3.18)$$

where:

TTR_t = turf transferable residue on day "t" (µg/cm^2);
AR = application rate (lbs ai/ft^2 or lb ai/acre);
F_{AR} = fraction of ai retained on turf (unitless);
F_D = 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 10^8 µg/lb); and
CF3 = area unit conversion factor (1.08 x 10^{-3} ft^2/cm^2 or 2.47 x 10^{-8} acre/cm^2).

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

$$D = \frac{E * AF}{BW} \quad (3.19)$$

where:

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

Post-application dermal exposure while mowing following applications to lawns and turf is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4* such as residue dissipation, product-specific re-treatment intervals, and activity patterns. If longer-term assessments (i.e., intermediate-, long-term, or lifetime exposures) are deemed necessary, similar refinements to more accurately reflect the exposure profile are recommended.

Post-application Dermal Exposure Algorithm Inputs and Assumptions - Mowing

Recommended values for post-application dermal mowing exposure assessments are provided in *Table 3-12*. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 3-12: Turf (Mowing) - Recommended Point Estimates for Post-Application Dermal Exposure Factors

Algorithm Notation	Exposure Factor (units)	Point Estimate(s)
AR	Application rate mass active ingredient per unit area	Maximum labeled application rate

Table 3-12: Turf (Mowing) - Recommended Point Estimates for Post-Application Dermal Exposure Factors			
F_{AR}	Fraction of AR as TTR following application	L/WP/WDG	0.01
		Granules	0.002
F_D	Daily residue dissipation	L/WP/WDG	0.1
		Granules	0.1
TC	Transfer Coefficient (cm^2/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 Transferable Residue (TTR)

See discussion of TTR in *Section 3.2.2* above.

Fraction of Application Rate Available For Transfer (F_{AR})

See discussion of F_{AR} in *Section 3.2.2* above.

Daily residue dissipation (F_D)

See discussion of F_D in *Section 3.2.2* above.

Transfer Coefficient (TC)

The transfer coefficients used for the "mower" dermal scenarios were derived from data collected during a golf course maintenance study (Klonne and Bruce, 2005). These data were gathered while human volunteers (1) mowed greens with a walk-behind mower (8 participants) and (2) mowed fairways with a riding mower (8 participants) on a golf course. The walk-behind mower activity consisted of mowing using a walk-behind reel mower with a grass catcher, emptying the grass catcher, and hosing off the mower with water at the conclusion of mowing. Greens mowing occurred in the morning and a monitoring event consisted of mowing 4 to 5 greens (approximately 2 to 3 hours). The riding mower activity consisted of mowing fairways (using a 5-reel riding mower), mowing tee boxes/surrounds (using a 3-reel riding mower), emptying the grass catcher, and hosing off the mower with water at the conclusion of mowing. Fairway mowing occurred in the morning and a monitoring event consisted of mowing either 5 to 6 fairways or tees/surrounds for 9 holes (approximately 2 to 4.5 hours). Post-application exposure resulting from golf course mowing was deemed an appropriate surrogate for residential homeowner mowing.

An analysis was performed to assess the statistical differences between the TCs calculated using the walk-behind mower data vs. the riding mower data. It was determined that there was no statistical difference between these datasets and, thus, in calculating the adult dermal "mower" transfer coefficient, the data were combined (*See Section D.7.1* of *Appendix D*). For children 11

< 16 years old, the transfer coefficient is adjusted for body surface area using a factor of 0.82 (i.e., a 18% reduction in the TC) as outlined in *Section 2.3*. *Table 3-13* provides some summary statistical information about the turf dermal transfer coefficient distribution for mowing activities.

The recommended point estimates for use in post-application adult and children 11 < 16 years old dermal exposure assessments are 5,500 and 4,500 cm^2/hr, respectively.

Table 3-13: Turf (Mowing) - Dermal Exposure Transfer Coefficients (T-shirt and Shorts) for Individuals Performing Mowing Activities

Statistic	Adult Transfer Coefficient (cm^2/hr)	Children 11 < 16 Years Old Transfer Coefficient (cm^2/hr) [1]
50th percentile	2,700	2,200
75th percentile	6,300	5,200
95th percentile	22,000	18,000
99th percentile	54,000	44,000
AM (SD)	5,500 (7,300)	4,500 (NA)
GM (GSD)	2,700 (3.5)	2,200 (NA)
Range	319–25,860	NA
N	16	NA

[1]A 18% reduction in the adult transfer coefficient is recommended to account for the differences of body surface areas between adults and children 11 < 16 years old.
AM (SD) = arithmetic mean (standard deviation)
GM (GSD) = geometric mean (geometric standard deviation)

Exposure Time (ET)

Another important variable for addressing post-application exposure from treated turf is the duration of time spent mowing. No microactivity data were available that specifically examined the amount of time a person spends mowing their home lawn; however, the Bureau of Labor Statistics American Time Use Survey from 2007 (ATUS) examined the number of hours per day a person performs lawn and garden care activities around their home. **Based on these data, the recommended point estimate for use in post-application dermal exposure assessment is 1 hour/day for mowing activities.**

Future Research/Data Needs

Unavailable information that would refine post-application mowing exposure assessments for pesticide applications to turf include:

- Application intervals (i.e., how often chemicals are applied to turf) – either chemical-specific or generic intervals by pesticide-type (e.g., fungicides, insecticides, etc.).
- Survey information (preferably longitudinal) detailing:
    - General pesticide use to obtain, on a per capita basis, the probability of treating turf with pesticides;
    - Product-specific application rates to obtain the likelihood that the maximum rate is used; and,

- Daily activity patterns specific to the typical amount of time a person spends mowing their home lawn.

Exposure Characterization and Data Quality

Transfer Coefficient

- The use of the mowing component from a golf course maintenance study as a surrogate for residential homeowner mowing is reasonably representative of the exposures related to residential mowing activities. HED believes that residential mower's highest exposures are most likely to occur when clippings are removed by hand from collection bags for disposal and this activity was represented in the mowing activity of the golf course maintenance study.

Turf Transferable Residue

- The Modified California Roller Method was used in the selected turf dermal transfer coefficient study to collect TTR. This TTR collection method was agreed upon by the ORETF, CDPR, PMRA, and the Agency. For all assessments, transfer coefficients from this study should only be used with TTR studies that utilize the Modified California Roller Method. If chemical-specific TTR data collected via the Modified California Roller Method are not available, then default TTR data (i.e., based on the application rate) should be used.
- Absent chemical-specific data, estimates of turf transferable residue factors such as the amount available following application and dissipation are used generically based on existing data for a wide variety of chemicals. Use of this data generically, including using high-end estimates, may overestimate exposure for other chemicals.
- Assessors should recognize that mowing grass after an application may be limited by label directions indicating not to mow until a certain period of time has passed after application or else the product may not work.
- Assessors should recognize that real world factors such as rainfall/irrigation and grass growth can greatly impact the dissipation rate of pesticides on turf.

Exposure Time

- The extent to which the amount of time spent conducting certain activities varies over an extended period of time is unknown; therefore, the assumption that there is no variation when assessing longer-term exposure times is considered conservative.

3.2.8 Post-application Dermal Exposure Assessment: Golfing

This SOP provides a standard method for estimating potential dermal doses to golfers from dermal contact with turf that has previously been treated with pesticides. Considering the strengths and limitations of available data and behavioral characteristics of potentially exposed lifestages (*See Appendix A* for more details); exposure for adults, children 11 < 16 years old, and children 6 < 11 years old is calculated in this scenario. This scenario assumes that pesticide residues are transferred to the skin of adults and teens that play golf on treated turf.

It is assumed that individuals can be golfing on previously treated turf on the same day a pesticide is applied. However, the assessment can be refined to more accurately reflect exposure over a longer period of time (e.g., a week or month) if toxicological or activity information is available to allow for such calculations.

Post-application Dermal Exposure Algorithm – Golfing

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

$$E = TTR_t * CF1 * TC * ET \quad (3.20)$$

where:

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

and

$$TTR_t = AR * F * (1-F_D)^t * CF2 * CF3 \quad (3.21)$$

where:

TTR_t	= turf transferable residue on day "t" (µg/cm^2);
AR	= application rate (lbs ai/ft^2 or lb ai/acre);
F	= fraction of ai retained on turf (unitless);'
F_D	= 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 10^8 µg/lb); and
CF3	= area unit conversion factor (1.08 x 10^{-3} ft^2/cm^2 or 2.47 x 10^{-8} acre/cm^2).

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

$$D = \frac{E * AF}{BW} \quad (3.22)$$

where:

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

Post-application dermal exposure while golfing following applications to golf course turf is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4* such as residue dissipation, product-specific re-treatment intervals, and activity patterns. If longer-term assessments (i.e., intermediate-, long-

term, or lifetime exposures) are deemed necessary, similar refinements to more accurately reflect the exposure profile are recommended.

Post-application Dermal Exposure Algorithm Inputs and Assumptions - Golfing

Recommended values for post-application dermal golfing exposure assessments are provided in *Table 3-14*. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 3-14: Turf (Golfing) - Recommended Point Estimates for Post-Application Dermal Exposure Factors

Algorithm Notation	Exposure Factor (units)		Point Estimate(s)
AR	Application rate (mass active ingredient per unit area)		Maximum labeled rate
F	Fraction of AR as TTR following application	L/WP/WDG	0.01
		Granules	0.002
F_D	Daily residue dissipation	L/WP/WDG	0.1
		Granules	0.1
TC	Transfer Coefficient (cm^2/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

Turf Transferable Residue (TTR)

See discussion of TTR in *Section 3.2.2* above.

Fraction of Application Rate Available For Transfer (F)

See discussion of F in *Section 3.2.2* above.

Daily residue dissipation (F_D)

See discussion of F_D in *Section 3.2.2* above.

Transfer Coefficient (TC)

The transfer coefficients used for the "golfer" dermal scenarios were derived using the best available data. In this case, data collected during a golf course maintenance study (Klonne and Bruce, 2005) was considered to provide the best representation of the exposures that might be experienced by golfers. Data were gathered while human volunteers moved cups on golf greens (6 participants). The cup changing activity consisted of making a new hole with a hand operated

cup cutter, putting the plastic cup liner from the old hole into the new hole, filling the old hole with sand and the plug from the new hole. Some cup changers also repaired ball marks on the greens with a hand tool similar to those used by golfers. Cup changing occurred first thing in the morning and a monitoring event consisted of changing 18 cups. Most workers performed the cup changing while bending over and not contacting the turf with anything, but their shoes and hands; however, one worker routinely kneeled on one knee and two other workers kneeled for a few holes. HED has fit a distribution from the 6 cup changing exposures to calculate a surrogate transfer coefficient for golfers (See *Section D.7.1* of *Appendix D*).

For children 11 < 16 years old, the transfer coefficient is adjusted for body surface area using a factor of 0.82 (i.e., a 18% reduction in the TC) as outlined in *Section 2.3*. For children 6 < 11 years old, the transfer coefficient is adjusted for body surface area using a factor of 0.55 (i.e., a 45% reduction in the TC) as outlined in *Section 2.3*. *Table 3-15* provides some summary statistical information about the turf dermal transfer coefficient distribution for golfing activities.

The recommended point estimates for use in post-application adult, children 11<16 years old, and children 6<11 years old dermal exposure assessment are 5,300; 4,400; and 2,900 cm^2/hr, respectively.

Table 3-15: Turf (Golfing) - Dermal Exposure Transfer Coefficients (T-shirt and Shorts) for Individuals Golfing

Statistic	Adult Transfer Coefficient (cm^2/hr)	Children 11 < 16 Years Old Transfer Coefficient (cm^2/hr) [1]	Children 6 < 11 Years Old Transfer Coefficient (cm^2/hr) [2]
50th percentile	2,800	2,300	1,500
75th percentile	6,400	5,300	3,500
95th percentile	21,000	17,000	12,000
99th percentile	49,000	40,000	27,000
AM (SD)	5,300 (7,000)	4,400 (NA)	2,900 (NA)
GM (GSD)	2,800 (3.3)	2,300 (NA)	1,500 (NA)
Range	988–18,863	NA	NA
N	6	NA	NA

[1] A 18% reduction in the adult transfer coefficient is recommended to account for the differences of body surface areas between adults and children 11 < 16 years old.
[2] A 45% reduction in the adult transfer coefficient is recommended to account for the differences of body surface areas between adults and children 6 < 11 years old.
AM (SD) = arithmetic mean (standard deviation)
GM (GSD) = geometric mean (geometric standard deviation)

Exposure Time (ET)

Another important variable for addressing post-application exposure from treated turf while golfing is the duration of time spent golfing. The duration is assumed to be 4 hours for a chemical that can be used on all parts of a golf course (greens, tees, and fairways). This estimate is the average time it takes to play a round of golf and is based on a report completed by the Center for Golf Course Management (1992).

It should also be noted that some chemicals are limited to use on greens and tees or are primarily used on just greens and tees for cultural reasons. When chemicals meet these criteria, the exposure time is 1 hour because contact time is proportionately lower with the treated area. If a chemical has a label restriction for greens and tees, then a single exposure calculation should be completed for the 1 hour duration.

Future Research/Data Needs

Unavailable information that would refine post-application golfing exposure assessments for pesticide applications to turf include:

- Application intervals (i.e., how often chemicals are applied to turf) – either chemical-specific or generic intervals by pesticide-type (e.g., fungicides, insecticides, etc.).
- Survey information (preferably longitudinal) detailing:
    - General pesticide use to obtain, on a per capita basis, the probability of treating golf course turf with pesticides;
    - Product-specific application rates to obtain the likelihood that the maximum rate is used; and,
    - Daily activity patterns specific to the typical amount of time a person spends golfing.

Exposure Characterization and Data Quality

Risk assessments for children (< 5 years old) golfing are complex due to the extrapolation of adult dermal exposure data and because of the increased likelihood of other behaviors that might contribute to exposure, such as mouthing contaminated hands or golf balls. Therefore, the risk associated with children in a golfing scenario is addressed qualitatively below:

- Five-year-old children are assumed to be the representative lifestage for children in a golfing scenario. The surface area to body weight ratio (SA/BW) for male children 5 years of age (the difference is larger for males compared to females making the value more protective) was calculated by using the 95th percentile for body surface area and the 50th percentile for body weight. The ratio was intentionally skewed to account for the uncertainties that would be expected with calculating dose levels for children if more definitive data were available, and for potential additional exposure that may occur from mouthing behaviors. This skewed SA/BW ratio for children was compared to that of the average adult, and found to be approximately 70 percent greater. Based on this parameter alone, a child's exposure could be almost twice that of the adult golfer; however, it should be noted that a child is not expected to use the golf course for the same length of time as an adult. While an adult is likely to play a full round of golf (i.e., 18 holes), which takes approximately 4 hours, a child would probably only spend about 2 hours (i.e., the 75th percentile for time spent playing on grass by children aged 1-4 years and 5-11 years) on the course. Thus, the child's shorter duration on the golf course offsets the higher SA/BW ratio, and therefore, the child golfer's exposure is likely to be similar to that of the adult golfer.

Transfer Coefficient

- The use of the cup changing component from a golf course maintenance study is an acceptable surrogate for golfer exposure because it is assumed that a golfer's highest exposures are most likely to occur when contacting residues from turf on and around the greens and residues remaining on the golf ball. The actions associated with cup changing in the golf course maintenance study are similar to typical golfer actions and, as a result, the actions should result in similar exposures.

Turf Transferable Residue

- The Modified California Roller Method was used in the selected turf dermal transfer coefficient study to collect TTR. This TTR collection method was agreed upon by the ORETF, CDPR, PMRA, and the Agency. For all assessments, transfer coefficients from this study should only be used with TTR studies that utilize the Modified California Roller Method. If chemical-specific TTR data collected via the Modified California Roller Method are not available, then default TTR data (i.e., based on the application rate) should be used.
- Absent chemical-specific data, estimates of turf transferable residue factors such as the amount available following application and dissipation are used generically based on existing data for a wide variety of chemicals. Use of the data generically, including using high-end estimates, may result in overestimates for some chemicals.
- Assessors should recognize that real world factors such as rainfall/irrigation, grass growth, and grass mowing can greatly impact the dissipation rate of pesticides on turf. Irrigation and mowing are of particular importance to the golfer scenario in that both of these activities occur on almost a daily basis at most golf courses. Based on these factors, the golfer exposure scenario should be considered conservative in nature when compared to possible real world exposures.

Exposure Time

- The extent to which the amount of time spent conducting certain activities varies over an extended period of time is unknown; therefore, the assumption that there is no variation when assessing longer-term exposure times is considered conservative.

3.2.9 Combining Post-application Scenarios

Risk estimates resulting from different exposure scenarios are combined when it is likely that they can occur simultaneously based on the use pattern and when the toxicological effects across different routes of exposure are the same (see *Section 1.3.5*). When combining scenarios, it is important to fully characterize the potential for co-occurrence as well as characterizing the risk inputs and estimates. Risk estimates should be combined even if any one scenario or route of exposure exceeds the level of concern because this allows for better risk characterization for risk managers. The following issues should be considered when combining scenarios for the residential turf SOP:

- There are a number of non-dietary ingestion exposure scenarios that could potentially be combined with the dermal exposure scenario. These non-dietary ingestion scenarios should be considered inter-related and it is likely that they occur interspersed amongst

each other across time. For example, a child may place his hand in his mouth X number of times as well as place an object in his mouth Y number of times during a certain period of time. Each of these events could result in a potential transfer of residue, but could also result in a soil ingestion event as soil may be present on the hand or object during mouthing. The potential combinations of co-occurrence of the hand-to-mouth/object-to-mouth/soil ingestion scenarios across a particular period of time are limitless. Combining all three of these scenarios with the dermal exposure scenario would be overly-conservative because of the conservative nature of each individual assessment. Based on this discussion, the post-application exposure scenarios that should be combined for short-term exposure durations are the dermal and hand-to-mouth scenarios. This combination should be considered a protective estimate of children's exposure to pesticides used on turf.

Section 4 Gardens and Trees

The procedures outlined in this section should be used to assess dermal and inhalation exposure during (i.e., handler) and following pesticide applications (i.e., post-application) to gardens and trees at home by professional pesticide applicators or homeowners themselves. Other potential sources of exposure addressed by this section where professional applications could potentially lead to exposure by the general population, if applicable to the pesticide and its label under consideration, include "pick-your-own" farms and treated plants purchased at retail locations. For the purposes of this section, a "pick-your-own" farm is a commercial farming operation that allows public access for harvesting fruits, vegetables, or ornamental plants in large-scale fields that can be treated with commercially labeled pesticides. Additionally, as dietary exposure is a separate component of the overall human health exposure/risk assessment, this section does not include dietary exposure resulting from fruits or vegetables treated with pesticides at home.

The following are example use sites from pesticide product labeling that would necessitate an assessment for this scenario:

- Gardens:
    - Flowers (e.g., chrysanthemums);
    - Fruits (e.g., strawberries); and
    - Vegetables (e.g., tomatoes, squash, etc.).

- Trees:
    - Fruits (e.g., apples, citrus);
    - Nuts (e.g., pecans);
    - Shrubs (e.g., boxwood); and
    - Ornamentals (e.g., maples).

The exposure assessor should assume use is permitted for use in home gardens and trees or by homeowners unless a specific statement on the label indicates the product is only used in non-residential settings. Examples of such statements include:

- Commercial or research greenhouse use only;
- For nursery-grown ornamentals only; and
- For use in commercial plantings only.

Additionally, "Restricted Use Pesticide" classification indicates that the product cannot be bought or applied by homeowners (i.e., no residential handler exposure/risk assessment required), but it may be applied by commercial applicators to residential sites; therefore, a post-application risk assessment may be required.

Once scenarios are identified, the assessment should then characterize and estimate the potential for exposure by route (i.e., dermal, inhalation) using the methodologies outlined in this section.

4.1 Handler Exposure Assessment

Handler exposure can result from treating home gardens and trees with pesticides. Some key assumptions for these assessments include:

- Adults are considered the index lifestage for this scenario as it is assumed that pesticides are applied by adults only (i.e., individuals 16 years and older).
- All application equipment and methods are assumed feasible unless prohibited by the product label.

Dermal and Inhalation Handler Exposure Algorithm

As described in *Section 1.3.3*, 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:

$$E = UE * AR * A \quad (4.1)$$

where:

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

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

$$D = \frac{E * AF}{BW} \quad (4.2)$$

where:

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

Handler exposure for applications to gardens and trees is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.3* such as the product-specific application regimen.

Dermal and Inhalation Handler Exposure Algorithm Inputs and Assumptions

Recommended values for handler exposure (inhalation and dermal) assessments are provided in *Table 4-1* and *Table 4-2*. Following these tables, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions, ii) data

sources used to derive recommended input values, and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 4-1: Gardens and Trees – Recommended Unit Exposure (mg/lb ai) Point Estimates				
Formulation	**Equipment/Application Method**	**Dermal**	**Inhalation**	**Appendix Page Reference**
		Point Estimate	**Point Estimate**	
Granules	Push-type spreaders	0.81	0.0026	C-4
	Belly grinders	360	0.039	C-11
	Spoon	6.2	0.087	C-20
	Cup	0.11	0.013	C-24
	Hand dispersal	160	0.38	C-28
	Shaker can	No exposure data available for this application scenario. Exposure data for granule applications using a cup recommended as surrogate data.		
Dusts/Powders	Plunger duster	250	1.7	C-32
	Bulb duster	No exposure data available for this application scenario. Exposure data for plunger duster applications recommended as surrogate data.		
	Electric/power duster	No exposure data available for this application scenario. Exposure data for shaker can applications of dusts/powders recommended as surrogate data.		
	Hand crank duster	No exposure data available for this application scenario. Exposure data for shaker can applications of dusts/powders recommended as surrogate data.		
	Shaker can	4300	18	C-36
Liquid concentrates	Manually-pressurized handwand	63	0.018	C-56
	Hose-end sprayer	58	0.0014	C-79
	Backpack	130	0.14	C-91
	Sprinkler can	No exposure data available for this application scenario. Exposure data for hose-end sprayer applications of liquid concentrates recommended as surrogate data.		
Ready-to-Use (RTU)	Hose-end sprayer	6.26	0.034	C-107
	Trigger-sprayers	85.1	0.061	C-113
	Aerosol can	370	3.0	C-134
Wettable Powder	Manually-pressurized handwand	69	1.1	C-141
	Hose-end sprayer	No exposure data available for this application scenario. Exposure data for hose-end sprayer applications of liquid concentrates recommended as surrogate data.		
	Backpack	No exposure data available for this application scenario. Exposure data for manually-pressurized handwand applications of wettable powders recommended as surrogate data.		
	Sprinkler can	No exposure data available for this application scenario. Exposure data for hose-end sprayer applications of liquid concentrates recommended as surrogate data.		
Wettable Powder in Water-soluble Packaging	Manually-pressurized handwand	No exposure data available for this scenario. Exposure data for manually-pressurized handwand applications of liquid concentrates recommended as surrogate data.		
	Hose-end sprayer	No exposure data available for this scenario. Exposure data for RTU hose-end sprayers recommended as surrogate data.		

Table 4-1: Gardens and Trees – Recommended Unit Exposure (mg/lb ai) Point Estimates				
Formulation	**Equipment/Application Method**	**Dermal**	**Inhalation**	**Appendix Page Reference**
		Point Estimate	**Point Estimate**	
	Backpack	No exposure data available for this scenario. Exposure data for manually-pressurized handwand applications of liquid concentrates recommended as surrogate data.		
	Sprinkler can	No exposure data available for this scenario. Exposure data for RTU hose-end sprayers recommended as surrogate data.		
Dry Flowable / Water-dispersible Granule	Manually-pressurized handwand	No exposure data available for this scenario. Application method-specific exposure data for wettable powders recommended as surrogate data.		
	Hose-end sprayer			
	Backpack			
	Sprinkler can			
Micro-encapsulates	Manually-pressurized handwand	No exposure data available for this scenario. Application method-specific exposure data for liquid concentrates recommended as surrogate data.		
	Hose-end sprayer			
	Backpack			
	Sprinkler can			

Table 4-2: Gardens and Trees – Recommended Handler Exposure Factor Point Estimates		
Exposure Factor (units)		**Point Estimate(s)**
Application Rate (mass ai per unit area)		Maximum labeled rate
Garden Size (ft^2)		1200
Amount product or finished spray solution used	Manually-pressurized handwand (gallons)	5
	Backpack (gallons)	5
	Hose-end sprayer (gallons)	11
	Sprinkler can (gallons)	5
	Ready-to-use single use containers (e.g., aerosol cans, trigger-spray bottles, shaker cans)	2
Body Weight (kg)		80

Unit Exposures

As described in *Section 1.3.3*, the unit exposure is the ratio, for a given formulation/application method combination, between exposure and the amount of active ingredient handled, with units mass exposure per mass active ingredient handled (e.g., mg ai exposure/lb ai handled). **The recommended point estimates are shown in *Table 4-1*.** Data summaries can be found in *Appendix C*.

Amount of active ingredient Handled

The algorithm for estimating handler exposure requires some estimate of the amount of active ingredient handled per day. This factor varies based on the type of equipment or application

method used and is estimated based on the application rate specified on the product label. First, the assessor should assemble application rate information in terms of active ingredient per area treated (e.g., lb ai/1000 ft^2) and/or active ingredient concentration established per volume of spray (e.g., lb ai/gallon solution). For example, instructions for a granule formulation might direct application of 2 lbs of product per 100 square feet or a spray application might say to apply 2 gallons of solution per 100 square feet. Additionally, the assessment must reflect exposure resulting from use of the product and chemical at the maximum allowable application rate found on the product label. The probability of using a product at its maximum allowable rate at home is unknown, so additional information (e.g., use surveys or pest-specific application rates), can be used, if available, to characterize the exposure resulting from use at the maximum allowable rate.

Once the application rate is determined, an amount of area treated or amount of volume sprayed is used to convert the application rate into the amount of active ingredient handled (which is then used with the unit exposure to estimate handler exposure). For this scenario, the amount of area treated is estimated using information about garden size from a survey (Johnson et al., 1999). Note that these results represent garden sizes, not garden areas treated. *Table 4-3* below presents a statistical summary assuming a lognormal distribution for garden size to be used when application rates are in terms of area. **The recommended point estimate for garden size is 1200 ft^2.** Additional information and analysis is presented in *Section A.1* of *Appendix C*.

Table 4-3: Statistical Summary – Garden Size (ft^2)

50th percentile	80
75th percentile	390
95th percentile	3700
99th percentile	18000
AM (SD)	1200 (18000)
GM (GSD)	80 (10)
Range	unknown
N	364

AM (SD) = arithmetic mean (standard deviation)
GM (GSD) = geometric mean (geometric standard deviation)

If a case is being considered in which the application rate is based on spray concentration, an estimate for the amount of finished spray solution volume is necessary. Such a rate would be used for spraying trees, for example, where an "area-based" approach would not be appropriate or useful because label instructions provide target spray concentrations. However, this factor is likely application method-specific (i.e., one might apply more solution using a hose-end sprayer than a sprinkler can) and explicit information on volumes sprayed in home applications is unavailable.

For hose-end sprayers, application volume was derived from a study measuring exposure during applications of liquid formulations to fruit trees and ornamental shrubs using a hose-end sprayer (Merricks, 1998). A statistical summary assuming a normal distribution for application volume is provided in *Table 4-4* below. **The recommended point estimate for amount sprayed for hose-end sprayers is 11 gallons.** Statistical analyses and data summary are provided in *Section A.1* of *Appendix C*.

Table 4-4: Statistical Summary – Application Volume (gallons) for Hose-end Sprayers	
50th percentile	11
75th percentile	14
95th percentile	19
99th percentile	22
AM (SD)	11 (5.1)
GM (GSD)	10 (1.6)
Range	6 – 21
N	20
AM (SD) = arithmetic mean (standard deviation) GM (GSD) = geometric mean (geometric standard deviation)	

For all other applications, information on the amount of product used is largely unavailable. **For manually-pressurized handwands, backpacks, and sprinkler cans, a volume of 5 gallons is recommended; for aerosol cans and trigger-sprayers, 2 cans or containers per application is recommended. Should ready-to-use containers of granules or dusts/powders not specify an area-based application rate, 2 containers per application is recommended**. These are conservative estimates based on professional judgment informed by existing applicator studies which discussed the extent of use (e.g., duration, volume, etc.).

Future Research/Data Needs

Unavailable information that would refine handler exposure assessments for pesticide applications to gardens and trees include:

- Application intervals (i.e., how often chemicals are applied to gardens and trees) – either chemical-specific or generic intervals by pesticide-type (e.g., fungicides, insecticides, etc.).
- Survey information (preferably longitudinal) detailing:
  - Daily/weekly/monthly probability of treating gardens and trees with pesticides;
  - Amount of product or formulation used or area treated per application;
  - Product-specific application rates to obtain the likelihood that the maximum rate is used.
- Handler exposure data:
  - Specific for garden and tree applications, beyond what had been included in previous residential data call-ins (DCIs), including those formulations and/or application methods currently unavailable in *Table 4-2*;
  - Describing the extent to which an individual's exposure for a given formulation and application method varies from application-to-application.

Exposure Characterization and Data Quality

Unit Exposures

- The exposure data underlying unit exposures are considered reasonable for the purposes of estimating exposure. The data are from actual applications using standardized exposure sampling methodologies and laboratory analyses.
- The underlying assumption of the use of exposure data as unit exposures – proportionality between the amount of active ingredient handled and exposure – is uncertain, though potentially conservative. However, as a prediction mechanism, it is considered practical and useful for the purposes of handler exposure assessment in a regulatory context. It provides a straightforward handler exposure calculation method and enables risk mitigation in the form of formulation comparison and decreased application rates.
- The extent to which an individual's exposure (expressed via unit exposures) varies day-to-day or application-to-application is unknown; therefore, the assumption that there is no variation when assessing longer-term exposure durations is considered conservative.

Amount of active ingredient handled

- Information on the amounts of active ingredient handled for typical residential gardens and trees application equipment is largely unavailable. The estimates used however, are believed to result in health protective exposure estimates.
- The extent to which the amount an individual will handle per application varies from day-to-day or application-to-application is unknown; therefore, the assumption that there is no variation when assessing longer-term exposure durations is considered conservative.

4.2 Post-application Exposure Assessment

Post-application exposure can result from conducting activities in previously treated areas such as gardening or picking fruits following pesticide applications by professional pesticide applicators or by homeowners themselves.

Adults and children 6 < 11 years old are considered the index lifestages for this exposure scenario as it is assumed that younger children (i.e., < 6 years old) won't utilize these areas for playing nor engage in the types of activities associated with these areas (e.g., gardening or picking fruits) to the extent that older children will. Additionally, by law, "pick-your-own" farms cannot spray pesticides within the pre-harvest interval (PHI), e.g., 7 or 14 days prior to harvest. Therefore, assessments applicable for activities at "pick-your-own" farms should account for residue dissipation during the PHI (i.e., residue @ "day of application + PHI").

This section addresses standard methods for estimating exposure and dose for three scenarios resulting from contact with gardens and/or trees that have previously been treated with pesticides:

- Section 4.2.1 - adult/children 6 < 11 years old inhalation exposure resulting from activities in gardens and/or trees;
- Section 4.2.2 - adult/children 6 < 11 years old dermal exposure resulting from activities in gardens and/or trees; and

- Section 4.2.3 - children 1 < 2 years old non-dietary ingestion.

4.2.1 Post-application Inhalation Exposure Assessment

Post-application inhalation exposure while performing activities in previously treated gardens or trees is rarely assessed due to the combination of low vapor pressure for typical pesticide active ingredients and the expected dilution in outdoor air. These should be handled on a case-by-case basis.

4.2.2 Post-application Dermal Exposure Assessment

Post-application dermal exposure resulting from contact with previously treated gardens and trees is dependent on three exposure factors: foliar residue, leaf-to-skin residue transfer, and exposure time. Considering the strengths and limitations of available data and behavioral characteristics of potentially exposed lifestages, post-application dermal exposure is assessed for adults and children 6 < 11 years old.

Post-application Dermal Exposure Algorithm

The algorithm to calculate daily exposure and dose is shown below. As discussed in *Section 1.3.4*, 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.

$$E = DFR_t * CF1 * TC * ET \quad (4.3)$$

where:

E	= exposure (mg/day);
DFR_t	= dislodgeable foliar residue on day "t" (µg/cm^2);
CF1	= weight unit conversion factor (0.001 mg/µg);
TC	= transfer coefficient (cm^2/hr); and
ET	= exposure time (hrs/day).

In the absence of chemical-specific data, DFR_t can be calculated as follows:

$$DFR_t = AR * F_{AR} * (1-F_D)^t * CF2 * CF3 \quad (4.4)$$

where:

DFR_t	= dislodgeable foliar residue on day "t" (µg/cm^2);
AR	= application rate (lbs ai/ft^2 or lb ai/acre);
F_{AR}	= fraction of ai as dislodgeable residue following application (unitless);
F_D	= 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 10^8 µg/lb); and
CF3	= area unit conversion factor (1.08 x 10^{-3} ft^2/cm^2 or 2.47 x 10^{-8} acre/cm^2).

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

$$D = \frac{E * AF}{BW} \quad (4.5)$$

where:

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

Post-application dermal exposure following applications to gardens and trees is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4* such as residue dissipation, product-specific re-treatment intervals, and activity patterns. If longer-term assessments (i.e., intermediate-, long-term, or lifetime exposures) are deemed necessary, similar refinements to more accurately reflect the exposure profile are recommended.

Post-application Dermal Exposure Algorithm Inputs and Assumptions

Recommended values for post-application dermal exposure assessments are provided in *Table 4-5* below. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 4-5: Gardens, Trees, and "Pick-your-own" Farms – Recommended Point Estimates for Post-Application Dermal Exposure Factors

Algorithm Notation	Exposure Factor (units)				Point Estimate(s)
AR	Application rate (mass ai per unit area)				Maximum labeled rate
F_{AR}	DFR following application, if chemical-specific is unavailable (fraction)				0.25
F_D	Daily residue dissipation, if chemical-specific is unavailable (fraction)				0.10
TC	Transfer Coefficient (cm^2/hr)	Gardens[a]	Adults		8400
			Children 6 < 11 years old		4600
		Trees, Retail Plants (if applicable)[a]	Adults		1700
			Children 6 < 11 years old		930
		Indoor Plants	Adults		220
			Children 6 < 11 years old		120
ET	Exposure Time (hours per day)	Home activities[b]	Gardens	Adults	2.2
				Children 6 < 11 years old	1.1
			Trees, Retail Plants (if applicable)	Adults	1.0
				Children 6 < 11 years old	0.50

Table 4-5: Gardens, Trees, and "Pick-your-own" Farms – Recommended Point Estimates for Post-Application Dermal Exposure Factors					
Algorithm Notation	**Exposure Factor (units)**				**Point Estimate(s)**
			Indoor Plants	Adults	1.0
				Children 6 < 11 years old	0.50
		"Pick-your-own" Farms (if applicable)	Adults		5.0
			Children 6 < 11 years old		1.9
BW	Body weight (kg)		Adults		80
			Children 6 < 11 years old		32
[a] Transfer coefficient point estimates from a composite distribution assuming equal proportion of time spent conducting various activities. See "Transfer Coefficient" section below. Children 6 < 11 years old TC derived using surface area adjustment (see *Section 2.3*). [b] Activity time point estimates from a composite distribution assuming equal proportion of each respective activity. Time for children 6 < 11 years old derived using hrs/day ratio adjustment. See "Exposure Time" section below and *Section D.8.1* of *Appendix D,*					

Application Rate

The assessment must reflect exposure resulting from use of the product and chemical at the maximum allowable application rate found on the product label. The probability of using a product at its maximum allowable rate at home or at "pick-your-own" farms is unknown, so additional information (e.g., use surveys), can be used, if available, to characterize the exposure resulting from use at the maximum allowable rate.

When chemical-specific residue information is unavailable, the assessment methodologies outlined in this section require the application rate to be in terms of mass active ingredient per area (e.g., lb ai/ft^2). Typically, this is listed on the label however, it sometimes must be estimated based on the solution concentration (e.g., lb ai/gallon dilute solution) and the volume of solution applied (e.g., 0.5 gallons solution/ft^2). This "area-based" approach is intuitive for garden applications where a user can approximate their garden's size and spray accordingly.

This is more difficult, however, for applications to trees since a user would not typically spray trees on a square footage basis. More likely, the product label directs the user to "spray to run off" or "as needed". In these cases, a label indicating the chemical's application rate for orchards or other trees used by professional applicators should be used – typically listed as an "area-based" rate in pounds of active ingredient per acre (lb ai/acre). In the event there is no professional label, the "area-based" application rate from sprays to gardens should be used. The assumption of similar foliar concentration for gardens and trees is reasonable absent chemical- and site-specific residue data.

Dislodgeable Foliar Residue

Estimates of Chemical Residue following Pesticide Applications

Following an application, some pesticide residue remains on the leaves of the target plant for an individual to contact and remove from the leaf surface. This is represented by a measurement from a standardized analytical method (Iwata, et al., 1977) and is referred to as dislodgeable foliar residue (DFR). If DFR measurements are unavailable, it can be estimated from the application rate using default fractions. Either way, the goal is to establish an average concentration of pesticide residue per unit area of foliage (e.g., $\mu g/cm^2$) that an individual can potentially contact over the course of the exposure period. Exposure can then be predicted using a surface-to-skin residue "transfer coefficient" (discussed below) – a metric which accounts for contact with treated surfaces based on the type of crop and activity being performed (e.g., harvesting apples).

As stated previously, it is assumed that contact with previously treated residential gardens or trees occur on the same day of application. Therefore, whether measured or estimated, the exposure assessment needs to include an estimated exposure based on the DFR on the day of application (i.e., $DFR_{t=0}$). For "pick-your-own" farms, however, individuals cannot conduct activities until the PHI has expired; therefore, residue should be representative of residue that has dissipated for a number of days (e.g., at 7 days or $DFR_{t=7}$). When chemical- and crop-specific data are available, DFR on the day of application and subsequent days can be estimated using a standard exponential decay model. Notably, the Agency recently revised the data requirements that pertain to conventional pesticides. As part of these revisions, DFR studies were classified as required for all occupational and residential uses under 40 CFR 158, subpart K (158.1070; post-application exposure data requirements table).

In the absence of data, however, DFR can be estimated using generic assumptions for both the initial residue available (i.e., $DFR_{t=0}$) and residue dissipation. Analysis of DFR data from field studies for various types of crops and various active ingredients indicate that the amount of dislodgeable residue, on the day of application, expressed as a fraction of the application rate, ranges from 0.02 to 0.89 (i.e., 2% to 89%). The data were fit to a lognormal distribution with a geometric mean of 0.18 and a geometric standard deviation of 2.21. Because dislodgeable residue cannot physically be greater than that deposited, the distribution must be truncated at 1.0 (i.e., 100% of the application rate). Note that this distribution is only meant as a basis for selecting a generic value for the DFR on the day of application as a fraction of the application rate and is inappropriate to use probabilistically. Because the data are comprised of a variety of chemicals on a variety of crops under a variety of conditions, this distribution represents the variability of many different situations. Within each particular DFR study, because the nature of the sampling results in an *average* DFR estimate, the distribution of the DFR on the day of application as a fraction of the application rate is much less variable – indicating that, for a given chemical the range may be only 2 – 5% or 30 – 35%, not 2 – 89%. Furthermore, because the chemical-specific variability of this fraction is small, a distribution for use probabilistically is unnecessary (i.e., it will not have much effect on the outcome) and a point estimate is appropriate for use in both deterministic and probabilistic assessments. When chemical-specific data are unavailable the **recommended default value for the fraction of application rate as**

dislodgeable foliar residue for both liquid and solid formulations following application is 0.25 (25%). Complete data analysis can be found in *Section D.6.2* of *Appendix D.*

Residue Dissipation

An analysis of various available studies was conducted to determine residue dissipation for use in exposure assessment in the absence of chemical-specific data. Expressed as a fraction per day, residue dissipation ranges from 0.03 to 0.47 (i.e., 3% to 47%) with a geometric mean of 0.16 and a geometric standard deviation of 2.18. Complete data analysis can be found in *Section D.6.2* of *Appendix D.* **The recommended default residue dissipation for both liquid and solid formulations for use in exposure assessment is 0.10 (10% per day).**

Transfer Coefficient

Post-application dermal exposure can be predicted using estimates for foliar residue, leaf-to-skin residue transfer for individuals contacting treated foliage during certain activities, and exposure time. The measure of leaf-to-skin residue transfer for a given crop and activity is known as the transfer coefficient (TC). Transfer coefficients are derived from concurrent measurements of exposure and foliar residue, and are the ratio of exposure rate, measured in mass of chemical per time (e.g., µg/hr), to residue, measured in mass of chemical per foliar surface area (e.g., $\mu g/cm^2$). In other words, transfer coefficients are exposure rates (e.g., mg/hr) normalized to residue (e.g., mg/cm^2), with resulting units of cm^2/hr. It follows that exposure rate for a given crop and activity can then be predicted from a given residue using the transfer coefficient. Additionally, transfer coefficients are typically applied generically – that is, for any given chemical, crop-activity transfer coefficients (e.g., apple harvesting) can be used.

Unlike occupational settings where individuals generally perform one task on one crop throughout the day (e.g., harvesting apples), individuals in residential settings are likely to conduct various activities related to gardening and tree or plant maintenance. Transfer coefficients from occupational reentry exposure studies conducted by the Agricultural Reentry Task Force (ARTF), were used to establish composite transfer coefficients representing an array of plausible activities likely to occur in residential settings associated with home gardening and other scenarios. Additionally, also unlike occupational settings, the transfer coefficients represent individuals wearing shorts and short-sleeve shirts by using "outer dosimeter" exposure measurements for the forearm and lower leg sections.

Transfer coefficients were derived for activities conducted in gardens and in trees (both at home and at "pick-your-own" farms), as well as for indoor plants and retail plants treated at commercial locations. *Table 4-6* below lists the representative crops and activities and the occupational field reentry studies used to derive their respective transfer coefficients. Because the individuals monitored in these studies were adults, use of these transfer coefficients to assess post-application exposure for children 6 < 11 years old requires an adjustment for body surface area as described in *Section 2.3*. **The recommended adjustment factor for children 6 < 11 years old is 0.55.** In practice, this means that a transfer coefficient for children 6 < 11 years old are expected to be approximately 55% of an adult transfer coefficient (i.e., Adult TC * 0.55). Complete data analysis for all transfer coefficients can be found in *Section D.7.2* of *Appendix D.*

Table 4-6: Gardens, Trees, and "Pick-your-own" Farms – Transfer Coefficient Studies			
Residential Post-application Activity	**Representative Crop/Activity Combinations**	**Study Code**	
		MRID	**ARTF #**
Gardens (vegetables, fruits, and flowers)	Cabbage weeding	45191701	ARF037
	Tomato tying	45530103	ARF051
	Squash harvesting	45491902	ARF049
	Chrysanthemum pinching	45344501	ARF039
Trees and Retail Plants (fruits, nuts, ornamentals, shrubs, bushes)	Ornamental citrus tree pruning	45469501	ARF043
	Apple harvesting	45138202	ARF025
	Orange harvesting	45432301	ARF041
	Grapefruit harvesting	45432302	ARF042
Indoor Plants	Ornamental citrus tree pruning	45469501	ARF043

Gardens

Transfer coefficients for residential gardening were derived using studies representing likely residential gardening activities such as weeding and picking flowers, fruits, or vegetables. Also, when appropriate for certain pesticides, these would be applicable for activities in "pick-your-own" farms growing field grown crops (e.g., pumpkins, strawberries, etc.). Four separate exposure studies were used: a study each for cabbage weeding (Klonne, et al., 2000; MRID 45191701), tomato tying (Klonne, et al., 2001; MRID 45530103), squash harvesting (Klonne, et al., 2001; MRID 45491902), and chrysanthemum pinching (Klonne, et al., 2000; MRID 45344501). Each individual study was fit to a lognormal distribution, and then combined into a single custom distribution via simulation assuming an equal proportion (e.g., 25%) for each distribution. *Table 4-7* below summarizes the statistical information for this data set. Based on this composite dataset, **the recommended point estimates for use in post-application dermal exposure assessment for gardens are 8400 cm^2/hr for adults and 4600 cm^2/hr for children 6 < 11 years old.**

Table 4-7: Statistical Summary – Gardening Transfer Coefficients (cm^2/hr)	
50th percentile	3200
75th percentile	13000
95th percentile	31000
99th percentile	38000
AM	8400
Range	160 – 41000
N	67
AM = arithmetic mean Note: Distributional parameters are not applicable for this distribution. Users are directed to the distributional parameters for each of the sub-distributions outlined in *Section D.7.2* of *Appendix D.*	

Trees and Retail Plants

Transfer coefficients were derived representing activities at home that individuals would perform on trees such as picking roses or apples or thinning shrubs and bushes. Also, when appropriate for certain pesticides, these would be applicable for activities in "pick-your-own" farms growing tree crops (e.g., apples, some flowers, etc.) as well as for contact with retail plants previously treated with pesticides at commercial locations. Four separate exposure studies were used: a

study each for apple harvesting (Klonne, et al., 2000; MRID 45138202), orange harvesting (Klonne, et al., 2000; MRID 45432301), grapefruit harvesting (Klonne, et al., 2000; MRID 45432302), and ornamental citrus tree pruning (Klonne, et al., 2000; MRID 45469501).

Each individual study was fit to a lognormal distribution, and then combined into a single custom distribution via simulation assuming an equal proportion (e.g., 25% each) for each distribution. *Table 4-8* below summarizes the statistical information for this data set. Based on this composite dataset, **the recommended point estimates for use in post-application dermal exposure assessment are 1700 cm^2/hr for adults and 930 cm^2/hr for children 6 < 11 years old.**

Table 4-8: Statistical Summary – Tree Activity Transfer Coefficients (cm^2/hr)	
50th percentile	1900
75th percentile	2600
95th percentile	3300
99th percentile	3900
AM	1700
Range	90 – 3400
N	60
AM = arithmetic mean Note: Distributional parameters are not applicable for this distribution. Users are directed to the distributional parameters for each of the sub-distributions outlined in *Section D.7.2* of *Appendix.*	

Indoor Plants

Transfer coefficients were derived representing activities for indoor plants using the study measuring exposure while pruning ornamental citrus trees (Klonne, et al., 2000; MRID 45469501). *Table 4-9*below summarizes the statistical information for this data set. **The recommended point estimates for use in post-application dermal exposure assessment are 220 cm^2/hr for adults and 120 cm^2/hr for children 6 < 11 years old.**

Table 4-9: Statistical Summary – Indoor Plant Activities Transfer Coefficients (cm^2/hr)	
50th percentile	200
75th percentile	270
95th percentile	440
99th percentile	620
AM (SD)	220 (120)
GM (GSD)	200 (1.6)
Range	90 – 500
N	15
Statistics based on a lognormal distribution. AM (SD) = arithmetic mean (standard deviation) GM (GSD) = geometric mean (geometric standard deviation)	

Exposure Time

As shown in the post-application dermal exposure algorithm and stated previously, daily exposure while contacting previously treated gardens and trees in residential settings can be predicted using foliar residue, a generic crop/activity transfer coefficient, and exposure time.

Home Activities

Exposure times for activities associated with gardens and trees at home were derived using a residential survey (Johnson et al., 1999) and Tsang and Klepeis, 1996 (as presented in 1997 EPA Exposure Factors Handbook; Vol. III, Table 15-62). While Tsang and Klepeis, 1996 includes information on "time spent working with soil in a garden or other circumstances working" for all lifestages including children 6 < 11 years old, the data are presented as hours/month, thus making it difficult to interpret daily exposure times necessary for exposure assessments of short duration. The residential survey (Johnson et al., 1999), on the other hand, asked about specific types of residential landscaping and maintenance activities and the amount of time an individual spends conducting such activities quantified in "hours per week" and "days per week". However, because this survey only included individuals 18 years or older, Tsang and Klepeis, 1996 (as presented in 1997 EPA Exposure Factors Handbook; Vol. III, Table 15-62) was used to adjust these results for those under 18 years. Analysis of this survey information can be found in *Section D.8.1* of *Appendix D*.

Gardens

As for transfer coefficients for gardening, a custom distribution for home gardening was simulated using cumulative distributions derived from the Johnson, et al. (1999) survey results for vegetable gardening and flower gardening in equal proportion (i.e., 50% each). Each cumulative distribution was truncated at 16 hours per day (i.e., 16 hrs = 100th percentile) to subtract for 8 hours of sleep. Additionally, as described in *Appendix D*, based on Tsang and Klepeis, 1996 (as presented in 1997 EPA Exposure Factors Handbook; Vol. III, Table 15-62), activity time for children 6 < 11 years old is considered to be approximately half that for adults and are adjusted accordingly. *Table 4-10* below provides a statistical summary of the composite distribution for time spent in home gardening activities. **The recommended point estimates for use in post-application dermal exposure assessment are 2.2 hours per day for adults and 1.1 hours per day for children 6 < 11 years old.**

Table 4-10: Home Gardening – Activity Time (hrs/day) Statistical Summary

Statistic	Gardening	
	Adults	Youths
50th percentile	1.4	0.7
75th percentile	2.9	1.5
95th percentile	6.9	3.5
99th percentile	13	6.5
AM	2.2	1.1
N	883	883

Notes:
AM = arithmetic mean
- Distributions are truncated at 16 hours per day
- Distributional parameters are not applicable (NA) for this distribution. Users are directed to the distributional parameters for each of the sub-distributions outlined in *Section D.8.1*of *Appendix D*

Trees, Retail Plants and Indoor Plants

A custom distribution for activity time associated with trees at home was simulated using cumulative distributions derived from the Johnson, et al., 1999 survey results for roses, shrubs/bushes, and fruit/nut trees (i.e., 33% each). This distribution is also considered a reasonable representation for time spent during activities associated with indoor plants. Each cumulative distribution was truncated at 16 hours per day (i.e., 16 hrs = 100th percentile) to subtract for 8 hours of sleep. *Table 4-11* below provides a statistical summary of the composite distribution. **The recommended point estimates for use in post-application dermal exposure assessment are 1.0 hour per day for adults and 0.5 hour per day for children 6 < 11 years old.**

Table 4-11: Home Trees, Retail Plants, and Indoor Plants – Activity Time (hrs/day) Statistical Summary

Statistic	Fruit, Nut, and Ornamental Trees and Bushes and Shrubs	
	Adults	Youths
50th percentile	0.5	0.25
75th percentile	1.4	0.7
95th percentile	3.4	1.7
99th percentile	6.3	3.2
AM	1.0	0.5
N	831	831

Notes:
AM = arithmetic mean
- Distributions are truncated at 16 hours per day.
- Distributional parameters are not applicable (NA) for this distribution. Users are directed to the distributional parameters for each of the sub-distributions outlined in *Section D.8.1* of *Appendix D*.

"Pick-your-own" Farm Activities

Survey information specifically for the amount of time spent at "pick-your-own" farms is unavailable. Therefore, information from Tsang and Klepeis, 1996 (presented in the 1997 EPA Exposure Factors Handbook; Vol. III Table 15-112) for amount of time "spent outdoors at a farm" was used. The time for adults, aged 18-64 years, ranged from 5 minutes to 16 hours per day, while the time for children, aged 5-11, ranged from 25 minutes to 4.4 hours per day. Note that, while the upper-end of the distribution indicates the time spent for adults is near 16 hours per day, it is assumed that anything greater than 8 hours at a "pick-your-own" farm is unlikely and values higher than this are likely a characteristic of the genericness of the data set used to estimate this exposure factor (i.e., "time spent outdoors at a farm" is not necessarily representative of "time spent at a "pick-your-own" farm"). *Table 4-12* below provides a statistical summary of this data. When a "pick your own" farm post-application exposure assessment is appropriate, **the recommended values for exposure time are 5.0 hours per day for adults and 1.9 hours per day for children 6 < 11 years old.** Additional information can be found in *Section D.8* of *Appendix D*.

Table 4-12: Time Spent at "Pick-your-own" Farms (hrs/day) Statistical Summary

Lifestage	Age (from data)	Statistics									
		N	Mean	Summary Percentiles							
				5	25	50	75	90	95	98	99
Adults	18-64	91	5.0	0.3	1.3	3.8	8.3	10.6	13.0	15.6	15.9

Children 6<11	5-11	7	1.9	0.4	0.8	1.7	2.2	4.4	4.4	4.4	4.4
Source: Tsang and Klepeis, 1996 (presented in 1997 EPA Exposure Factors Handbook Vol. III; Table 15-112).											

Future Research/Data Needs

Unavailable information that would refine post-application dermal exposure assessments for pesticide applications to gardens and trees include:

- Application intervals (i.e., how often chemicals are applied to gardens and trees) – either chemical-specific or generic intervals by pesticide-type (e.g., fungicides, insecticides, etc.).
- Survey information (preferably longitudinal) detailing:
  - Daily/weekly/monthly probability of treating gardens and trees with pesticides;
  - Product-specific application rates to obtain the likelihood that the maximum rate is used; and,
  - Daily activity patterns specific to gardens and trees.
- Post-application exposure data:
  - Specific for residential garden and tree activities;
  - Describing the extent to which an individual's exposure for a given activity varies.

Exposure Characterization and Data Quality

Transfer Coefficient: Because exposure data for deriving "residential" transfer coefficients were unavailable, they were derived using occupational exposure studies. This is likely health-protective due to the level of activity by workers compared to an individual conducting a similar activity at home (e.g., picking apples). Additionally, the relationships underlying the use of post-application exposure data as transfer coefficients – proportionality between exposure and time and between exposure rate (i.e., mg/hr) and residue – are uncertain, though potentially conservative.

Dislodgeable Foliar Residue: Absent chemical-specific data, estimates of dislodgeable foliar residue factors such as the amount available following application and dissipation are used generically based on existing data for a wide variety of chemicals. Use of these data generically, including using high-end estimates, may overestimate exposure for some chemicals.

Exposure Time: Information on the amount of time spent conducting certain activities, while from a robust survey, was not available in a "per day" format. Thus, to normalize weekly data on a "per day" basis, the assumption was made (based on the responses for "days per week" for these activities) that individuals conducted activities 2 days per week. Additionally, the survey did not provide information on individuals younger than 18 years of age; therefore, an adjustment was made to the survey information based on the distributional ratio of adults to children 6 < 11 years old for "time spent working with soil in a garden or other circumstances working" from Tsang and Klepeis, 1996 (as presented in the 1997 EPA Exposure Factors Handbook; Vol. III Table 15-62).

Information on time spent at a "pick-your-own" farm is unavailable; therefore "time spent outdoors on a farm" was used as a reasonable surrogate dataset.

4.2.3 Post-application Non-Dietary Ingestion Exposure Assessment

As a standard practice, post-application non-dietary ingestion exposure (i.e., hand-to-mouth, object-to-mouth, soil ingestion, etc.) for adults is not assessed – it is assumed that an adult would not place pesticide-contaminated hands, objects, or soil in their mouth. Additionally, for this scenario, post-application non-dietary ingestion exposure is also not assessed for young children. Unlike treated grass at home or in recreational areas or indoor floor surfaces, for this scenario the potential for exposure via non-dietary ingestion for young children is greatly diminished. Since the extent to which young children engage in the types of activities associated with these areas (e.g., gardening or picking fruits) or utilize these areas for prolonged periods of play is low, significant non-dietary ingestion exposure is not expected.

4.2.4 Combining Post-application Scenarios

Aggregation of post-application exposure is generally not applicable to activities associated with gardens and trees, given the lack of non-dietary ingestion exposure expected for the activities and index lifestages. In the event post-application inhalation exposure is assessed, it should be combined with post-application dermal exposure for adults and children 6 < 11 years old according to *Section 1.3.5*.

Section 5 Outdoor Fogging/Misting Systems

This section covers the following exposure scenarios:

- Outdoor aerosol space sprays (handler/post-application);
- Candles, coils, torches, mats (post-application);
- Outdoor residential misting systems (handler/post-application); and
- Animal barn misting systems (handler/post-application).

Each of these exposure scenarios is designated for outdoor use fogging products only. Each section offers additional description of the exposure scenario and the handler and/or post-application exposure. Indoor fogging products (i.e., "bug bombs") are covered in *Section 7*. While barns and stables are "indoors" (i.e., enclosed or semi-enclosed structures), they are included in this section because of methodological similarities to the other scenarios in this section and because barns often have significantly more air exchange than standard indoor commercial or residential spaces.

5.1 Outdoor Aerosol Space Sprays (OASS)

Outdoor aerosol space sprays are insecticide products available in aerosol cans formulated to kill or repel outdoor flying pests by an aerosol "fog". This section provides a standard method for estimating handler (i.e., applicator) exposure and post-application exposure to outdoor aerosol space sprays (OASS) used to kill or repel flying insects in outdoor spaces like yards or patios. This exposure scenario can also be used to assess wasp/hornet spray products that typically have a more directed spray pattern than other types of outdoor foggers, for lack of scenario-specific data for these types of products. For handlers, inhalation and dermal exposure may occur during the application of the aerosol spray product (i.e., the spray event); thus dermal and inhalation exposure should be assessed. Post-application exposure may occur from inhalation exposure following a spray application, as well as dermal and non-dietary ingestion exposure resulting from residues deposited on the turf or lawn.

5.1.1 Handler Exposure Assessment

This section provides a standard method for completing handler exposure assessments for adults treating an outdoor space with outdoor aerosol space sprays. It is assumed that only individuals 16 years of age or older handle (i.e., mix/load/apply) pesticides. The basis for this scenario is that handler exposure occurs as the aerosol spray is being applied by the applicator holding the product can and activating the spray. The method should be used for estimating potential doses that residential users may receive during aerosol applications from inhalation and dermal contact when chemical-specific data are unavailable.

This scenario assumes that pesticides may be inhaled or may come into contact with the skin during the application of aerosol spray products. The method to determine handler inhalation and dermal exposure to pesticides from aerosol applications relies on data from a study in which dermal and inhalation exposures were measured during use of an aerosol spray for indoor insecticide crack and crevice treatment, and is used in this scenario to represent an outdoor aerosol spray (See *Appendix C*). Thus, this method should be used in the absence of chemical-specific data, or as a supplement to estimates based on chemical-specific data.

Dermal and Inhalation Handler Exposure Algorithm

As described in *Section 1.3.3*, 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:

$$E = UE * AR \quad (5.1)$$

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:

$$AR = A_{product} * A.I. * CF1 * N \quad (5.2)$$

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:

$$AR = A_{product} * A.I. * CF1 * D_{product} * N \quad (5.3)$$

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).

Absorbed dermal and/or inhalation doses normalized to body weight are calculated as:

$$D = \frac{E * AF}{BW} \quad (5.4)$$

where:

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

Handler exposure for outdoor aerosol space spray applications is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.3* such as the product-specific application regimen.

Dermal and Inhalation Handler Exposure Algorithm Inputs and Assumptions

Recommended values for handler exposure (inhalation and dermal) assessments are provided in *Table 5-1* and *Table 5-2*. Following these tables, each scenario-specific input parameter is described in more detail. This description includes a summary of: i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 5-1: Outdoor Aerosol Space Sprays – Recommended Unit Exposure (mg/lb ai) Point Estimates

Formulation	Equipment/ Application Method	Dermal	Inhalation	Appendix Page Reference
		Point Estimate	Point Estimate	
Ready-to-Use (RTU)	Aerosol can	370	3.0	C-134

Table 5-2: Outdoor Aerosol Space Sprays – Recommended Handler Exposure Factor Point Estimates

Algorithm Notation	Exposure Factor (units)		Point Estimate(s)
AR	Application rate (lb ai/ day)		Product-specific
$D_{product}$	Density of product (g/mL)	Water-based products	1.0 (or product-specific)
		Solvent-based products	0.8 (or product-specific)
N	Number of cans used per day		1
A.I.	Percent ai in product		Product-specific
$A_{product}$	Amount of product per can (ounces, grams or milliliters)		Product-specific
BW	Body weight (kg)		80

Unit Exposures (UE)

As described in *Section 1.3.3*, the unit exposure is the ratio, for a given formulation/application method combination, of exposure to amount of active ingredient handled, with units of mass exposure per mass active ingredient handled (e.g., mg ai exposure/lb ai handled).

Application Rate (AR)

For the purposes of OASS handler exposure assessment, the application rate is the amount of active ingredient applied per day. The application rate can be determined from product-specific factors that are listed on the label or from generic factors listed above.

Number of Cans (N)

Absent product- or chemical-specific data, it **is assumed that 1 full can of product is applied by a residential handler at one time**, and that one can of product represents a residential handler's complete insecticidal aerosol product use per day. According to the Residential Exposure Joint Venture (REJV) survey (REJV, 2002), no household surveyed used more than one outdoor aerosol space spray product in one day. If extensive pest pressure exists, residential users would likely seek alternative application equipment.

Density ($D_{product}$)

The density should represent the product being assessed. If product-specific densities are available, they should be used in the assessment. Otherwise, **if the product is water-based, the assessor should use the density of water (1.0 g/mL). If the product is solvent-based, the assessor should use 0.8 g/mL**, an average based on an informal survey of various organic solvents described in CRC (Lide, 1981).

Amount of Product ($A_{product}$)

The amount of product (ounces, grams or milliliters per can) is a product-specific value and can be found on the product label.

Future Research/Data Needs

There are several main research/data needs with respect to the outdoor aerosol space spray handler scenario.

- A monitoring study is needed in which the spray application is conducted in a manner consistent with outdoor aerosol space sprays to more appropriately characterize dermal and inhalation handler exposure potential. The unit exposures for the outdoor aerosol space spray handler scenario were sourced from a study in which the spray application was completed indoors to baseboards.
- Use pattern information (i.e., amount handled, etc.) is needed to better characterize the residential handler exposure potential during application events.
- Scenario-specific unit exposure data are needed to more appropriately characterize dermal and inhalation handler exposure from wasp/hornet directed aerosol spray

applications; the wasp/hornet directed aerosol spray products typically have a modified delivery system (i.e., directed spray) than other outdoor products.

Exposure Characterization and Data Quality

Unit Exposures

- Only one study is available to represent unit exposures for residential handlers of aerosol spray products. The study is used to represent all residential handler (indoor and outdoor) aerosol exposure scenarios. The monitoring study was completed indoors where applicators directed the aerosol spray towards the baseboards of a residence. As the only data available, this study was considered a reasonable surrogate for outdoor aerosol space sprays.

Amount of active ingredient handled

- Information on the amounts of active ingredient handled for typical outdoor aerosol sprace sprays is largely unavailable. The estimates used however, are believed to result in health protective exposure estimates.
- The extent to which the amount an individual will handle per application varies from day-to-day or application-to-application is unknown; therefore, the assumption that there is no variation when assessing longer-term exposure durations is considered conservative.

5.1.2 Post-application Exposure Assessment

Post-application exposure can result from activities performed in a treated patio or yard following outdoor aerosol space spray pesticide applications. While exposure may occur for people of all ages, adults and children 1 < 2 years old are considered the index lifestages based on behavioral characteristics and the strengths and limitations of available data (see *Appendix A*).

This section addresses standard methods for estimating exposure and dose for three post-application exposure pathways resulting from use of area foggers:

- Section 5.1.2.1 - adult/children 1 < 2 years old inhalation exposure; and,
- Section 5.1.2.2 - adult/children 1 < 2 years old dermal and children 1 < 2 years old non-dietary exposure.

Post-application exposure is not anticipated to occur following pesticide application of wasp/ hornet products. These products are applied directly to insect nests/hives and it is not likely that residential bystanders would be present in these areas.

5.1.2.1 Post-application Inhalation Exposure Assessment

The well-mixed box (WMB) model was used to develop the exposure equation for the outdoor aerosol space spray post-application inhalation scenario (*See Section D.3* of *Appendix D* for additional detail on the WMB). The WMB was used to model pesticide air concentrations within an enclosed, fixed volume (i.e., a box) over time after an initial outdoor aerosol space spray application. The WMB model incorporates a number of simplifying assumptions: fresh air

(having no pesticide concentration) enters the box at a constant airflow rate; a turbulent internal airflow thoroughly mixes the fresh air with the pesticide-laden air resulting in a uniform pesticide air concentration within the box; and the perfectly mixed air exits the box at the same constant airflow rate (i.e., the inflow rate equals the outflow rate). Thus, the outdoor area where the aerosol is being applied is assumed to be in an enclosed box. Using the WMB model is conservative for estimation of exposures for an open patio, deck or yard where dissipation is expected to be greater than the enclosed space that the WMB depicts.

The evacuation of the aerosol from the box depends on airflow. For an outdoor scenario, the airflow, Q, is the product of the cross-sectional area and the wind velocity. The cross-sectional area is dependent on the area/volume of the treated space, and is defined in each SOP sub-scenario. The WMB model developed for this scenario models the pesticide air concentrations *after* an initial, instantaneous release of an outdoor aerosol space spray. Only dissipation due to airflow into and out of the box is modeled.

For the inhalation route of exposure, the point of departure (POD) could be based on the reference concentration (RfC) methodology. In the RfC methodology, air concentrations are not converted to doses, rather, risks are assessed on the basis of comparison of exposure concentrations with reference concentrations typically determined from animal studies. This approach is not always available for every chemical; therefore, the exposure assessor should discuss the possibility of this approach with a toxicologist.

Post-application Inhalation Exposure Algorithm

Post-application inhalation exposure to adults or children in an outdoor area that has been treated with an aerosolized pesticide is largely dependent on the amount applied and the airflow. It should be noted that two factors, exposure time and volume, are not significant factors for calculation of exposure from outdoor aerosol space sprays. Exposure time is not a significant factor in the exposure calculation due to the rapid dissipation of pesticide air concentrations from outdoor aerosol space sprays. Based on the minimum airflow rate (Q) given in *Table 5-3* below, the pesticide air concentration within the enclosed space is virtually zero (less than 0.1% of the initial concentration) after approximately 7 minutes. The integration of the WMB model equation to derive the exposure equation results in the volume term used to calculate the initial concentration (mass of active ingredient/volume of box) canceling out the volume term from the decay rate constant (See *Section D.3.1* of *Appendix D* for equation description and derivation).

$$E = \frac{IR * AR}{Q} \tag{5.5}$$

where:

E	= exposure (mg/day);
IR	= inhalation rate (m^3/hour);
AR	= application rate (mg ai/day); and
Q	= airflow through the treated area (m^3/hour).

The airflow through the treated space can be calculated as follows:

$$Q = AV * CF1 * CF2 * A_{cross\text{-}section} \quad (5.6)$$

where:

Q	= airflow through treated space (m^3/hr);
AV	= air velocity (m/s);
CF1	= time unit conversion factor (60 seconds/1 minute);
CF2	= time unit conversion factor (60 minutes / hour); and
$A_{cross\text{-}section}$	= cross-section of outdoor space treated (m^2).

Application rate can be calculated as follows:

$$AR = A_{product} * A.I. * CF1 * N \quad (5.7)$$

where:

AR	= application rate (mg 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 (28,350 mg/oz or 1,000 mg/g); and
N	= number of cans applied per day 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:

$$AR = A.I. * A_{product} * CF * D_{product} * N \quad (5.8)$$

where:

AR	= application rate (mg ai/day);
A.I.	= percent active ingredient in product (% ai);
$A_{product}$	= amount of product per can (mL/can);
CF	= conversion factor to convert grams to milligrams (1,000 mg/1 g);
$D_{product}$	= density of product (g/mL); and
N	= number of cans applied per day in one application (cans/day).

Absorbed inhalation dose normalized to body weight is calculated as:

$$D = \frac{E * AF}{BW} \quad (5.9)$$

where:

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

Post-application inhalation exposure following applications of outdoor aerosol space sprays is generally considered short-term in duration, but is dependent on the use pattern of the specific product being assessed and the dissipation/degradation properties of the active ingredient. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4* such as residue dissipation, product-specific re-treatment intervals, and activity patterns. If longer-term assessments (i.e., intermediate-, long-term, or lifetime exposures) are deemed necessary, similar refinements to more accurately reflect the exposure profile are recommended.

Post-application Inhalation Exposure Algorithm Inputs and Assumptions

Recommended parameters for post-application inhalation exposure assessments are provided in *Table 5-3* below. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of: i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 5-3: Outdoor Aerosol Space Sprays – Recommended Post-application Inhalation Exposure Factor Point Estimates

Algorithm Notation	Exposure Factor (units)		Point Estimate(s)
AR	Application rate (mg ai/ day)		Product-specific
$A_{cross\text{-}section}$	Cross sectional area of area treated (m^2)		15
AV	Air velocity (m/s)		0.1
Q	Airflow through treated area (m^3/hr)		5,400
N	Number of cans applied per day in one application (cans/day)		1
$D_{product}$	Density of product (g/mL)	Water-based products	1.0
		Solvent-based products	0.8
A.I.	Percent ai in product (%)		Product-specific
$A_{product}$	Amount of product (mL/can)		Product-specific
IR	Inhalation rate (m^3/hour)	Adult	0.64
		Children (1 < 2 years old)	0.33
BW	Body Weight (kg)	Adult	80
		Children (1 < 2 years old)	11

Application Rate (AR)

The application rate is the amount of active ingredient applied per day. The application rate can be determined from product-specific factors that are listed on the product label. This application rate is determined by amount of product in a can, how many cans are used in an application, and the percentage of active ingredient.

Air Velocity (AV)

The air velocity is the speed of the air moving through the treated area defined for the well-mixed box model. The fraction of the chemical available for inhalation in outdoor air is a function of the movement of air into and out of the backyard "box". The air velocity determines the rate at which the contents of the outdoor area treated are evacuated. Wind velocity is an influencing factor affecting flying pest nuisance. Bidlingmayer et al. (1995) examined the effect of wind velocity on suction trap catches. Their research noted that trap catches declined as wind velocities increased over the entire range of observed velocities. Wind velocities within the range of normal mosquito flights, about 1 m/s, resulted in trap catch reductions on significant nights of approximately 50% by wind at 0.5 m/s and 75% at 1.0 m/s.

The wind speed range considered here corresponds with the lower two tiers of the Beaufort wind force scale, an empirical measure for describing wind speed. The Beaufort wind force scale is a range on a numerical basis of 0-10, from still air conditions up to hurricane force winds. This SOP covers Beaufort numbers 0-1. The Beaufort number 0 corresponds to calm wind conditions of <0.3 m/s [18 meters/minute; 0.7 mph]. The Beaufort number 1 corresponds to light air conditions of 0.3-1.5 m/s [18-90 meters/minute; 0.7–3.4 mph]. This SOP provides a distribution of wind velocities from 0.1-1.5 m/s [0.2-3.4 mph], the upper limit for "light air" condition on the Beaufort scale and a reasonable upper bound for wind velocities where these products would be used to control flying pests. This windspeed represents a range of values foreseeable where OASS products may be used (i.e., in a yard or on an outdoor patio where flying pests may pose a nuisance). When wind velocities are higher than 1.5 m/s, these products are less likely to be used because of reduced flying pest pressure.

The recommended point estimate for use in a deterministic exposure assessment is 0.1 m/s (0.22 mph). The range of air velocities applicable to this assessment are 0.1 m/s to 1.5 m/s.

$A_{cross\ section}$

$A_{cross\text{-}section}$ represents the cross-sectional area of the volume of treated space for this exposure scenario, with units m^2. Unless otherwise specified by the product label, the exposure scenario for outdoor aerosol space sprays considers a 20 ft. x 20 ft. x 8 ft. (height) space treated. Therefore, **the cross-sectional area for the treated space is 160 ft^2 (20 ft width x 8 ft height) or 15 m^2**.

Airflow (Q)

Airflow (Q) is defined as the volume of natural air that uniformly passes through a given area in a specified period of time. In the well-mixed box model, the airflow through the treated space is the product of the air velocity (AV) and the cross-sectional area ($A_{cross\ section}$), with units m^3/hour. As mentioned above, the cross-sectional area of the space treated is assumed to be 20 ft x 8 ft (160 ft^2 or 15 m^2). The range of air velocities to represent calm air conditions is 0.1 m/s to a maximum of 1.5 m/s. Therefore, the airflow for a typical space treated is assumed to range from **5,400 m^3/hour (as the conservative default value)** to 81,000 m^3/hour (representing a high-end air velocity for calm air conditions).

Number of Cans per Day (N)

Absent product- or chemical-specific data, **it is assumed that 1 full can of product is applied by a residential handler at one time**, and that one can of product represents a residential handler's complete insecticidal aerosol product use per day. According to the Residential Exposure Joint Venture (REJV) survey (REJV, 2002), no household surveyed used more than one outdoor aerosol space spray product in one day. If extensive pest pressure exists, residential users would likely seek alternative application equipment.

Density ($D_{product}$)

The density should represent the product being assessed. If product-specific densities are available, they should be used in the assessment. Otherwise**, if the product is water-based, the assessor should use the density of water (1.0 g/mL). If the product is solvent-based, the assessor should use 0.8 g/mL**, an average based on an informal survey of various organic solvents described in CRC (Lide, 1981).

Amount of Product ($A_{product}$)

The amount of product (ounces, grams, or milliliters per can) is a product-specific value and should be stated on the label.

Future Research/Data Needs

There are several research/data needs with respect to the post-application outdoor aerosol space spray scenario.

- Survey data could be developed to examine the actual size of the space treated by typical outdoor aerosol space sprays. The OASS exposure scenario assumes that residential users treat a 20 ft x 20 ft space, unless otherwise specified on the label.
- Limited data are available to characterize the spatio-temporal distribution pattern that results from the release of an aerosol spray can.
- Use pattern information (i.e., amount handled, etc.) is needed to better characterize the residential post-application exposure potential after application events.

Exposure Characterization and Data Quality

The OASS exposure scenario also makes the following health protective assumptions:

- all the amount of the applied pesticide is in the air available for inhalation exposure, and
- all the amount of the applied pesticide settles onto the treated area (e.g.,turf) and is available for dermal exposure
- the simplifying assumptions implicit in the well-mixed box model identified in the first two paragraphs of *Section 5.1.2.1* would be health protective, since the modeled air concentrations would dissipate less rapidly (resulting in higher pesticide concentrations) in the artificially defined fixed volume compared to a true open outdoor space.

5.1.2.2 Post-application Dermal and Non-dietary Ingestion Exposure Assessment

Dermal and incidental oral post-application exposures are expected to occur after the spray settles onto the treated areas of a yard (e.g., deck, patio, or turf). Based on the data available and the assumptions that would be considered for assessing dermal and non-dietary ingestion exposures from smooth surfaces (e.g., patios and decks) and textured surfaces (e.g., turf/lawns), this SOP makes a health protective assumption that all of the outdoor spray settles onto turf. This settling is assumed to occur in a uniform fashion throughout the treated area, similar to a direct lawn broadcast treatment. Once the application rate is determined, the turf transferable residues and resulting dermal and incidental oral exposures should be assessed following the methodologies outlined in *Section 3.2*.

The following equation can be used to convert the application rate in pounds ai per square foot as is deposited on the turf:

$$AR = \frac{A_{product} * A.I. * CF1 * N}{T_A} \quad (5.10)$$

where:

AR = application rate (lb ai/ft^2 or lb ai/A);
$A_{product}$ = amount of product per 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);
N = number of cans applied per day in one application (cans); and
T_A = treated area (ft^2 or A).

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:

$$AR = \frac{A_{product} * A.I. * CF * D_{product} * N}{T_A} \quad (5.11)$$

where:

AR = application rate (lb ai/ft^2 or lb ai/A);
A.I. = percent active ingredient in product (% ai);
$A_{product}$ = amount of product per can (mL/can);
CF = conversion factor (1 lb/454 g);
$D_{product}$ = density of product (g/mL);
N = number of cans per day in one application (cans); and
T_A = treated area (ft^2 or A).

Post-application dermal and non-dietary ingestion exposure following applications of outdoor aerosol space sprays is generally considered short-term in duration, but is dependent on the use pattern of the specific product being assessed and the dissipation/degradation properties of the active ingredient. Refinement of this dose estimate to reflect a more accurate short-term multi-

day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4* such as residue dissipation, product-specific re-treatment intervals, and activity patterns. If longer-term assessments (i.e., intermediate-, long-term, or lifetime exposures) are deemed necessary, similar refinements to more accurately reflect the exposure profile are recommended.

Post-application Dermal and Non-Dietary Ingestion Algorithm Inputs and Assumptions

The following provides a general discussion for each exposure factor and recommended point estimates for use in exposure assessment.

Application Rate (AR)

The application rate is the amount of spray applied per unit area. The application rate per day/spray can be determined from product-specific factors that are listed on the label or from generic factors listed above. This application rate is calculated in lbs ai/ft^2 or lb ai/A.

Amount of Product ($A_{product}$)

The amount of product (ounces, grams, or milliliters per can) is a product-specific value and should be stated on the label.

Number of Cans per Day (cans)

Absent product- or chemical-specific data, **it is assumed that 1 full can of product is applied by a residential handler at one time**, and that one can of product represents a residential handler's complete insecticidal aerosol product use per day. According to the Residential Exposure Joint Venture (REJV) survey (REJV, 2002), no household surveyed used more than one outdoor aerosol space spray product in one day. If extensive pest pressure exists, residential users would likely seek alternative application equipment.

Percent Active Ingredient in Product (A.I.)

The percent active ingredient in the product being assessed can be determined from the product label.

Treated Area (T_A)

An outdoor living space with dimensions of **20 ft. x 20 ft. x 8 ft. (i.e., 400 ft^2) is assumed when calculating airborne concentration levels and turf deposition**. The recommended treated area is based on a recent survey on U.S. decking market, which was conducted by the Center for International Trade in Forest Products (CINTRAFOR). This deck size was selected to represent the typical area treated on a patio, deck, or yard. In this survey, CINTRAFOR contacted a random sample of U.S. homebuilders via telephone. Based on the survey results, the mean deck size for "spec" homes (n=109) was 361ft^2. This translates to approximately a 20 ft x 18 ft surface area. The mean deck size for custom homes (n=174) was 490 ft^2 (Eastin et al., 2005). This translates to approximately 20 ft x 24.5 ft surface area. The overall mean deck size identified in this survey is believed to be an appropriate surrogate for the amount of outdoor living space treated by aerosol fogging products. Therefore, in the absence of additional

information, 20 ft. x 20 ft. x 8 ft. is used as the volume of space that is treated with an outdoor aerosol space spray and 20 ft x 20 ft is used as the surface area of a treated area.

Density ($D_{product}$)

The density should represent the product being assessed. If product-specific densities are available, they should be used in the assessment. Otherwise**, if the product is water-based, the assessor should use the density of water (1.0 g/mL). If the product is solvent-based, the assessor should use 0.8 g/mL**, an average based on an informal survey of various organic solvents described in CRC (Lide, 1981).

Future Research/Data Needs

There are four main potential research/data needs with respect to the post-application exposure from the outdoor aerosol space spray scenario.

- The OASS exposure scenario assumes that residential users treat a 20 ft x 20 ft space unless otherwise specified on the product label. Survey and efficacy data could be developed to examine the actual size of the amount of space treated by typical outdoor aerosol space sprays.
- Extremely limited data are available to indicate the spatio-temporal deposition pattern that results from the release of an aerosol spray can. Additional studies could be designed to capture the deposition pattern of aerosol spray pesticides in outdoor conditions.
- Survey data could be developed to examine the amounts of aerosol spray product/active ingredient handled during typical outdoor treatment scenarios.
- No data are available to indicate the extent of dermal deposition on skin from airborne particles as a result of aerosolized pesticide spray events. Studies could be designed to capture the extent of dermal deposition as a result of aerosolized pesticide sprays.

Exposure Characterization and Data Quality

The OASS exposure scenario makes the following health protective assumptions:

- all the amount of the applied pesticide is in the air available for inhalation exposure, and
- all the amount of the applied pesticide settles onto the turf and is available for dermal exposure.

5.1.2.3 Combining Post-application Scenarios

Risk estimates resulting from different exposure scenarios are combined when it is likely that they can occur simultaneously based on the use pattern and when the toxicological effects across different routes of exposure are the same. When combining scenarios, it is important to fully characterize the potential for co-occurrence as well as characterizing the risk inputs and estimates. Risk estimates should be combined even if any one scenario or route of exposure exceeds the level of concern because this allows for better risk characterization for risk managers.

It is likely that children could be exposed to an area treated by an OASS product via inhalation, dermal and non-dietary ingestion (hand-to-mouth) routes and that these scenarios could occur simultaneously. Therefore, these exposure scenarios should be combined when toxicological effects are the same across these routes of exposure.

5.2 Candles, Coils, Torches & Mats (CCTM)

Candles, coils, torches, and mats (CCTM) are pesticide products that are ignited or placed on a burner to release the active ingredient as a smoke or vapor in order to repel insects. The scenario represents use of CCTM products for a gathering of people outdoors in a yard or on a patio using the product(s) to repel flying pests. This section provides standard methods for estimating potential exposure to pesticides from the use of pesticidal candle, coil, torch or mat for the purposes of outdoor pest control.

Handler exposure, both dermal and inhalation, is expected to be negligible as the application activity (i.e., product activation) does not involve application (e.g., spraying liquids or spreading granules) in the typical sense. However, adult and child post-application inhalation exposure resulting from being in proximity to CCTM products following activation is the primary exposure route. Post-application dermal exposure from CCTM use is expected to be negligible.

5.2.1 Handler Exposure Assessment

Pesticidal candles, coils, torches and mats are typically marketed for residential use to repel flying insects and pests. Upon activation (i.e., ignition or heating), these products emit small particles (<2 µm) over the useful life of the product (Lucas, J., EPA, Allethrins SMART Meeting, 10/17/03). Handler exposure does not need to be assessed quantitatively because the ignition or activation of these products is instantaneous and quantitative post-application exposure adequately assesses the exposure potential from CCTM.

5.2.2 Post-Application Exposure Assessment

Post-application exposure can result from presence in a patio or yard during use of candles, coils, torches, or mats containing pesticides. While exposure may occur for people of all ages, adults and children 1 < 2 years old are considered the index lifestages based on behavioral characteristics and the strengths and limitations of available data (see *Appendix A*).

This section addresses standard methods for estimating exposure and dose for three post-application exposure pathways resulting from use of candles, coils, torches, and mats:

- Section 5.2.2.1 - adult/children 1 < 2 years old inhalation exposure; and,
- Section 5.2.2.2 - adult/children 1 < 2 years old dermal and children non-dietary exposure.

5.2.2.1 Post-application Inhalation Exposure Assessment

Post-application inhalation exposure occurs as a result of inhalation of the airborne emission released by the pesticidal candle, coil, torch or mat. This section provides a standard method for completing post-application inhalation exposure assessments for adults and children during the use of pesticidal candles, coils, or mats for short-term pest control.

As with the outdoor aerosol space sprays, the algorithm assumes a simple WMB model adequately represents the exposure scenario (See *Section D.3* of *Appendix D* for additional details on the WMB). The algorithms presented in this scenario assume that no further inhalation exposure occurs after the CCTM is spent or extinguished. The exposure scenario assumes that the CCTM product is in use for the entire exposure time.

The WMB model was used to develop the exposure equation for the CCTM post-application inhalation scenario (Fan et al, 2001). The CCTM scenario differs from the other exposure scenarios in this SOP section in that the WMB model includes a constant emission rate term during the exposure time and, thus, results in a more complex exposure equation. The WMB model was used to model pesticide air concentrations within an enclosed, fixed volume (i.e., a box) over time during the constant emission of a pesticide from a CCTM product. The WMB model incorporates a number of simplifying assumptions: fresh air (having no pesticide concentration) enters the box at a constant airflow rate; a turbulent internal airflow thoroughly mixes the fresh air with the pesticide-laden air resulting in a uniform pesticide air concentration within the box; and the perfectly mixed air exits the box at the same constant airflow rate (i.e., the inflow rate equals the outflow rate). Thus, the outdoor area where the CCTM product is being applied is assumed to be in an enclosed box. Using the WMB model is conservative for estimation of exposures for an open patio or deck where dissipation is expected to be greater than the enclosed space that the WMB depicts.

The evacuation of the CCTM emission from the box depends on airflow. For an outdoor scenario, the airflow, Q, is the product of the cross-sectional area and the wind velocity. The cross-sectional area is dependent on the area/volume of the treated space, and is defined in each SOP sub-scenario. The WMB model developed for this scenario models the pesticide air concentrations *during* a constant emission of pesticide from a CCTM product. Only constant emission and dissipation due to airflow into and out of the box is modeled.

For the inhalation route of exposure, the point of departure (POD) could be based on the reference concentration (RfC) methodology. In the RfC methodology, air concentrations are not converted to doses, rather, risks are assessed on the basis of comparison of exposure concentrations with reference concentrations typically determined from animal studies. This approach is not always available for every chemical; therefore, the exposure assessor should discuss the possibility of this approach with a toxicologist.

Post-application Inhalation Exposure Algorithm

The following algorithm is used to determine post-application inhalation exposure to the CCTM products (See *Section D.3.2* of *Appendix D* for equation description and derivation):

$$E = \frac{IR \cdot V_E \cdot ER}{Q}\left(ET - \frac{V}{Q}\right) \quad (5.12)$$

where:

E = exposure (mg/day);
IR = inhalation rate (m^3/hr);
V_E = vaporization efficiency (%);
ER = emission rate (mg ai/hr);
ET = exposure time (hr/day);
V = volume of treated space (m^3); and
Q = airflow (m^3/hr).

The airflow through the treated space can be calculated as follows:

$$Q = AV * CF1 * CF2 * A_{cross\text{-}section} \quad (5.13)$$

where:

Q = airflow through treated space (m^3/hr);
AV = air velocity (m/s);
CF1 = time unit conversion factor (60 seconds/1 minute);
CF2 = time unit conversion factor (60 minutes / hour); and
$A_{cross\text{-}section}$ = cross-section of outdoor space treated (m^2).

The emission rate from a CCTM product can be calculated as follows:

$$ER = \frac{A * N_P}{UL} \quad (5.14)$$

where:

ER = emission rate (mg ai/hr);
A = amount of mg ai in CCTM product (mg ai/product);
N_P = number of products used (products); and
UL = useful life of product (hours).

Inhalation dose normalized to body weight is calculated as:

$$D = \frac{E * AF}{BW} \quad (5.15)$$

where:

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

Post-application inhalation exposure following uses of candles, coils, torches, or mats is generally considered short-term in duration, but is dependent on the use pattern of the specific product being assessed and the dissipation/degradation properties of the active ingredient. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4* such as residue dissipation, product-specific re-treatment intervals, and activity patterns. If longer-term assessments (i.e., intermediate-, long-term, or lifetime exposures) are deemed necessary, similar refinements to more accurately reflect the exposure profile are recommended.

Post-application Inhalation Exposure Algorithm Inputs and Assumptions

Recommended values for post-application inhalation exposure assessments are provided in *Table 5-4* below. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of: i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 5-4: CCTM – Recommended Post-application Inhalation Exposure Factor Point Estimates

Algorithm Notation	Exposure Factor (units)		Point Estimate(s)
V_E	Vaporization efficiency (percent)		100% assumed unless registrant provides data for product
A	Amount of ai in the product (mg)		Product-specific
ER	Emission rate (mg ai/hr)		Calculated
UL	Useful life (hours)	Candles/Coils/Torches	4
		Mats	4
ET	Exposure time (hours)	Adults	2.3
		Children 1 < 2 years old	2.3
V	Volume of treated space (m^3)		51
Q	Airflow through treated area (m^3/hr)		4,000
AV	Air velocity (m/s)		0.1
N_P	Number of products used (# products)		1 product per treated area
$A_{cross\text{-}section}$	Cross sectional area of area treated (m^2)		11
IR	Inhalation rate (m^3/hour)	Adults	0.64
		Children 1 < 2 years old	0.33
BW	Body Weight (kg)	Adults	80
		Children 1 < 2 years old	11

Vaporization Efficiency (V_E)

Vaporization efficiency is the percentage of active ingredient in the product that becomes available for inhalation exposure through heating, burning, or activation of the product. As a CCTM product is heated or burned, it is likely that not all of the active ingredient in the product will be available for inhalation exposure. If this information is available through product

efficacy studies or other sources, it can be used in the equation. In the absence of data, 100% vaporization efficiency will be assumed for the active ingredient.

Amount of Active Ingredient in Product (A)

The amount of active ingredient available in the product (e.g., mg ai/product) is found on the product label.

Useful Life (UL)

The useful life is the time (measured in hours) that the CCTM product is active (i.e., it is active as an emission source). For example, many candles and coils have a 4-6 hour useful life. Mosquito mats often have a **useful life of 4 hours.** This can also be a product-specific input. (Lucas, J., EPA Allethrins SMART Meeting, 10/17/03).

Emission Rate (ER)

The emission rate (mg ai/hour) is the amount of active ingredient available in the product, measured in milligrams ai/product, divided by the useful life (UL) of the product.

Exposure Time (ET)

Another important variable for addressing post-application exposure is the duration of time spent in areas treated by CCTM products. The exposure time for adults and children conservatively assumes that the time spent in the volume of treated space is equivalent to the time spent at home outdoors in the yard or other areas around the house ("doers only"). The exposure time values are from the Exposure Factors Handbook 2011 Edition (Table 16-20), converted from minutes per day to hours per day. The original analysis generated statistics for the subset of the survey lifestage that reported being in the location or doing the activity in question (i.e., "doers only"). **Based on these data, the recommended point estimate for use in post-application inhalation CCTM exposure assessment for adults and children is 2.3 hrs/day.**

Table 5-5: Time Spent Outdoors At Home in the Yard or Other Areas Outside the House

Statistic	Hours per Day	
	Adults	Children 1 < 2 years old
5th percentile	0.1	0.4
25th percentile	0.5	1.0
50th percentile	1.5	1.5
75th percentile	3.0	3.0
90th percentile	5.5	5.1
95th percentile	7.3	5.8
Arithmetic Mean	2.3	2.3
	Reference: 2011 EFH, Table 16-20 (Adults 18-64)	Reference: 2011 EFH, Table 16-20 (Children 1 < 4 years old)

Volume (V)

The **volume of treated space is assumed to be 51 m^3** for CCTM products, unless otherwise noted on an available product label. The 51 m^3 volume represents a 15 ft. x 15 ft. x 8 ft. (1800

ft^3) treated space. This represents a typical treated space based on experience and professional judgment and review of current product labels that pertain to this exposure scenario.

Air Velocity (AV)

The air velocity is the speed of the air moving through the treated volume defined for the well-mixed box model. The fraction of the chemical available for inhalation in outdoor air is a function of the movement of air into and out of the backyard "box". The air velocity determines the rate at which the contents of the outdoor area treated are evacuated. Wind velocity is an influencing factor affecting flying pest nuisance. Bidlingmayer et al. 1995 examined the effect of wind velocity on suction trap catches. Their research noted that trap catches declined as wind velocities increased over the entire range of observed velocities. Wind velocities within the range of normal mosquito flights, about 1 m/s resulted in trap catch reductions on significant nights of approximately 50% by wind of 0.5 m/s and 75% at 1.0 m/s.

The wind speed range considered here corresponds with the lower two tiers of the Beaufort wind force scale, an empirical measure for describing wind speed. The Beaufort wind force scale is a range on a numerical basis of 0-10, from still air conditions up to hurricane force winds. This SOP covers Beaufort numbers 0-1. The Beaufort number 0 corresponds to calm wind conditions of <0.3 m/s [18 meters/minute; 0.7 mph]. The Beaufort number 1 corresponds to light air conditions of 0.3-1.5 m/s [18-90 meters/minute; 0.7–3.4 mph]. Thus, this SOP provides a distribution of wind velocities from 0.1-1.5 m/s [0.2-3.4 mph], the upper limit for "light air" condition on the Beaufort scale and a reasonable upper bound for wind velocities where these products would be used to control flying pests. This windspeed represents a range of values foreseeable where CCTM products may be used (i.e., in a yard or on an outdoor patio where flying pests may pose a nuisance). When wind velocities are higher than 1.5 m/s, these products are less likely to be used because of reduced flying pest pressure.

The recommended point estimate for use in a deterministic exposure assessment is 0.1 m/s (0.22 mph). The range of air velocities applicable to this assessment are 0.1 m/s to 1.5 m/s.

$A_{cross\ section}$

$A_{cross\text{-}section}$ represents the cross-sectional area of the volume of treated space for this exposure scenario, measured in m^2. Unless otherwise specified by the product label, the exposure scenario for CCTM considers a 15ft x 15 ft x 8 ft space; therefore **the cross-sectional area for the treated space is 120 ft^2 (15 ft width x 8 ft height) or 11 m^2.**

Airflow (Q)

Airflow (Q) is defined as the volume of natural air that uniformly passes through a given area in a specified period of time. The airflow is a function of the cross-sectional area and wind velocity In the well-mixed box model, the airflow through the treated space is the product of the air velocity and the cross-sectional area, and is measured in m^3/hour. As mentioned above, the cross-sectional area of the space treated is assumed to be 15 ft x 8 ft (120 ft^2, or 11 m^2). The range of air velocities to represent calm air conditions is 0.1 m/s to a maximum of 1.5 m/s. Therefore, the airflow for a typical space treated is assumed to range from **4,000 m^3/hour (as the health-protective default value)** to 60,000 m^3/hour.

Number of Products Used (Np)
The number of products is related to the size of the space treated by the product user. A product user is typically directed to use a proportional amount of product per area (e.g., if 1 CCTM treats a 15 ft x 15 ft area, then treating twice the space would require double the product). The airborne concentration of active ingredient is the same in both examples. Therefore, the CCTM exposure scenario considers the smallest typical treatment area (i.e., 15 ft x 15 ft). **The recommended point estimate for use in a deterministic exposure assessment is 1 product used for the default treated space size (15 ft x 15 ft area)**. This value can be adjusted based on product-specific label directions for how many CCTM products can treat the typical 15 ft by 15 ft area.

Future Research/Data Needs

The following area areas for research/data need with respect to the post-application exposure from the CCTM scenario:

- the extent of post-application inhalation exposure potential as a result of airborne particles released from the activation of candles, coils, torches, and mats
- studies designed to capture the extent of inhalation exposure as a result of the activation and use of these types of consumer products.

Exposure Characterization and Data Quality

- The simplifying assumptions implicit in the well-mixed box model identified in the first two paragraphs of *Section 5.2.2.1*would tend to be health protective since the modeled air concentrations would dissipate less rapidly (resulting in higher pesticide concentrations) in the artificially defined fixed volume compared to a true open outdoor space.
- Due to the relative useful life (e.g., 4-6 hours for candles & mats) of CCTM products compared to the time spent outdoors, the algorithm models the air concentration during the "burn time" of the CCTM products. Exposure time is typically less than the burn time of the product. If time spent outdoors (ET) were to exceed the useful life of such products, the exposure equation derived for this section would need to be modified to account for the change in the emission rate of the product.
- A source emission continued beyond the useful life of the product would overestimate pesticide air concentrations, thus the use of the exposure equation in this section represents a health protective approach.

5.2.2.2 Post-application Dermal and Non-Dietary Ingestion Exposure Assessment

The inhalation route of exposure is expected to be the primary post-application exposure route. Residues deposited on patios or other surfaces are expected to be negligible after use of a CCTM product. Due to the size fraction of particles released from the activation of CCTM products, particles are expected to remain airborne rather than be deposited on surfaces. Therefore, dermal and incidental oral post-application exposures to surface residues do not need to be quantitatively assessed.

5.2.2.3 Combining Post-application Scenarios

Risk estimates resulting from different exposure scenarios are combined when it is likely that they can occur simultaneously based on the use pattern and when the toxicological effects across different routes of exposure are the same. When combining scenarios, it is important to fully characterize the potential for co-occurrence as well as characterizing the risk inputs and estimates. Risk estimates should be combined even if any one scenario or route of exposure exceeds the level of concern because this allows for better risk characterization for risk managers.

As no residues from CCTM products are expected to be deposited on patios or other surfaces, no post-application dermal and non-dietary ingestion exposures are expected to occur. Therefore, these exposure scenarios are not quantitatively assessed, and are not combined with post-application inhalation exposure.

5.3 Outdoor Residential Misting Systems (ORMS)

Outdoor residential misting systems (sometimes called "mosquito misters") are application systems designed to spray pesticides in a fine mist to kill mosquitoes and other insects outdoors. Misting systems include spray nozzles that are mounted around the perimeter of a home in the lawn or landscaping, or on parts of the house or fence. The spray nozzles are connected by tubing to a supply of insecticide. These systems can operate automatically (i.e., at preset intervals) or manually (e.g., remote control or switch).

This section provides standard methods for estimating potential doses from pesticides applied using outdoor residential misting systems (ORMS) in yards or on patios. Adults filling the ORMS drums with the pesticide may experience dermal and inhalation exposure. Adults and children occupying the yard or patio following the application of a pesticide using an ORMS may experience inhalation, dermal and incidental oral exposure. This section describes the methods for estimating the potential dose for handlers using ORMS, the method for estimating the potential dose from post-application inhalation exposure to a treated yard or patio, as well as the method for estimating residue deposited on the lawn following a pesticide treatment from the ORMS which can be used in conjunction with methods outlined in *Section 3.2* to estimate dermal and oral post-application doses following direct applications to lawns.

5.3.1 Handler Exposure Assessment

Misting systems are typically marketed as systems that include a mix tank, a timer controlled pump, and fixed pipes or hoses that run to the nozzles. The systems are often professionally installed and include a service contract to cover maintenance and insecticide refilling. Nevertheless, it is possible for residential homeowners to purchase the pesticide and load the tank (or drums) themselves; therefore, a residential handler assessment may be required.

This section provides a standard method for conducting handler exposure assessments for adults mixing and loading pesticides to be used in outdoor residential misting systems. It is assumed that only individuals 16 years of age or older mix and load (i.e., handle) pesticides.
The basis for this scenario is that handler exposure occurs as the pesticide is poured into the drum by the applicator holding the product container; no applicator scenario is required as misting systems spray the pesticide in the treatment area automatically.

This scenario assumes that pesticides can be inhaled or can come into contact with the skin during the mixing and loading of the pesticide products in the drums as part of the residential misting system. The method to determine handler inhalation and dermal exposure to pesticides from these activities relies on data measuring dermal and inhalation exposure during mixing and loading (i.e., pouring a liquid pesticide). Thus, this method should be used in the absence of chemical-specific data, or as a supplement to estimates based on chemical-specific data.

Dermal and Inhalation Handler Exposure Algorithm

As described in *Section 1.3.3*, daily dermal and inhalation exposure (mg/day) for residential pesticide handlers is estimated for a given formulation-application method combination 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:

$$E = UE * AR \tag{5.16}$$

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:

$$AR = V_D * N * DR * A.I. * D_{H2O} \tag{5.17}$$

where:

AR = application rate per day (lb ai/ day);
V_D = volume of the drum of the misting system (gallons/drum);
N = number of drums filled per day (drums/day)
DR = dilution rate (volume product /volume total solution);
A.I. = percent active ingredient in product (%); and
D_{H2O} = water density (lb/gal).

Absorbed dermal and/or inhalation doses normalized to body weight are calculated as:

$$D = \frac{E * AF}{BW} \tag{5.18}$$

where:

D = dose (mg/kg-day);

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

Handler exposure for outdoor residential misting systems is generally considered short-term in duration as filling the centralized reservoir tanks typically occur once in a 90-day period. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.3* such as the product-specific application regimen.

Dermal and Inhalation Handler Exposure Algorithm Inputs and Assumptions

Recommended values for handler exposure (inhalation and dermal) assessments are provided in *Table 5-6* and *Table 5-7*. Following these tables, each scenario-specific input parameter is described in more detail. This description includes a summary of: i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 5-6: Outdoor Residential Misting Systems – Recommended Unit Exposure (mg/lb ai) Point Estimates

Formulation	Equipment/ Application Method	Dermal	Inhalation	Appendix Page Reference
		Point Estimate	Point Estimate	
Liquid concentrates	Mixing/loading	0.232	0.000219	NA

NA = not applicable – data from occupational handler data source (see: http://www.epa.gov/pesticides/science/handler-exposure-data.html)

Table 5-7: Outdoor Residential Misting Systems – Recommended Handler Exposure Factor Point Estimates

Algorithm Notation	Exposure Factor (units)	Point Estimate(s)
AR	Application rate (lb ai/ day)	Product-specific
D_{H20}	Density of product (lb/gal)	8.34
V_D	Volume of Drum (gallons/drum)	55
DR	Dilution Rate (volume product /volume total solution)	Product-specific
N	Number of drums filled per day (drums/day)	1
A.I.	Percent ai in product (%)	Product-specific
BW	Body weight (kg)	80

Unit Exposure (UE)

As described in *Section 1.3.3*, the unit exposure is the ratio between exposure and the amount of active ingredient handled for a given formulation/application method combination, with units mass exposure per mass active ingredient handled (e.g., mg ai exposure/lb ai handled).

Drum Volume (V_D)

The drum feeds into the plumbing that leads to the nozzles of the residential misting system. The default drum size is based on **a typical drum size (30 or 55 gallons)**.

Number of Drums Filled per Day (N)

One drum is assumed to be filled per day, as residential misting systems are likely only connected to one drum.

Dilution Rate (DR)

The label should state the amount (e.g., gallons) of concentrated product per amount of water. This can also be given as parts of product per parts of water. Dilution rate is the volume of the product amount stated on the label divided by the sum of product volume and water volume (i.e., volume total solution).

Water Density (D_{H2O})

The dilute solution of pesticide for application through the misting system is **assumed to have the same density as water (i.e., 8.34 lbs/gallon),** since pesticide concentrate is typically mixed with large volumes of water.

Future Research/Data Needs

Potential research/data need with respect to the outdoor residential misting system scenario include:

- survey data to examine the prevalence of these systems in the United States
- information detailing the breakdown of maintenance (i.e., characterizing the percentage of systems that are professional maintained versus homeowner maintained), and
- equipment type (e.g., how often the systems are refilled/reloaded, and the spray frequency of these systems).

Exposure Characterization and Data Quality

Unit Exposures

- The unit exposures used for this scenario are from the "All Liquids, Open Mixing and Loading" Scenario in EPA's Occupational Pesticide Handler Unit Exposure Surrogate Reference Table (http://www.epa.gov/pesticides/science/handler-exposure-table.pdf). The use of occupational exposure data may overestimate homeowner exposure. Additionally, the values were adjusted to represent the type of clothing a homeowner or non-professional residential handler would wear (i.e., short-sleeved shirt, shorts and no chemical-resistant gloves) and are the best available data set for determining residential exposures during open pouring with liquid chemicals.
- The underlying assumption of the use of exposure data as unit exposures – proportionality between the amount of active ingredient handled and exposure – is

uncertain, though potentially conservative. However, as a prediction mechanism, it is considered practical and useful for the purposes of handler exposure assessment in a regulatory context. It provides a straightforward handler exposure calculation method and enables risk mitigation in the form of formulation comparison and decreased application rates.

- The extent to which an individual's exposure (expressed via unit exposures) varies day-to-day or application-to-application is unknown; therefore, the assumption that there is no variation when assessing longer-term exposure durations is considered conservative.

5.3.2 Post-Application Exposure Assessment

Post-application exposure can result from physical activities in areas previously treated by residential misting systems. While exposure may occur for people of all ages, adults and children 1 < 2 years old are considered the index lifestages depending on the exposure scenario based on behavioral characteristics and the strengths and limitations of available data (see *Appendix A*).

Automatic spray systems were originally used in animal housing structures, such as dairy barns, to control flying insects. Recently, these systems have been adapted for use in residential sites, including residential yards, to control mosquitoes and other pests. These systems are fed from a central holding tank and utilize an array of spray nozzles to automatically deliver a fine mist of dilute solution at specified intervals throughout the day.

It is currently unclear whether these systems are intended to target flying insects or insect resting surfaces. According to a discussion paper written by the Consumer Specialty Products Association (CSPA, 2005), these systems are designed to apply product to resting surfaces where insects seek harborage during non-feeding periods. However, in an efficacy study conducted by Florida A & M University, it was determined that the system was only efficacious against flying insects (Cilek et. al, 2008). Despite the discrepancy, it is reasonable to assume that some residue deposits on outdoor surfaces and is available for both dermal and non-dietary ingestion exposure.

This section addresses standard methods for estimating exposure and dose for three post-application exposure pathways resulting from contact during outdoor activities in patios and backyards following use of an outdoor residential misting system:

- Section 5.3.2.1 - adult/children 1 < 2 years old inhalation exposure resulting from activities on patios and backyards; and,
- Section 5.3.2.2 - adult/children 1 < 2 years old dermal and children 1 < 2 years old non-dietary ingestion exposure.

5.3.2.1 Post-application Inhalation Exposure Assessment

This SOP provides a standard method for completing post-application inhalation exposure assessments for adults and children after a pesticide treatment in an outdoor space. The basis for this scenario is that inhalation exposure occurs from the airborne aerosols released by mister

nozzles. The well-mixed box (WMB) model was used to develop the exposure equation for the outdoor residential misting systems (ORMS) post-application inhalation scenario.[9] The WMB model incorporates a number of simplifying assumptions: fresh air (having no pesticide concentration) enters the box at a constant airflow rate; a turbulent internal airflow thoroughly mixes the fresh air with the pesticide-laden air resulting in a uniform pesticide air concentration within the box; and the perfectly mixed air exits the box at the same constant airflow rate (i.e., the inflow rate equals the outflow rate). Thus, the outdoor area where the aerosol is being applied is assumed to be in an enclosed box. Using the WMB model is conservative for estimation of exposures for an open patio, deck or yard where dissipation is expected to be greater than the enclosed space that the WMB depicts. Also, this scenario assumes instantaneous spray releases, that is, the total amount of aerosol released at each spray event is modeled to occur instantaneously.

The evacuation of the aerosol from the box depends on airflow. For an outdoor scenario, the airflow, Q, is the product of the cross-sectional area and the wind velocity. The cross-sectional area is dependent on the area/volume of the treated space, and is defined in each SOP sub-scenario. The WMB model developed for this scenario models the pesticide air concentrations *after* multiple instantaneous aerosol spray releases at regular time intervals[10]. Only dissipation due to airflow into and out of the box is modeled.

For the inhalation route of exposure, the point of departure (POD) could be based on the reference concentration (RfC) methodology. In the RfC methodology, air concentrations are not converted to doses, rather, risks are assessed on the basis of comparison of exposure concentrations with reference concentrations typically determined from animal studies. This approach is not always available for every chemical; therefore, the exposure assessor should discuss the possibility of this approach with a toxicologist.

Post-Application Inhalation Exposure Algorithm

The following algorithm is used to determine post-application inhalation exposure to the ORMS (See *Section D.3.3* of *Appendix D* for equation description and derivation):

$$E = \frac{IR * C_0 * V}{Q}\left[\text{int}(ET \cdot PR) + \frac{(1 - R^{frac(ET \cdot PR)})}{(1 - R)}\right] \qquad (5.19)$$

where:

E	= exposure (mg/day);
IR	= inhalation rate (m^3/hr);
C_0	= initial air concentration (mg/m^3);
V	= volume of treated space (m^3);
Q	= airflow (m^3/hr);
ET	= exposure time (hours/day);

[9] For the ORMS and animal barn scenarios, the WMB models describing the air concentrations over time have the same form. The parameterization of these models is the only difference. For the ORMS scenario, the decay rate constant is specified by the ratio of the airflow rate and the volume of the treated space; whereas for the animal barn scenario, the decay rate constant is specified by the air changes per hour.
[10] The regular spray applications are assumed to continue for the entire time spent outdoors.

PR = pulse rate (spray events/hr);
frac(ET·PR) = fraction portion of the product of the exposure time (ET) and the pulse rate (PR);
int(ET·PR) = integer (i.e., whole number) portion of the product of the exposure time (ET) and the pulse rate (PR).
R $= e^{-\frac{Q}{V}T_{BA}}$
T_{BA} = time between application events (i.e., the inverse of the pulse rate, or 1/PR).

For example, if the time between applications is 40 minutes or 2/3 hour (i.e., $T_{BA} = 0.67$) or equivalently, the pulse rate is 3 sprays over 2 hours (i.e., PR = 1.5); and the exposure time is three hours (ET = 3), then int(ET·PR) = int(3 × 1.5) = int(4.5) = 4; and frac(ET·PR) = frac(4.5) = 0.5.

Note: If you are assessing (1) exposure due to one spray event or (2) exposure due to multiple spray events when the exposure time is a whole number multiple of the time between applications, see *Section D.3.3* of *Appendix D*, equation D.17 and D.20, respectively.

The airflow in the patio/backyard is determined as follows:

$$Q = AV * CF1 * CF2 * A_{cross\text{-}section} \quad (5.20)$$

where:
Q = airflow through treated space (m^3/hr);
AV = air velocity (m/s);
CF1 = time unit conversion factor (60 seconds/1 minute);
CF2 = time unit conversion factor (60 minutes/ hour); and
$A_{cross\text{-}section}$ = cross-section of outdoor space treated (m^2).

If chemical-specific data are available, air concentration is the air concentration at time 0. Specifically, the scenario assumes that individuals could be exposed to the air concentration immediately after application. While most product labels indicate that ORMS must be programmed so that "people or pets may not be present", there are frequently no restrictions on reentry time into the treated area. If data are not available, then the initial air concentration can be calculated using the following formula:

$$C_0 = AR * CF1 * CF2 \quad (5.21)$$

where:
C_0 = initial air concentration (mg/m^3);
AR = application rate per spray event (lbs ai/ft^3);
CF1 = weight unit conversion factor (454,000 mg/lb); and
CF2 = volume unit conversion factor (35.3 ft^3/ 1.0 m^3).

If application rates are given on the label, these rates should be used. Application rates are typically given in ounces of solution per 1000 ft^3 per spray event. The following equation can be used to convert this rate to pounds ai per ft^3:

$$AR = \frac{AR_{label} * A.I. * CF * D_{H2O}}{V_{NC}} \quad (5.22)$$

where:

AR = application rate per spray (lb ai/ ft^3);
AR_{label} = application rate on label (given as ounces per 1000 ft^3) (oz);
A.I. = percent active ingredient in product (%);
CF = volume unit conversion factor (1 gallon/128 ounces);
D_{H2O} = water density (lb/gal); and
V_{NC} = nozzle coverage volume (as stated on label) (typically 1000 ft^3, or as otherwise stated on the product label).

If application rate is not given on the label, it can be calculated as follows:

$$AR = \frac{A.I. * DR * GPM * SD * D_{H2O}}{V_{NC}} \quad (5.23)$$

where:

AR = application rate per spray (lb ai/ft^3);
A.I. = percent active ingredient in product (%);
DR = dilution rate (volume of product/volume total solution);
GPM = nozzle flowrate (gal/min);
SD = spray duration (min);
D_{H2O} = water density (lb/gal); and
V_{NC} = nozzle coverage volume (ft^3).

Absorbed inhalation dose normalized to body weight is calculated as:

$$D = \frac{E * AF}{BW} \quad (5.24)$$

where:

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

Post-application inhalation exposure following applications by outdoor residential misting systems is generally considered short-term in duration but is dependent on the use pattern of the specific product being assessed and the dissipation/degradation properties of the active

ingredient. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4* such as residue dissipation, product-specific re-treatment intervals, and activity patterns. If longer-term assessments (i.e., intermediate-, long-term, or lifetime exposures) are deemed necessary, similar refinements to more accurately reflect the exposure profile are recommended.

Post-application Inhalation Exposure Algorithm Inputs and Assumptions

Recommended values for post-application inhalation exposure assessments are provided in *Table 5-8* below. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of: i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 5-8: Outdoor Residential Misting Systems – Recommended Post-application Inhalation Exposure Factors Point Estimates

Algorithm Notation	Exposure Factor (units)		Point Estimate(s)
AR	Application rate per spray event (lb ai/1000 ft^3)		Product-specific
PR	Pulse Rate (sprays/hr)		1 (unless otherwise specified on label)
DR	Dilution Rate (volume product/volume total solution)		Product-specific
GPM	Nozzle flowrate (gal/min)		0.014
SD	Spray duration (min)		1
D_{H2O}	Water density (lb/gal)		8.34
V_{NC}	Nozzle coverage volume (ft^3)		1,000 ft^3 per nozzle
V	Volume of treated space (m^3)		90.6
Q	Airflow (m^3/hr)		5,400
AV	Air velocity (m/s)		0.1
C_0	Initial air concentration (mg/m^3)		Calculated; concentration at time "0"
$A_{cross\text{-}section}$	Cross sectional area of area treated (m^2)		15 m^2
ET	Exposure time (hours/day)	Adult	2.3
		Children 1 < 2 years old	2.3
IR	Inhalation rate (m^3/hour)	Adult	0.64
		Children 1 < 2 years old	0.33
BW	Body weight (kg)	Adult	80
		Children 1 < 2 years old	11

Application Rate (AR)

The application rate is the amount of spray applied per unit area times the number of sprays applied per day. The application rate can be determined from product-specific factors that are listed on the label or from generic factors listed above. This application rate needs to be determined on a volume basis (i.e., lb ai applied per 1,000 cubic feet) to determine inhalation exposures.

Dilution Rate (DR)

The label should state the amount (e.g., gallons) of concentrated product per amount of water. This can also be given as parts of product per parts of water. Dilution rate is the volume of the product amount stated on the label divided by the sum of product volume and water volume (i.e., volume total solution).

Pulse Rate (PR): Number of Spray Events per hour

The pulse rate, or number of spray events per hour, is label-specific. **A default of 1 spray event per hour** is assumed when no product-specific data are available (CSPA 2005). This value is combined with exposure time (hours/day) to determine exposure to the individual. It is assumed that the airborne residues would disperse between applications.

Nozzle Flowrate (GPM)

The nozzle flowrate is a function of the amount of water the system will use in a 24-hr period. For this SOP, **a nozzle flowrate (gal/min) of 0.011-0.014 gal/min is assumed** (CSPA, 2005; Cilek, et. al., 2008). The nozzle flow rate is a function of the number of nozzles on the system and the number of minutes that the system operates each day. This is the amount of diluted product released from the nozzle per unit of time.

Spray Duration (SD)

Available information indicates the spray duration is approximately 30-60 seconds (0.5 – 1.0 min) in length (CSPA, 2005). **The recommended point estimate for use in a deterministic risk assessment is 60 seconds (1 minute).**

Water Density (D_{H2O})

The dilute solution of pesticide for application through the misting system is **assumed to have the same density as water (i.e., 8.34 lbs/gallon)**, as the pesticide concentrate is typically mixed with large volumes of water.

Nozzle Coverage Volume (V_{NC})

The nozzle coverage volume is specified in the product label. **If no volume is specified, the volume coverage of 1,000 ft^3 per nozzle is assumed.** The range of volume coverage is 880-1440 ft^3 per nozzle (CSPA, 2005; Cilek, et. al., 2008),

Volume of Treated Space (V)

An outdoor living space with dimensions of **20 ft. x 20 ft. x 8 ft. (i.e., 3,200 ft^3 or 90.6 m^3) is assumed when calculating airborne concentration levels**. This volume was selected to represent typical treated space – e.g., a patio, deck, or yard. This value is based on a recent survey on U.S. decking market which was conducted by the Center for International Trade in Forest Products (CINTRAFOR). In this survey, CINTRAFOR contacted a random sample of U.S. homebuilders via telephone. Based on the survey results, it was determined that the mean deck size for "spec" homes (n=109) was 361ft^2. This translates to approximately a 20 ft x 18 ft surface area. The mean deck size for custom homes (n=174) was 490 ft^2 (Eastin et al., 2005). This translates to approximately 20 ft x 24.5 ft surface area. The overall mean deck size identified in this survey is believed to be is an appropriate surrogate for the amount of outdoor living space treated by ORMS. Therefore, in the absence of additional information, 20 ft. x 20 ft. x 8 ft. is used as the volume of outdoor space that is treated with ORMS and other outdoor sprays and 20 ft x 20 ft is used as the surface area of a treated area.

$A_{cross\ section}$

$A_{cross\text{-}section}$ represents the cross-sectional area of the volume of treated space for this exposure scenario, measured in m^2. Unless otherwise specified by the product label, the exposure scenario for misting systems considers a 20ft x 20 ft x 8 ft area; therefore, **the cross-sectional area for the treated space is 160 ft^2 (20 ft width x 8 ft height) or 15 m^2**.

Air velocity (AV)

The air velocity is the speed of the air moving through the treated area defined for the well-mixed box model. The fraction of the chemical available for inhalation in outdoor air is a function of the movement of air into and out of the backyard "box". The air velocity determines the rate at which the contents of the outdoor area treated are evacuated. Wind velocity is an influencing factor affecting flying pest nuisance. Bidlingmayer et al., 1995 examined the effect of wind velocity on suction trap catches. Their research noted that trap catches declined as wind velocities increased over the entire range of observed velocities. Wind velocities within the range of normal mosquito flights, about 1 m/s resulted in trap catch reductions on significant nights of approximately 50% by wind of 0.5 m/s and 75% at 1.0 m/s.

The wind speed range considered here corresponds with the lower two tiers of the Beaufort wind force scale, an empirical measure for describing wind speed. The Beaufort wind force scale is a range on a numerical basis of 0-10, from still air conditions up to hurricane force winds. This SOP covers Beaufort numbers 0-1. The Beaufort number 0 corresponds to calm wind conditions of <0.3 m/s [18 meters/minute; 0.7 mph]. The Beaufort number 1 corresponds to light air conditions of 0.3-1.5 m/s [18-90 meters/minute; 0.7–3.4 mph]. Thus, this SOP provides a distribution of wind velocities from 0.1-1.5 m/s [0.2-3.4 mph], the upper limit for "light air" condition on the Beaufort scale and a reasonable upper bound for wind velocities where these products would be used to control flying pests. This windspeed represents a range of values foreseeable in which ORMS may be used (i.e., in a yard or on an outdoor patio where flying pests may pose a nuisance). When wind velocities are higher than 1.5 m/s, ORMS are less likely to be used because of reduced flying pest pressure.

The recommended point estimate for use in a deterministic exposure assessment is 0.1 m/s (0.22 mph). The range of air velocities applicable to this assessment are 0.1 m/s to 1.5 m/s.

Airflow (Q)

Airflow is defined as the volume of natural air that uniformly passes through a given area in a specified period of time. In the well-mixed box model, the airflow through the treated space is the product of the air velocity and the cross-sectional area, and is measured in m^3/hour. As mentioned above, the cross-sectional area of the space treated is assumed to be 20 ft x 8 ft (160 ft^2 or 15 m^2). The range of air velocities to represent calm air conditions is 0.1 m/s to a maximum of 1.5 m/s. Therefore, the airflow for a typical space treated is assumed to range from **5,400 m^3/hour (as the health protective default value)** to 81,000 m^3/hour.

Air Concentration (C_0)

The initial concentration is based upon instantaneous release of diluted product and mixing into a fixed space (nozzle coverage area). It is assumed there is complete mixing of the applied product in the area.

Exposure Time (ET)

Another important variable for addressing post-application exposure is the duration of time spent in areas treated by outdoor residential misting systems. The exposure time for adults and children conservatively assumes that the time spent in the volume of treated space is equivalent to the time spent at home outdoors in the yard or other areas around the house ("doers" only). The exposure time values are from the Exposure Factors Handbook 2011 Edition (Table 16-20), converted from minutes per day to hours per day. The original analysis generated statistics for the subset of the survey lifestage that reported being in the location or doing the activity in question (i.e., "doers" only). **Based on these data, the recommended point estimate for use in post-application inhalation exposure assessment for adults and children is 2.3 hrs/day.**

Table 5-9: Time Spent Outdoors At Home in the Yard or Other Areas Outside the House

Statistic	Hours per Day	
	Adults	Children 1 < 2 years old
5th percentile	0.1	0.4
25th percentile	0.5	1.0
50th percentile	1.5	1.5
75th percentile	3.0	3.0
90th percentile	5.5	5.1
95th percentile	7.3	5.8
Arithmetic Mean	2.3	2.3
	Reference: 2011 EFH, Table 16-20 (Adults 18-64)	Reference: 2011 EFH, Table 16-20 (Children 1 < 4 years old)

Future Research/Data Needs

Areas where future research would address some data gaps with respect to the post-application ORMS scenario include:

- Limited air monitoring data are available for ORMS. Studies could be designed to

characterize the air concentration of aerosolized pesticide sprays after misting applications.
- No data are available to characterize the prevalence of outdoor residential misting systems in different regions of the U.S. A survey could be conducted to determine ORMS use patterns.

Exposure Characterization and Data Quality

- The simplifying assumptions implicit in the well-mixed box model identified in the first two paragraphs of *Section 5.3.2.1* would be health protective; the modeled air concentrations would dissipate less rapidly (i.e., resulting in higher pesticide concentrations) in the artificially defined fixed volume compared to a true open outdoor space.
- The ORMS exposure scenario makes the health protective assumption that all of the applied pesticide is in the air available for inhalation exposure, and then that all of the applied pesticide settles onto the turf and is available for dermal exposure.

5.3.2.2 Post-application Dermal and Non-dietary Ingestion Exposure Assessment

Dermal and incidental oral post-application exposures are expected to occur after the spray settles onto the treated areas of a yard (e.g., deck, patio, or turf). Based on the data available and the assumptions that would be considered for assessing dermal and non-dietary ingestion exposures from smooth surfaces (e.g., patios and decks) and textured surfaces (e.g., turf/lawns), this SOP makes a health protective assumption that all of the outdoor spray settles onto turf. This settling is assumed to occur in a uniform fashion throughout the treated area, similar to a direct lawn broadcast treatment. While exposure may occur for people of all ages, adults and children 1 < 2 years old are considered the index lifestages based on behavioral characteristics and the strengths and limitations of available data. Once the application rate is determined, the turf transferable residues and resulting dermal and incidental oral exposures should be assessed following the methodologies outlined in *Section 3.2*.

To calculate the residue on turf, use one of the following equations.

If application rates are given on the label, these rates should be used. Application rates are typically given in ounces per 1000 ft^3. A high-end height estimate of 8 feet is assumed which allows for a smaller turf surface area for the pesticide to be deposited on and, therefore, a higher concentration of residue is available. The following equation can be used to convert the application rate in pounds ai per square foot as is deposited on the turf:

$$AR = \frac{AR_{label} * A.I. * CF * D_{H2O} * H}{V_{NC}} \qquad (5.25)$$

where:

AR = application rate per spray (lb ai/ ft^2);

AR_{label} = application rate on label (in ounces per 1,000 cubic feet) (oz);
A.I. = percent active ingredient in product (%);
CF = conversion factor to convert ounces to gallons (1 gallon/128 ounces);
D_{H2O} = water density (lb/gal);
H = height of nozzle (8 ft); and
V_{NC} = nozzle coverage volume (ft^3).

If application rate is not given on the label, it can be calculated using the following formulas:

$$AR = \frac{\text{A.I.} * \text{DR} * \text{GPM} * \text{SD} * \text{D}_{\text{H2O}}}{A_{NC}} \quad (5.26)$$

where:

AR = application rate per spray (lb ai/ft^2);
A.I. = percent active ingredient in product (%);
DR = dilution rate (volume product/volume total solution);
GPM = nozzle flowrate (gal/min);
SD = spray duration (min);
D_{H2O} = water density (lb/gal); and
A_{NC} = nozzle coverage area (ft^2).

Post-application dermal and non-dietary exposure following applications by outdoor residential misting systems is generally considered short-term in duration, but is dependent on the use pattern of the specific product being assessed and the dissipation/degradation properties of the active ingredient. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4* such as residue dissipation, product-specific re-treatment intervals, and activity patterns. If longer-term assessments (i.e., intermediate-, long-term, or lifetime exposures) are deemed necessary, similar refinements to more accurately reflect the exposure profile are recommended.

Post-application Dermal and Non-Dietary Ingestion Algorithm Inputs and Assumptions

The following provides a general discussion for each exposure factor and derivation of recommended point estimates for use in exposure assessment.

Application Rate (AR)

The application rate is the amount of spray applied per unit area times the number of sprays applied per day. The application rate can be determined from product-specific factors that are listed on the label or from generic factors listed above. This application rate needs to be determined on an area basis (i.e., lbs ai applied per square foot) to assess incidental oral and dermal exposures.

Dilution Rate (DR)

The label should state the amount (e.g., gallons) of concentrated product per amount of water. This can also be given as parts of product per parts of water. Dilution rate is the volume of the product amount stated on the label divided by the sum of product volume and water volume (i.e., volume total solution).

Nozzle Flowrate (GPM)

The nozzle flowrate is a function of the amount of water your system will use in a 24-hr period. For this SOP, **a nozzle flowrate (gal/min) of 0.011-0.014 gal/min is assumed** (Cilek, et. al., 2008; CSPA, 2005). The nozzle flow rate is a function of the number of nozzles on the system and the number of minutes that the system operates each day. This is the amount of diluted product released from the nozzle per unit of time.

Spray Duration (SD)

Each spray event is assumed to last for approximately 30-60 seconds (0.5 – 1.0 min) (CSPA, 2005). **The recommended point estimate for use in a deterministic risk assessment is 60 seconds (1 minute)**, in the absence of available product-specific information.

Water Density (D_{H2O})

The dilute solution of pesticide for application through the misting system is **assumed to have the same density as water (i.e., 8.34 lbs/gallon)**, as the pesticide concentrate is typically mixed with large volumes of water.

Nozzle Coverage Area or Volume (A_{NC} or V_{NC})

The nozzle coverage volume is specified in the product label as **1,000 ft^3 per nozzle** (V_{NC}). A conservative height estimate of 8 ft is assumed, making the **ground area coverage 125 ft^2 per nozzle** (A_{NC}). A high-end height estimate of 8 feet is assumed which allows for a smaller turf surface area for the pesticide to be deposited on and, therefore, a higher concentration of residue is available, thus producing a health protective estimate. An 8 foot height is also the assumed height of the box model, and a reasonable high-end estimate of the height of the residential misting system based on professional judgment.

Future Research/Data Needs

Future areas of research that could address data gaps with respect to the post-application ORMS scenario include:

- No data are available to characterize the prevalence of outdoor residential misting systems in different regions of the U.S. A survey could be conducted to determine ORMS use patterns.
- No data are available to characterize the deposition pattern of ORMS systems in the outdoor environment. Studies could be designed to capture the deposition patterns, air concentrations, and chemical fate during for ORMS treatments.
- No data are available to indicate the extent of dermal deposition on human skin from aerosolized pesticides released from ORMS. Studies could be designed to capture the extent of dermal deposition as a result of airborne aerosols released from ORMS.

Exposure Characterization and Data Quality

- Outdoor Residential Misting Systems typically operate on timed applications or by remote control activation. The ORMS scenario models residential bystander exposure in that it assumes bystanders are present immediately following a spray event, not during the application.
- The ORMS exposure scenario makes the health protective assumption that all of the applied pesticide is in the air available for inhalation exposure, and then that all of the applied pesticide settles onto the turf and is available for dermal and incidental oral exposure.

5.3.2.3 Combining Post-application Scenarios

Risk estimates resulting from different exposure scenarios are combined when it is likely that they can occur simultaneously based on the use pattern and when the toxicological effects across different routes of exposure are the same. When combining scenarios, it is important to fully characterize the potential for co-occurrence as well as characterizing the risk inputs and estimates. Risk estimates should be combined even if any one scenario or route of exposure exceeds the level of concern because this allows for better risk characterization for risk managers.

It is likely that children could be exposed to an area treated by ORMS via inhalation, dermal and non-dietary ingestion (hand-to-mouth) routes and that these scenarios could occur simultaneously. Therefore, these exposure scenarios should be combined when toxicological effects are the same across these routes of exposure.

5.4 Animal Barn Misting Systems

Animal barn residential misting systems are application systems designed to spray an aerosolized insecticide to kill mosquitoes and other nuisance insects in and around barns. These systems are fed from a central holding tank and utilize an array of spray nozzles to automatically deliver an aerosolized insecticide at specified intervals throughout the day. The spray nozzles are typically mounted between 8-10 feet high. These systems operate automatically (i.e., at preset intervals) or manually (e.g., via remote control or switch).

This section provides standard methods for estimating potential doses from pesticides applied using misting systems in animal barns. Adults filling the misting system drums with the pesticide have the potential for dermal and inhalation exposure. Adults and children occupying animal barns following the application of a pesticide using a misting system can experience inhalation, dermal and incidental oral exposure.

This section provides the methods for estimating the potential dose for handlers using misting systems, the method for estimating the potential dose from post-application inhalation exposure to a treated barn, as well as the method for estimating residue deposited on hard surfaces following a pesticide treatment from a animal barn misting system which can be used in

conjunction with methods outlined in *Section 3.2* source not found to estimate dermal and oral post-application doses following direct applications to indoor surfaces.

5.4.1 Handler Exposure Assessment

Barn misters are typically marketed as systems that include a mix tank, a timer-controlled pump, and fixed plumbing that run to the spray nozzles. The systems are generally expected to be professionally installed and include a service contract to cover maintenance and insecticide refilling. However, it is possible for a residential user to purchase pesticide concentrates and load the drum/holding tank to refill these systems. Therefore, a residential handler scenario may be necessary.

This section provides a standard method for completing handler exposure assessments for adults who are mixing and loading insecticides to be used in barn misting systems. The basis for this scenario is that handler exposure occurs as the pesticide is poured into the drum by the handler holding the product container; no applicator scenario is required to be assessed as the misting nozzles spray the pesticide in the treatment area automatically (without contact with the residential handlers).

This scenario assumes that pesticides are available to be inhaled or have the potential to contact the skin during the mixing and loading of the pesticide products in drums/holding tanks as part of the barn misting system. It is assumed that only individuals 16 years of age or older mix and load (i.e., handle) pesticides. The method to determine handler inhalation and dermal exposure to pesticides from these activities relies on data measuring dermal and inhalation exposure during mixing and loading (e.g., pouring a liquid pesticide). Thus, this method should be used in the absence of chemical-specific data, or as a supplement to estimates based on chemical-specific data.

Dermal and Inhalation Handler Exposure Algorithm

As described in *Section 1.3.3*, 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:

$$E = UE * AR \tag{5.27}$$

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:

$$AR = V_D * N * DR * A.I. * D_{H2O} \tag{5.28}$$

where:

AR = application rate per day (lb ai/ day);
V_D = volume of the drum of the misting system (gallons/drum);
N = number of drums filled per day (drums/day);
DR = dilution rate (volume of product/volume of total solution);
A.I. = percent active ingredient in product (%); and
D_{H2O} = water density (lb/gal).

Absorbed dermal and/or inhalation doses normalized to body weight are calculated as:

$$D = \frac{E * AF}{BW} \quad (5.29)$$

where:

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

Handler exposure for animal barn misting systems is generally considered short-term in duration as filling the centralized reservoir tanks typically occur once in a 90 day period. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.3* such as the product-specific application regimen.

Dermal and Inhalation Handler Exposure Algorithm Inputs and Assumptions

Recommended values for handler exposure (inhalation and dermal) assessments are provided in *Table 5-10* and *Table 5-11*. Following these tables, each scenario-specific input parameter is described in more detail. This description includes a summary of: i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 5-10: Animal Barn Misting Systems – Recommended Unit Exposure (mg/lb ai) Point Estimates

Formulation	Equipment/ Application Method	Dermal	Inhalation	Appendix Page Reference
		Point Estimate	Point Estimate	
Liquid concentrates	Mixing/loading	0.232	0.000219	NA

NA = not applicable – data from occupational handler data source (see: http://www.epa.gov/pesticides/science/handler-exposure-data.html)

Table 5-11: Animal Barn Misting Systems – Recommended Handler Exposure Factor Point Estimates

Algorithm Notation	Exposure Factor (units)	Point Estimate(s)
AR	Application rate (lb ai/ day)	Product-specific

Table 5-11: Animal Barn Misting Systems – Recommended Handler Exposure Factor Point Estimates		
D_{H20}	Density of product (lb/gal)	8.34
V_D	Volume of Drum (gallons/drum)	55
DR	Dilution Rate (volume of product / volume of total solution)	Product-specific
N	Number of drums filled per day (drums/day)	1
A.I.	Percent ai in product concentrate (%)	Product-specific
BW	Body weight (kg)	80

Unit Exposure (UE)

As described in *Section 1.3.3*, the unit exposure is the ratio between exposure and the amount of active ingredient handled for a given formulation/application method combination, with units mass exposure per mass active ingredient handled (e.g., mg ai exposure/lb ai handled).

Drum Volume (V_D)

The default assessment can provide risk estimates based on **three typical drum/holding tank sizes (30, 55, or 125 gallons)** as part of the animal barn misting system, unless additional scenario-specific information is provided on the product labels. The 30 and 55 gallon drums represent likely configurations of a residential animal barn misting system and the 55 and 125 gallon systems represent likely configurations of the commercial stable animal misting system.

Number of Drums Filled per Day (N)

One drum is assumed to be filled per day on an episodic basis, as residential misting systems are likely only connected to one drum.

Dilution Rate (DR)

The label should state the amount (e.g., gallons) of concentrated product per amount of water. This can also be given as parts of product per parts of water. Dilution rate is the volume of the product amount stated on the label divided by the sum of product volume and water volume (i.e., volume total solution). For example, a 1:3 dilution would be a 0.25 dilution rate.

Water Density (D_{H2O})

Pesticide products used in misting systems are typically mixed with large volumes of water. Therefore, the dilute insecticide solution applied through the misting system is **assumed to have the same density as water (i.e., 8.34 lbs/gallon)**.

Future Research/Data Needs

Future research that could address data needs with respect to the animal barn misting system scenario include:

- survey data that could be produced to examine the prevalence of these systems in the

United States.
- Information detailing the breakdown of maintenance (i.e., characterizing the percentage of systems that are professional maintained versus homeowner maintained), and
- equipment type (i.e., how often the systems are refilled/reloaded, and the spray frequency of these systems) could be useful to fully characterize the residential handler exposure potential.

Exposure Characterization and Data Quality

Unit Exposures

- The unit exposures used for this scenario are from the "All Liquids, Open Mixing and Loading" Scenario in EPA's Occupational Pesticide Handler Unit Exposure Surrogate Reference Table (http://www.epa.gov/pesticides/science/handler-exposure-table.pdf). The use of occupational exposure data may overestimate homeowner exposure. Additionally, the values were adjusted to represent the type of clothing a homeowner or non-professional residential handler would wear (i.e., short-sleeved shirt, shorts and no chemical-resistant gloves) and are the best available data set for determining residential exposures during open pouring with liquid chemicals.
- The underlying assumption of the use of exposure data as unit exposures – proportionality between the amount of active ingredient handled and exposure – is uncertain, though potentially conservative. However, as a prediction mechanism, it is considered practical and useful for the purposes of handler exposure assessment in a regulatory context. It provides a straightforward handler exposure calculation method and enables risk mitigation in the form of formulation comparison and decreased application rates.
- The extent to which an individual's exposure (expressed via unit exposures) varies day-to-day or application-to-application is unknown; therefore, the assumption that there is no variation when assessing longer-term exposure durations is considered conservative.

5.4.2 Post-application Exposure Assessment

Post-application exposure can result from presence in residential barns or commercial stables following pesticide applications. While exposure may occur for people of all ages, adults and children 3 < 6 years old are considered the index lifestage depending on the exposure scenario based on behavioral characteristics and the strengths and limitations of available data.

This section addresses standard methods for estimating exposure and dose for three post-application exposure pathways resulting from time spent in animal barns that have previously been treated by a misting system:

- Section 5.4.2.1 - adult/children 3 < 6 years old inhalation exposure; and,
- Section 5.4.2.2 - adult/children 3 < 6 years old dermal and children 3 < 6 years old non-dietary ingestion exposure.

5.4.2.1 Post-application Inhalation Exposure Assessment

This section provides a standard method for completing post-application inhalation exposure assessments for adults and children after a pesticide treatment in a animal barn. The basis for this scenario is that inhalation exposure occurs from the airborne aerosols released by mister nozzles. As with the ORMS scenario, the well-mixed box (WMB) model was used to develop the exposure equation for the animal barn misting systems post-application inhalation scenario[11]. The WMB model incorporates a number of simplifying assumptions: fresh air (having no pesticide concentration) enters the box at a constant airflow rate (based on the number of air changes per hour), a turbulent internal airflow thoroughly mixes the fresh air with the pesticide-laden air resulting in a uniform pesticide air concentration within the box, and the perfectly mixed air exits the box at the same constant airflow rate (i.e., the inflow rate equals the outflow rate). Thus, the indoor area where the aerosol is being applied (i.e., barn) is assumed to be in an enclosed box, which is a reasonable assumption for a walled, indoor space. This scenario assumes instantaneous spray releases; that is, the total amount of aerosol released at each spray event is modeled to occur instantaneously.

The evacuation of the aerosol from the box depends on airflow. For an indoor scenario, the airflow is the product of the volume of the treated space and the number of air changes per hour, ACH. The WMB model developed for this scenario models the pesticide air concentrations *after* multiple instantaneous aerosol spray releases at regular time intervals[12]. Only dissipation due to airflow into and out of the box is modeled.

For the inhalation route of exposure, the point of departure (POD) could be based on the reference concentration (RfC) methodology. In the RfC methodology, air concentrations are not converted to doses, rather, risks are assessed on the basis of comparison of exposure concentrations with reference concentrations typically determined from animal studies. This approach is not always available for every chemical; therefore, the exposure assessor should discuss the possibility of this approach with a toxicologist.

Post-Application Inhalation Exposure Algorithm

Post-application inhalation exposure for adults/children resulting from animal barns that have been previously treated with pesticide can be calculated using the following equations (See *Section D.3.4* of *Appendix D* for equation description and derivation):

$$E = \frac{IR \cdot C_0 \cdot ET \cdot PR}{ACH} \tag{5.30}$$

where:

E = exposure (mg/day);
IR = inhalation rate (m^3/hr);
ACH = air changes per hour ($hour^{-1}$);

[11] For the ORMS and animal barn scenarios, the WMB models describing the air concentrations over time have the same form. The parameterization of these models is the only difference. For the ORMS scenario, the decay rate constant is specified by the ratio of the airflow rate and the volume of the treated space; whereas for the animal barn scenario, the decay rate constant is specified by the air changes per hour.
[12] The regular spray applications are assumed to continue for the entire time spent inside the animal barn.

C_0 = initial concentration (mg/m^3);
PR = pulse rate (sprays/hr); and
ET = exposure time (hrs/day).

Note: If you are assessing (1) exposure due to one spray event or (2) exposure due to multiple spray events when the exposure time is not a whole number multiple of the time between applications, see *Section D.3.4* of *Appendix D*, equation D.30 and D.35, respectively.

If product-specific data are available, air concentration is the residue immediately after a spray, typically referred to as "time 0". This exposure scenario assumes that individuals are exposed to the air concentration immediately after the application event. However, if chemical-specific data are not available, the initial air concentration can be calculated using the following formula:

$$C_0 = AR * CF1 * CF2 \quad (5.31)$$

where:
C_0 = initial air concentration (mg/m^3);
AR = application rate per spray event (lbs ai/ft^3);
CF1 = weight unit conversion factor (454,000 mg/lb); and
CF2 = volume unit conversion factor (35.3 ft^3/ 1.0 m^3).

If application rates are given on the product label, these rates should be used. Application rates are typically given on product labels in ounces per 1000 ft^3. The following equation can be used to convert the application rate from ounces product per 1000 ft^3 to pounds ai per ft^3:

$$AR = \frac{AR_{label} * A.I. * CF * D_{H2O}}{V_{NC}} \quad (5.32)$$

where:
AR = application rate per spray (lb ai/ ft^3);
AR_{label} = application rate on label (given as ounces per 1000 ft^3) (oz);
A.I. = percent active ingredient in product (%);
CF = volume unit conversion factor (1 gallon/128 ounces);
D_{H2O} = water density (lb/gal); and
V_{NC} = nozzle coverage volume (as stated on label) (1000 ft^3).

If application rate is not given on the label, it can be calculated as follows:

$$AR = \frac{A.I. * DR * GPM * SD * D_{H2O}}{V_{NC}} \quad (5.33)$$

where:
AR = application rate per spray (lb ai/ft^3);
A.I. = percent active ingredient in product (%);

DR = dilution rate (volume of product/volume of total solution);
GPM = nozzle flowrate (gal/min);
SD = spray duration (min);
D_{H2O} = water density (lb/gal); and
V_{NC} = nozzle coverage volume (ft^3).

Absorbed inhalation dose normalized to body weight is calculated as:

$$D = \frac{E * AF}{BW} \quad (5.34)$$

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

Post-application inhalation exposure following applications by misting systems in animal barns is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4* such as residue dissipation, product-specific re-treatment intervals, and activity patterns. If longer-term assessments (i.e., intermediate-, long-term, or lifetime exposures) are deemed necessary, similar refinements to more accurately reflect the exposure profile are recommended.

Post-application Inhalation Exposure Algorithm Inputs and Assumptions

Recommended values for post-application inhalation exposure assessments are provided in *Table 5-12* below. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of: i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 5-12: Animal Barn Misting Systems – Recommended Inhalation Exposure Factor Point Estimates

Algorithm Notation	Exposure Factor (units)	Point Estimate(s)
AR	Application rate per spray event (lb ai/ ft^3)	Product-specific
DR	Spray dilution rate (volume of product/ volume of total solution)	Product-specific
GPM	Nozzle flowrate (gal/min)	0.014
SD	Spray duration (min)	1
V_{NC}	Nozzle coverage volume (ft^3)	1,000 ft^3 per nozzle, or label specific
ACH	Air changes per hour ($hour^{-1}$)	4
D_{H2O}	Water density	8.34

Table 5-12: Animal Barn Misting Systems – Recommended Inhalation Exposure Factor Point Estimates			
	(lb/gal)		
PR	Pulse Rate (sprays/hr)		1 spray event per hour
C_0	Initial air concentration (mg/m^3)		Calculated; Concentration at time "0"
ET	Exposure time (hr/day)	Adult	4
		Children 3 < 6 years old	2
IR	Inhalation rate (m^3/hour)	Adult	0.64
		Children 3 < 6 years old	0.42
BW	Body weight (kg)	Adult	80
		Children 3 < 6 years old	19

Application Rate (AR)

The application rate is the amount of spray applied per unit volume per spray event. The application rate can be determined from product specific factors that are listed on the label or from generic factors listed above. This application rate needs to be determined on a volume basis (i.e., lb ai applied per 1000 cubic feet) to determine inhalation exposures.

Dilution Rate (DR)

The label should state the amount (e.g., gallons) of concentrated product per amount of water. This can also be given as parts of product per parts of water. Dilution rate is the volume of the product amount stated on the label divided by the sum of product volume and water volume (i.e., volume total solution).

Nozzle Flowrate (GPM)

The nozzle flowrate is a function of the amount of water the system will use in a 24 hr period. **A nozzle flowrate (gal/min) of 0.011-0.014 gal/min is assumed** (CSPA, 2005; Cilek, et. al., 2008). The nozzle flow rate is a function of the number of nozzles on the system and the number of minutes that the system operates each day. This is the amount of dilute pesticide spray released from the nozzle per unit of time.

Spray Duration (SD)

Each spray event is assumed to last for approximately 30-60 seconds (0.5 – 1.0 min) (CSPA, 2005). **The recommended point estimate for use in a deterministic risk assessment is 60 seconds (1 minute).**

Nozzle Coverage Volume (V_{NC})

The nozzle coverage volume is specified in the product label. **If no volume is specified, it is assumed that the nozzle coverage area is 1,000 ft^3 per nozzle** (CSPA, 2005; Cilek, et. al., 2008). The range is 880-1440 ft^3.

Air Changes per Hour (ACH)

Air changes per hour is the rate that air within an indoor environment is replaced by outdoor air. For a typical barn, the air exchange rate **ranges between 4 and 8 air changes per hour**. This is the ratio of the airflow over the volume of space (Q/V). Typical equine references suggest this

range of air changes per hour to maintain fresh air conditions and good air quality in the more challenging stable environments. A lower number of air changes per hour reflect winter conditions and a higher number of air changes represent warmer weather conditions (Horse Stable Ventilation Publication, Penn State University 2003).

Water Density (D_{H2O})

Pesticide products used in these systems are typically mixed with large volumes of water. Therefore, the dilute pesticide solution applied through the misting system is **assumed to have the same density as water (i.e., 8.34 lbs/gallon).**

Air Concentration (C_0)

The initial concentration is based upon instantaneous release of diluted product and mixing into a fixed space (nozzle coverage area). It is assumed there is complete mixing of the applied product in the area.

Pulse Rate (PR): Number of Spray Events per Hour

The number of spray events per hour is label-specific. **A default value of 1 spray event per hour** will be assumed when no product-specific data are available (CSPA, 2005). Based on an evaluation of product information, this value is considered a health protective assumption.

Exposure Time (ET)

The exposure time of **adults who spend time in and around animal barns is 4 hours per day** in the treated space. **Children are assumed to spend 2 hours per day** in the treated space. These recommended exposure time values are based on a study that examined the relationship between respiratory problems and time spent in animal barns (Mazan, 2009). In this study, it was reported that anecdotal evidence suggests that casual riders are unlikely to spend more than 1-2 hours per day and a total 2-5 days per week in a barn. Based on this anecdotal evidence, 4 hours per day is believed to be a conservative estimate of time spent inside an animal barn for the adult rider who also performs some non-occupational barn-related tasks. Similarly, since casual child riders are likely to spend less time performing non-riding activities than adults, 2 hours per day is believed to be a conservative estimate for children.

Future Research/Data Needs

There are three main research/data needs with respect to the post-application animal barn misting system scenario.

- Limited air monitoring data are available for animal barn misting systems. Studies could be designed to characterize the air concentration of aerosolized pesticide sprays.
- No data are available to characterize the prevalence of animal barn misting systems in different regions of the U.S. A survey could be conducted to determine animal barn misting system use patterns.
- No data are available to determine how much time a person spends in a residential animal barn and a commercial animal stable. A time-activity survey could be conducted to determine the breakdown of activities and time spent in animal barns.

Exposure Characterization and Data Quality

- Animal Barn Misting Systems typically operate on timed applications or by remote control activation. The scenario models residential post-application inhalation exposure and it assumes individuals are present immediately following a spray event, not during the application.

5.4.2.2 Post-application Dermal and Non-Dietary Ingestion Exposure Assessment

For pesticide use in an animal barn misting system, there is potential for post-application dermal and incidental oral exposure once the aerosol settles on surfaces inside the barn. A person could potentially be exposed to these residues when cleaning the barn, taking out equipment, and interacting with animals housed in barns.

Dermal and incidental oral post-application exposures are expected to occur after the spray settles onto the areas inside the barn. While exposure may occur for people of all ages, adults and children 3 < 6 years old are considered to be the most representative index lifestages for the animal barn misting system scenarios. This assumption is based on the behavioral characteristics of the index lifestages, safety rules and precautions inside animal barns, and the strengths and limitations of available data. Aerosol settling is assumed to occur in a uniform fashion throughout the treated area, and exposure is assumed to be similar to a broadcast indoor treatment.

The indoor post-application exposure scenario should be used as a surrogate to assess animal barn hard surfaces after a broadcast treatment. Thus, once the animal barn application rate is determined, the barn's surface transferable residues and resulting dermal and incidental oral exposures should be assessed following the methodologies outlined in *Section 7.2*, with some exposure inputs more specific to animal barn circumstances. While the indoor post-application scenario assigns children 1 < 2 years old as the index lifestage, the index lifestage for animal barns is children 3 < 6 years old; thus, the transfer coefficient and body weight inputs should be representative of children 3 < 6 years old. In addition, exposure time ("ET") should be the same as that used in the animal barn misting system post-application inhalation exposure assessment (*Section 5.4.2.1*).

To calculate the residue on indoor hard surfaces, use one of the following equations.

If application rates are given on the label, these rates should be used. Application rates are typically given in ounces per 1000 ft^3. A high-end height estimate of 8 feet is assumed which allows for a smaller turf surface area for the pesticide to be deposited on and, therefore, a higher concentration of residue is available. The following equation can be used to convert the application rate in pounds ai per square foot as is deposited on indoor surfaces:

$$AR = \frac{\mathrm{AR_{label}} * \mathrm{A.I.} * \mathrm{CF1} * \mathrm{D_{H2O}} * \mathrm{CF2} * \mathrm{H}}{V_{NC}} \qquad (5.35)$$

where:

AR = application rate per spray (lb ai/ cm^2);
AR_{label} = application rate on label (in ounces per 1,000 cubic feet) (oz);
A.I. = percent active ingredient in product (%);
CF_1 = conversion factor to convert ounces to gallons (1 gallon/128 ounces);
D_{H2O} = water density (lb/gal);
CF_2 = conversion factor (1 ft^2/929 cm^2);
H = height of nozzle (8 ft); and
V_{NC} = nozzle coverage volume (ft^3).

If application rate is not given on the label, it can be calculated using the following formulas:

$$AR = \frac{\text{A.I.} * \text{DR} * \text{GPM} * \text{SD} * \text{CF} * \text{D}_{\text{H2O}}}{A_{NC}} \quad (5.36)$$

where:

AR = application rate per spray (lb ai/cm^2);
A.I. = percent active ingredient in product (%);
DR = dilution rate (volume product/volume total solution);
GPM = nozzle flowrate (gal/min);
SD = spray duration (min);
CF = conversion factor (1 ft^2/929 cm^2);
D_{H2O} = water density (lb/gal); and
A_{NC} = nozzle coverage area (ft^2).

Post-application dermal exposure following applications by animal barn misting systems is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4* such as residue dissipation, product-specific re-treatment intervals, and activity patterns. If longer-term assessments (i.e., intermediate-, long-term, or lifetime exposures) are deemed necessary, similar refinements to more accurately reflect the exposure profile are recommended.

Post-application Dermal and Non-Dietary Ingestion Algorithm Inputs and Assumptions

The following provides a general discussion for each exposure factor and derivation of recommended point estimates for use in exposure assessment.

Application Rate (AR)

The application rate is the amount of spray applied per unit area times the number of sprays applied per day. The application rate can be determined from product specific factors that are listed on the label or from generic factors listed above. This application rate needs to be determined on an area basis (i.e., lbs ai applied per square centimeter) to assess incidental oral and dermal exposures.

Dilution Rate (DR)

The label should state the amount (e.g., gallons) of concentrated product per amount of water. This can also be given as parts of product per parts of water. Dilution rate is the volume of the product amount stated on the label divided by the sum of product volume and water volume (i.e., volume total solution).

Nozzle Flowrate (GPM)

The nozzle flowrate is a function of the amount of water your system will use in a 24-hr period. **A nozzle flowrate (gal/min) of 0.011-0.014 gal/min is assumed** (Cilek, et. al., 2008; CSPA, 2005). The nozzle flow rate is a function of the number of nozzles on the system and the number of minutes that the system operates each day. This is the amount of diluted product released from the nozzle per unit of time.

Spray Duration (SD)

Each spray event is assumed to last for 30-60 seconds approximately (0.5 – 1.0 min) (CSPA, 2005). **The recommended point estimate for use in a deterministic risk assessment is 60 seconds (1 minute).**

Water Density (D_{H2O})

The dilute solution of pesticide for application through the misting system is **assumed to have the same density as water (i.e., 8.34 lbs/gallon)**, as the pesticide concentrate is typically mixed with large volumes of water.

Nozzle Coverage Area or Volume (A_{NC} or V_{NC})

The nozzle coverage volume is specified in the product label as **1,000 ft^3 per nozzle** (V_{NC}). A conservative height estimate of 8 ft is assumed, making the **ground area coverage 125 ft^2 per nozzle** (A_{NC}). A high-end height estimate of **8 feet is assumed** which allows for a smaller turf surface area for the pesticide to be deposited on and, therefore, a higher concentration of residue is available, thus making the exposure estimate health-protective. An 8 foot height is also the assumed height of the box model, and a reasonable high end estimate of the height of the residential animal barn misting system based on professional judgment.

Transfer Coefficient

The transfer coefficient (TC) provides a measure of surface-to-skin residue transfer and is derived from concurrent measurements of exposure and surface residue. Specifically, the TC is the ratio of exposure rate, measured in mass of chemical per time (e.g., µg/hr), to residue, measured in mass of chemical per foliar surface area (e.g., µg/cm^2). As the indoor environments scenario represents the best surrogate for the animal barn scenario, the transfer coefficients outlined in *Section 7.2.2.1* should be utilized. **For adults, the recommended transfer coefficient is therefore 6,800 cm^2/hr** as shown in *Table 7-10*: **Transfer coefficients (TC; cm^2/hr)**. **For children 3 < 6 years old, the index lifestage for this scenario, the transfer coefficient is 2,700 cm^2/hr** (calculated using the adult TC and the corresponding adjustement factor, 0.39, shown in *Table 2-4*).

Exposure Time (ET)

Though the indoor environments exposure scenario methodology is the best surrogate for post-application exposures in animal barns, some inputs, including exposure time, are different. The exposure time of **adults who spend time in and around animal barns is 4 hours per day** in the treated space. **Children are assumed to spend 2 hours per day** in the treated space. These recommended exposure time values are based on a study that examined the relationship between respiratory problems and time spent in animal barns (Mazan, 2009). In this study, it was reported that anecdotal evidence suggests that casual riders are unlikely to spend more than 1-2 hours per day and a total 2-5 days per week in a barn. Based on this anecdotal evidence, 4 hours per day is believed to be a conservative estimate of time spent inside an animal barn for the adult rider who also performs some non-occupational barn-related tasks. Similarly, since casual child riders are likely to spend less time performing non-riding activities than adults, 2 hours per day is believed to be a conservative estimate for children.

Future Research/Data Needs

There are three main research/data needs with respect to the post-application animal barn scenario.

- No data are available to characterize the prevalence of animal barn misting systems in different regions of the U.S. A survey could be conducted to determine animal barn misting systems use patterns.
- No data are available to characterize the deposition pattern of animal barn misting systems. Studies could be designed to capture the deposition patterns on hard surfaces for animal barn misting systems and residue available for transfer.
- No data are available to indicate the extent of dermal deposition on human skin from aerosolized pesticides released from animal barn misting systems. Studies could be designed to capture the extent of dermal deposition as a result of airborne aerosols released from animal barn misting systems.

Exposure Characterization and Data Quality

- Animal Barn Misting Systems typically operate on timed applications or by remote control activation. The animal barn scenario models residential post-application exposure and assumes individuals are present immediately following a spray event, not during the application.
- The animal barn exposure scenario makes the health protective assumption that all the amount of the applied pesticide is in the air available for inhalation exposure, and that all the amount of the applied pesticide settles onto the ground in the barn and is also available for dermal and incidental oral exposure.
- Quantitative dermal post-application exposure assessment is assumed to be health-protective for animal barn misting systems. Persons are not likely to be participating in activities on animal barn floors that would result in significant contact and/or transferable residue available for dermal exposure, such as the indoor activities assumed as part of the indoor hard surface post-application dermal assessment. Therefore, the surrogate post-application dermal methodology (derived as part of the Indoor Environments SOP) is a health protective surrogate to estimate animal barn post-application dermal exposure.
- Non-dietary ingestion post-application exposure is expected to be minimal compared to

the post-application dermal and inhalation exposure. It is expected that those children entering animal barns are typically under adult supervision. Therefore, a quantitative assessment of hand-to-mouth exposure is health protective.

5.4.2.3 Combining Post-application Scenarios

Risk estimates resulting from different exposure pathways are combined when it is likely that they can occur simultaneously based on the use pattern, the behavior associated with the exposed lifestage, and when the toxicological effects across different routes of exposure are the same. When combining scenarios, it is important to fully characterize the potential for co-occurrence as well as characterizing the risk inputs and estimates. Risk estimates should be combined even if any one scenario or route of exposure exceeds the level of concern because this allows for better risk characterization for risk managers.

For animal barn misting system scenarios, it is likely that children could be exposed to an area treated via the inhalation, dermal and non-dietary ingestion (hand-to-mouth) routes. Therefore, these exposure scenarios should be considered and combined, if appropriate, when toxicological effects are the same across these routes of exposure.

Section 6 Insect Repellents

This section provides an outline of the procedures used to assess, estimate and characterize exposures resulting from the use of personal insect repellents available in many formulations such as aerosol sprays, lotions, pump sprays, gels, towelettes and wrist bands. It also includes repellents formulated with sunscreens. Other repellent-type products are covered under separate sections such as mosquito coils (*Section 5.2*), misting systems (*Section 5.1*), or repellent-impregnated clothing or textiles (*Section 9*).

Exposure results from deliberate application to the skin and clothing of individuals. Repellent use can be on the order of days or weeks or longer, depending on the activity pattern and geographic area. Insect repellents are used on people of all ages. While exposure may occur for people of all ages, considering the strengths and limitations of available data and behavioral characteristics of potentially exposed lifestages, adults and children 1 < 2 years old are considered the index lifestages whose exposure assessments are expected to encompass those for all lifestages.

Repellents are all "ready-to-use" (i.e., there is no mixing of liquid concentrates or powders) and are sprayed or otherwise applied onto the skin or clothing. The individual applying insect repellents is, for the purposes of this section, the "handler". Adults are assumed to experience both dermal and inhalation handler exposure, as well as post-application dermal and, potentially, inhalation exposure. Adults are assumed to apply repellents to themselves or to others. However, for aerosol and pump-spray repellents, individuals to whom the products are being applied can experience indirect inhalation exposure during the application. For children, post-application exposure consists of dermal, (potentially) inhalation, and hand-to-mouth exposure.

6.1 Handler Exposure Assessment

Unlike other pesticide applications, "handler" and "post-application" exposures resulting from repellent applications are not truly separate events since many applications are self-applications. Therefore, for the purposes of this SOP, "handler" dermal exposure can be considered in concert with "post-application" dermal exposure (i.e., dermal exposure is only assessed as part of the post-application dermal scenario). However, for aerosol and pump-sprayer repellent products, inhalation exposure for adults and children during the application process is possible and can be assessed under the standard "handler" process described below.

Dermal and Inhalation Handler Exposure Algorithm

As described in *Section 1.3.3*, 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:

$$E = UE * AR \quad (6.1)$$

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:

$$AR = A.I * W * N \quad (6.2)$$

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)

Absorbed dermal and/or inhalation doses normalized to body weight are calculated as:

$$D = \frac{E * AF}{BW} \quad (6.3)$$

where:

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

Handler exposure for repellent applications is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in Sections *1.3.2* and *1.3.3* such as the product-specific application regimen.

Dermal and Inhalation Handler Exposure Algorithm Inputs and Assumptions

Recommended values for repellent handler exposure (inhalation only) assessments are provided in *Table 6-1* and *Table 6-2.* Following these tables, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions, ii) data sources used to derive recommended input values, and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 6-1: Insect Repellents – Recommended Unit Exposure (mg/lb ai) Point Estimates

Formulation	Equipment/Application Method	Dermal	Inhalation	Appendix Page Reference
		Point Estimate	Point Estimate	

Table 6-1: Insect Repellents – Recommended Unit Exposure (mg/lb ai) Point Estimates				
Formulation	**Equipment/Application Method**	**Dermal**	**Inhalation**	**Appendix Page Reference**
		Point Estimate	**Point Estimate**	
Ready-to-Use (RTU)	Aerosol can	Dermal handler exposure for repellent applications considered as part of post-application dermal exposure.	3.0	C-134
	Trigger-pump sprayers		0.061	C-113

Table 6-2: Insect Repellents – Recommended Handler Exposure Factor Point Estimates		
Exposure Factor (units)		**Point Estimate(s)**
Application Rate (% ai in product)		Maximum labeled rate
Amount used	# aerosol cans or pump sprays per day	1
Body Weight (kg)	Adult	80
	Children 1 < 2 years old	11

Unit Exposures

As described in *Section 1.3.3*, the unit exposure is the ratio, for a given formulation/application method combination, between exposure and the amount of active ingredient handled, with units mass exposure per mass active ingredient handled (e.g., mg ai exposure/lb ai handled). **The recommended point estimates are shown in *Table 6-1*.** Data summaries can be found in *Appendix C*.

Application Rate

The algorithm for estimating handler exposure requires some estimate of the amount of active ingredient handled per day. For repellents, this factor varies based on the type of product being applied and is estimated based on the percentage of active ingredient specified on the product label and the amount of product being sprayed. Both of these can be determined on a product- and chemical-specific basis, however, **as a default, 1 can or pump spray bottle per day for handlers** is assumed based on professional judgment.

Future Research/Data Needs

Unavailable information that would refine handler exposure assessments for repellents include:

- Application intervals (i.e., how often repellents are applied)
- Survey information detailing:
  - Daily/weekly/monthly probability of using a repellent product;
  - Amount of product or formulation used per application; and,
- Handler exposure data:
  - Specific for repellent applications;
  - Describing the extent to which an individual's exposure for a given formulation and application method varies from application-to-application.

Exposure Characterization and Data Quality

Unit Exposures

- This section relies on surrogate data considered reasonable for estimating handler exposure for scenarios that are lacking data.
- The underlying assumption of the use of exposure data as unit exposures – proportionality between the amount of active ingredient handled and exposure – is uncertain, though potentially conservative. However, as a prediction mechanism, it is considered practical and useful for the purposes of handler exposure assessment in a regulatory context. It provides a straightforward handler exposure calculation method and enables risk mitigation in the form of formulation comparison and decreased application rates.
- The extent to which an individual's exposure (expressed via unit exposures) varies day-to-day or application-to-application is unknown; therefore, the assumption that there is no variation when assessing longer-term exposure durations is considered conservative.

Amount of active ingredient handled

- Information on the amount of product/formulation (thus, active ingredient) handled per application is largely unavailable. The recommended point estimates are, therefore, intended to be conservative to ensure an appropriately health protective exposure estimate.
- The assumption that each the applicator ("handler") and the person to whom the repellent is being applied to are equally exposed to an entire repellent product during application is a conservative estimate for screening-level purposes. It is not possible for them to be simultaneously exposed to the entire can, but the actual proportions of active ingredient to which each participant is exposed is unknown.
- The extent to which the amount an individual will handle per application varies from day-to-day or application-to-application is unknown; therefore, the assumption that there is no variation when assessing longer-term exposure durations is considered conservative.

6.2 Post-application Exposure Assessment

Post-application dermal and non-dietary ingestion exposure may occur as a direct result of a repellent application via dermal absorption and hand-to-mouth activities, respectively. Post-application inhalation exposure should be considered based on the chemical's volatility. While post-application exposure may occur for people of all ages, the assessment for adults and children 1 < 2 years old are expected to encompass the exposures for all lifestages.

This section addresses standard methods for estimating exposure and dose for three individual scenarios resulting from use of insect repellents:

- Section 6.2.1 – adult/children 1 < 2 years old inhalation exposure;
- Section 6.2.2 – adult/children 1 < 2 years old dermal exposure; and

- Section 6.2.3 – children 1 < 2 years old non-dietary ingestion via hand-to-mouth activity.

6.2.1 Post-application Inhalation Exposure Assessment

Post-application inhalation exposure resulting from insect repellents is generally not assessed and should be handled on a case-by-case basis. The combination of low vapor pressure for chemicals typically used as active ingredients in insect repellent products and dilution in outdoor air is expected to result in minimal inhalation exposure.

6.2.2 Post-application Dermal Exposure Assessment

This SOP provides a standard method for estimating dermal doses among adults and children 1 < 2 years old from skin treated with insect repellents, as well as sunscreens containing insect repellents.

Post-application Dermal Exposure Algorithm

Post-application dermal exposure resulting from repellent treatments is a function of the amount of product applied to the body. Thus, it is dependent on three factors:

- The application rate (i.e., the target concentration of chemical on the skin per application);
- The total area of the body to which the repellent is applied; and,
- The number of applications.

If reliable product-specific information is available that details the target concentration of active ingredient applied to the skin (e.g., mg active ingredient per square centimeter of skin), that information is preferable and should be used in this SOP in the formula below. However, in the event that such information is unavailable, or otherwise considered unreliable, the assessor can use a formulation-specific rate described in this SOP combined with the label-specified percentage of active ingredient to obtain a reasonable estimate of the target skin concentration of active ingredient (see the formula below). The algorithms to calculate dose are presented below. Discussion of each factor is presented in the remainder of this SOP.

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

$$D = AR_P * \#Apps * SA/BW * F_{Body} * AF \quad (6.4)$$

where:

D = dose (mg/kg-day);
AR_P = product-specific application rate (mg ai/cm^2 skin);
#Apps = number of repellent applications per day;
SA/BW = total body surface area to body weight ratio (cm^2/kg);
F_{Body} = clothing-dependent fraction of body exposed (fraction exposed/application);
AF = absorption factor.

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

$$D = AR_F * F_{AI} * \#Apps * SA/BW * F_{Body} * AF \quad (6.5)$$

where:

D = dose (mg/kg-day);
AR_F = formulation-specific application rate (mg product/cm^2 skin);
F_{AI} = product-specific fraction of active ingredient (mg ai/mg product);
#Apps = number of repellent applications per day
SA/BW = total body surface area to body weight ratio (cm^2/kg);
F_{Body} = clothing-dependent fraction of body exposed (fraction exposed/application);
AF = absorption factor.

where (for either method):

$$\#Apps = ET * AppF \quad (6.6)$$

#Apps = number of repellent applications per day
ET = exposure time (hours/day);
AppF = application frequency (applications/hour)

Post-application exposure following repellent applications is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4* such as product-specific application intervals and activity patterns. If longer-term assessments (i.e., intermediate-term, long-term, or lifetime exposures) are deemed necessary, similar refinements to more accurately reflect the exposure profile are recommended.

Post-application Dermal Exposure Algorithm Inputs and Assumptions

Recommended values for post-application dermal exposure assessments are provided in *Table 6-3* below. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions, ii) data sources used to derive recommended input values, and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 6-3: Insect Repellents - Recommended Point Estimates for Post-Application Dermal Exposure Factors

Algorithm Notation	Exposure Factor (units)		Point Estimate(s)
AR_F	Formulation-specific application rate (mg product/cm^2 skin)	Aerosol	1.1
		Pump spray	0.62
		Lotion	2.0
		Towelette	1.1
F_{AI}	Amount of active ingredient (%)		Maximum labeled rate (product-specific)
F_{Body}	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^2/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

Application Rate (AR_F; mg product/cm^2 skin)

Most of the products assessed will not have labels that state active-ingredient-based application rates in quantifiable terms (e.g., mg ai/cm^2). Application rates vary depending on the formulation, with lotions being applied most heavily. Efficacy studies were used as the basis for application rates, since these data are formulation-specific and are from actual repellent applications (Carroll, S.P. 2007a, 2007b, 2007c, 2007d, 2007e, 2008a, 2008b). While the studies themselves vary with respect to the application location and different types of active ingredients the repellent efficacy studies that EPA receives are conducted by treating a portion of a subject's skin with insect repellent, exposing the treated skin to mosquitoes, and observing the rate at which the insects "bite" the subject's skin. *Table 6-4* provides a summary for the formulation-based application rates. **The recommended point estimates are shown in *Table 6-3***. See *Section D.11* of *Appendix D* for detailed information on application rates for various formulations.

Table 6-4: Statistical Summary – Repellent Product Application Rate (mg product/cm^2)

Statistic	Aerosol	Pump-spray	Lotion	Towelette
50th percentile	0.92	0.50	1.9	1.1
75th percentile	1.5	0.78	2.4	1.3
95th percentile	2.9	1.5	3.5	1.8
99th percentile	4.7	2.3	4.6	2.3
AM (SD)	1.1 (0.93)	0.62 (0.45)	2.0 (0.80)	1.1 (0.36)
GM (GSD)	0.92 (2.0)	0.50 (1.9)	1.9 (1.5)	1.1 (1.4)
Range	0.17 – 3.5	0.056 – 2.3	0.68 – 4.5	0.5 – 2.5
N	144	420	120	240

Statistics based on lognormal distributions.
AM (SD) = arithmetic mean (standard deviation)
GM (GSD) = geometric mean (geometric standard deviation)

Number of Repellent Applications (#Apps)

The number of applications of an insect repellent determines the amount of repellent ingredients available for absorption through the skin or other potential routes of exposure. Direct information on the number of repellent applications in a day is unavailable; thus, this variable is determined as a function of the amount of time someone spends in settings where repellents might be used and how often someone is expected to apply to themselves or someone else (i.e., based on the repellent efficacy). Descriptions of these two inputs are below.

Because individuals will experience exposure from the number of applications per day, the product of exposure time (ET) and application frequency (AppF) needs to be expressed as a whole number. For example, if an individual is outdoors for 3.5 hours and applying a repellent at the rate of 1 application per hour, they are exposed to 3 applications. The product of 3.5 hours and 1 application per hour is 3.5 applications, but that would imply someone applied an additional ½ of an application, a non-intuitive situation. Thus the calculation of "# applications" using exposure time and application frequency needs to reflect this situation.

Exposure Time (ET)

For duration of time during which repellents are applied, the amount of time spent performing outdoor recreational activities was used (U.S. EPA, 2011; Tables 16-26 and 16-25, "doers only"). It is likely that insect repellents would be used when adults and children are performing outdoor activities, so this dataset was considered a reasonable surrogate. Children 1 < 2 is considered the index lifestage because of the expected greater use of repellents compared with younger children due to time spent in activities during which repellents would be used. However, no data were available for this lifestage, so time spent in outdoor recreation for children 3 < 6 years old was used as a surrogate dataset. Note that only the "doers" are represented, meaning that individuals who did not respond that they perform outdoor recreational activities were excluded. **Based on these data, the recommended point estimates for use in post-application dermal exposure assessment for adults and children 1 < 2 years old are 3.7 and 3.5 hrs/day, respectively.**

Table 6-5: Time Spent Outdoors (hrs/day)

Statistic	Adults	Children 1 < 2 years old
5th percentile	0.5	0.5
25th percentile	1.3	1.0
50th percentile	2.9	2.5
75th percentile	5.2	4.0
90th percentile	8.4	9.8
95th percentile	9.8	10.1
99th percentile	11.5	10.4
Mean	3.7	3.5
	Source: U.S. EPA, 2011; Table 16-26	Source: U.S. EPA, 2011; Table 16-25 (children 3 < 6 years old data used as a surrogate dataset – not available for children 1 < 2 years old).

Application Frequency (AppF):

The assessor should consider the exposure scenario, formulation, and target pest while determining the number of applications per hour. Most insect repellent labels do not specify the number of applications to be made per hour. More commonly, a label will carry a statement such as "reapply as needed." Efficacy studies are designed to measure the duration of repellency provided by the products tested. If product-specific information on the duration of efficacy repellency is available, the assessor should use it

in their assessment to determine the application frequency specific to the individual product.

However, if this information is unavailable, **a generic application frequency of 1 every 4 hours (0.25 applications/hour) is recommended for traditional repellents, while an application frequency of 1 every 2 hours (0.5 applications/hour) is recommended for repellents formulated with sunscreens.** Sunscreen applications are assumed to occur more frequently. This is based on information from the Center for Disease Control (CDC) indicating effective repellency times vary from 2-6 hours (i.e., 1 application every 2-6 hours) depending on the product and formulation (Fradin and Day, 2002).

Body Weight and Surface Area

The exposure algorithm uses surface area (SA) and body weight (BW) as a ratio instead of as two separate factors. **The recommended point estimate ratio for adults is 280 cm^2/kg and 640 cm^2/kg for children 1 < 2,** from the Exposure Factors Handbook 2011 Edition, Table 7-15 (U.S. EPA, 2011). *Table 6-6* below provides a summary of this exposure parameter.

Table 6-6: Surface Area to Body Weight Ratio (cm^2/kg)

%tile	Adult	Youth	Child
	Males and Females; > 18 yrs.	Males and Females; 2-18 yrs.	Males and Females; < 2 yrs.
95	330	590	850
90	320	500	780
75	300	450	720
50	290	420	620
25	270	380	560
10	240	330	510
5	240	290	470
Mean	280	420	640

Source: U.S. EPA, 2011, Table 7-15.

Fraction of Body Exposed (F_{Body})

Clothing-dependent fraction of body exposed (surface area body exposed/total body surface area) are presented in *Table 6-7* below. These estimates are based on Wong, et al. (2000) and are intended to represent a range of exposure scenarios in different activity and weather conditions. **A default point estimate of 75% is recommended** to reflect males and females in swimwear. Other estimates are shown – 17% represents an individual wearing a long-sleeve shirt, pants, socks, and shoes; 31% represents an individual wearing a short-sleeve shirt, shorts, socks, and shoes – to reflect additional clothing scenarios should the assessment require additional characterization.

Table 6-7: Percentage of Total Body Surface Area Exposed

Clothing Scenario	Body Parts Exposed	% of Body SA Exposed	
		Per Body Part	Total
Long-sleeve shirt, pants, socks, shoes	Face/Neck	5%	17%
	Hands/wrists	6%	
	Ankles	6%	
Short-sleeve shirt, shorts, socks, shoes	Lower thighs/upper shins	13%	31%
	Forearms	6%	

	Face/Neck	6%	
	Feet	7%	
Shorts (males); Shorts and top (females)	Torso	38%	75%
	Arms		
	Lower thighs/upper shins	13%	
	Lower shins	6%	
	Feet	7%	
	Hands	5%	
	Face/Neck	5%	

Future Research/Data Needs

Unavailable information that would refine post-application dermal exposure assessments for pesticide applications to insect repellents include:

- Measurements of "whole body" exposure following repellent applications under differing situations (e.g., single-event as well as longitudinal repeated applications at campsites, beaches, etc.) to replace method of extrapolating from forearm or leg measurements.
- Survey information detailing:
  - Daily/weekly/monthly probability of using a repellent
  - Repellent application regimens (i.e., applications per day) – both daily and longitudinal frequencies.

Exposure Characterization and Data Quality

Formulation-specific Application Rates: The formulation-specific application rates were derived from available repellent efficacy studies where the amount of repellent applied to a known surface area (i.e., the area of a certain section of forearm or leg) was measured typically via a "before-and-after" weighing. The extent to which the data in these studies present a true statistical representation of repellent application rates is unknown. Furthermore, because the applications were to legs or forearms only, the use of these rates in the post-application dermal exposure equation requires extrapolation to the rest of the body, assuming the same loading for across body parts.

Fraction of Body Exposed: Though a default of 75% is recommended, three "scenarios" described by the amount of body exposed per application are meant to represent the broad range of repellent exposure situations and can be used for additional exposure characterization. This is because, for example, the proportion of total repellent applications comprising heavy-use repellent applications (i.e., an application to 75% of a person's skin) is unknown.

Daily Application Frequency: The number of repellent applications per day would be highly chemical-specific, since it would be dependent on the product's efficacy. However, in the event this information is unknown, the range of 1 application every 2-6 hours (Fradin and Day, 2002) is reasonable.

6.2.3 Post-application Non-Dietary Ingestion Exposure Assessment: Hand-to-Mouth

This SOP provides a standard method for estimating the dose for children 1 < 2 years old from incidental ingestion of pesticide residues from skin treated with insect repellents. This scenario assumes that pesticide residues resulting from the application of insect repellents on the skin are subsequently ingested as a result of hand-to-mouth transfer.

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):

$$E = \left[HR * \left(F_M * SA_H\right) * \left(\#Apps\right) * \left(1 - \left(1 - SE\right)^{\frac{ET * Freq_HtM}{\#Apps}}\right)\right] \quad (6.7)$$

where:

E	= exposure (mg/day);
HR	= hand residue loading (mg/cm^2);
F_M	= fraction hand surface area mouthed/event (fraction/event);
SA_H	= typical surface area of one hand (cm^2);
#Apps	= number of applications per day (#/day);
SE	= saliva extraction factor (i.e., mouthing removal efficiency); and
Freq_HtM	= number of hand-to-mouth contacts events per hour (events/hour).

where:

$$\#Apps = ET * AppF \quad (6.8)$$

#Apps	= number of repellent applications per day
ET	= exposure time (hours/day);
AppF	= application frequency (applications/hour)

and

$$HR = AR_F * F_{AI} \quad (6.9)$$

where:

HR	= hand residue loading (mg/cm^2);
AR_F	= formulation-specific application rate (mg ai/cm^2 skin);
F_{AI}	= product-specific fraction of active ingredient (mg ai/mg product);

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

$$D = \frac{E}{BW} \quad (6.10)$$

where:

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

Post-application hand-to-mouth exposure following repellent applications is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4* such as residue dissipation, product-specific re-treatment intervals, and activity patterns. If longer-term assessments (i.e., intermediate-, long-term, or lifetime exposures) are deemed necessary, similar refinements to more accurately reflect the exposure profile are recommended.

Post-application Hand-to-Mouth Exposure Algorithm Inputs and Assumptions

Recommended values for post-application hand-to-mouth exposure assessments are provided in *Table 6-8*. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions, ii) data sources used to derive recommended input values, and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 6-8: Insect Repellents - Recommended Point Estimates for Post-Application Hand-to-Mouth Exposure Factors

Algorithm Notation	Exposure Factor (units)		Point Estimate(s)
AR_F	Formulation-specific application rate (mg product/cm^2 skin)	Aerosol	1.1
		Pump spray	0.62
		Lotion	2.0
		Towelette	1.1
F_{AI}	Amount of active ingredient (%)		Maximum labeled rate (product-specific)
SA_H	Typical surface area of one hand (cm^2), children 1 < 2 years old		150
F_M	Fraction hand surface area mouthed (fraction/event)		0.127
AppF	Application Frequency	Traditional	0.25
		With sunscreen	0.5
ET	Exposure Time (hours/day)		3.5
SE	Saliva extraction factor (fraction)		0.48
Freq_HtM	Hand-to-mouth events per hour (events/hr)		13.9
BW	Body Weight (kg)		11.4

Hand Residue Loading (HR)

The application rate described in the post-application dermal exposure section is assumed to be equally distributed across the body. Therefore, those rates can be directly used as the concentration on the hands following a repellent application. Thus, the concentration on the hands is the product of the formulation-specific rates shown in *Table 6-8* and the amount of active ingredient in the repellent.

Fraction Hand Surface Area Mouthed (F_M)

See *Section 2.4* of this SOP for discussion of the fraction of hand surface area mouthed distribution. **The recommended point estimate for use in post-application hand-to-mouth exposure assessment is 0.127 (12.7%).**

Hand Surface Area (SA_H)

The **hand surface area for children 1 < 2 years old of 150 cm^2**, for one hand, is recommended based on the Exposure Factors Handbook 2011 Edition, Table 7-2 (U.S. EPA, 2011).

Number of Repellent Applications (#Apps)

The number of applications of an insect repellent determines the amount of repellent ingredients available for absorption through the skin or other potential routes of exposure. Direct information on the number of repellent applications in a day is unavailable; thus, this variable is determined as a function of the amount of time someone spends in settings where repellents might be used and how often someone is expected to apply to themselves or someone else (i.e., based on the repellent efficacy). Descriptions of these two inputs are below.

Because individuals will experience exposure from the number of applications per day, the product of exposure time (ET) and application frequency (AppF) needs to be expressed as a whole number. For example, if an individual is outdoors for 3.5 hours and applying a repellent at the rate of 1 application per hour, they are exposed to 3 applications. The product of 3.5 hours and 1 application per hour is 3.5 applications, but that would imply someone applied an additional ½ of an application, a non-intuitive situation. Thus the calculation of "# applications" using exposure time and application frequency needs to reflect this situation.

Exposure Time (ET)

For duration of time during which repellents are applied, the amount of time spent performing outdoor recreational activities was used (U.S. EPA, 2011; Tables 16-25, "doers only"). It is likely that insect repellents would be used when children are performing outdoor activities, so this dataset was considered a reasonable surrogate. Children 1 < 2 is considered the index lifestage because of the expected greater use of repellents compared with younger children due to time spent in activities during which repellents would be used. However, no data were available for this lifestage, so time spent in outdoor recreation for children 3 < 6 years old was used as a surrogate dataset. Note that only the "doers" are represented, meaning that individuals who did not respond that they perform outdoor recreational activities were excluded. **Based on these data, the recommended point estimate for use in post-application hand-to-mouth exposure assessment for children 1 < 2 years old is 3.5 hrs/day.**

Table 6-9: Time Spent for Repellent Use (hrs/day)	
Statistic	**Children 1 < 2 years old**

5th percentile	0.5
25th percentile	1.0
50th percentile	2.5
75th percentile	4.0
90th percentile	9.8
95th percentile	10.1
99th percentile	10.4
Mean	3.5
	Source: U.S. EPA, 2011; Table 16-25 (data for children 1 < 2 year unavailable – children 3 < 6 years old data used as a surrogate dataset).

Application Frequency (AppF):

Unlike other hand-to-mouth scenarios where replenishment can come from treated indoor surfaces or treated turf, replenishment for insect repellents is assumed to only occur when an application occurs. As a result, application frequency is used to represent replenishment intervals per hour (see "N_Replen" in other hand-to-mouth exposure equations).

The assessor should consider the exposure scenario, formulation, and target pest while determining the number of applications per hour. Most insect repellent labels do not specify the number of applications to be made per hour. More commonly, a label will carry a statement such as "reapply as needed." Efficacy studies are designed to measure the duration of repellency provided by the products tested. If product-specific information on the duration of efficacy repellency is available, the assessor should use it in their assessment to determine the application frequency specific to the individual product. However, if this information is unavailable, **a generic application frequency of 1 every 4 hours (0.25 apps/hour) is recommended for traditional repellents and 1 every 2 hours (0.5 apps/hour) is recommended for repellents formulated with sunscreens.** This is based on information from the Center for Disease Control (CDC) indicating effective repellency times vary from 2-6 hours (i.e., 1 application every 2-6 hours) depending on the product and formulation (Fradin and Day, 2002).

Fraction of Pesticide Extracted by Saliva (SE)

See *Section* 2.6 for discussion of the distribution of values for the fraction of pesticide extracted by saliva distribution. **The recommended point estimate for use in post-application hand-to-mouth exposure assessment is 0.48.**

Hand-to-Mouth Events per Hour (Freq_HtM)

Frequency of hand-to-mouth events is an important variable for hand-to-mouth post-application exposure assessments. However, there are currently no data available that specifically address the number of hand-to-mouth events that occur relative to the amount of time a child is in contact with an insect repellent. As a result, the estimates for frequency of hand-to-mouth events in outdoor environments from the Xue et al. (2007) meta-analysis were selected as a surrogate. The outdoor data were selected because they represent the most likely time when insect repellents will be used on children. The insect repellent SOP utilizes hand-to-mouth frequency data for the 1 < 2 year old lifestage to represent children. Distributions for different lifestages can be used if

there is a need to assess a more specific exposure lifestage. The estimates of hand mouthing frequency (events/hour) for 1 < 2 years old were derived from 4 studies representing 32 participants. Based on an analysis of the data by Xue et al., it was determined that a Weibull distribution (scale= 13.8, shape= 0.98) best fits the observed data. *Table 6-10* provides distributions and point estimates of hand-to-mouth events for use in residential pesticide exposure assessment and *Appendix D.9.1* provides additional analysis. **The recommended point estimate for use in post-application hand-to-mouth exposure assessment is 13.9 events/hour.**

Table 6-10: Frequency of Hand-to-Mouth Events (events/hour)	
Statistic	**Children 1 < 2 years old**
50th percentile	8.0
75th percentile	19.2
95th percentile	42.2
AM (SD)	13.9 (13.6)
Range	1 – 46.7
N	32
AM (SD) = arithmetic mean (standard deviation)	

Future Research/Data Needs

Information that would refine post-application dermal exposure assessments for the application of insect repellents are listed below. Existing surveys such as the REJV survey and DEET Joint Venture Survey can be further reviewed for this information.

- Repellent application regimens – both daily and longitudinal frequencies
- Survey information detailing:
  - Daily/weekly/monthly probability of using a repellent; and
  - Product- and/or formulation-specific application rates enabling determination of hand-specific concentrations under differing scenarios as well as repeat applications to measure the extent to which the rate varies per individual.

Exposure Characterization and Data Quality

Formulation-specific Application Rates: The formulation-specific application rates were derived from available repellent efficacy studies where the amount of repellent applied to a known surface area (i.e., the area of a certain section of forearm or leg) was measured typically via a "before-and-after" weighing. Though the applications in these studies were to legs or forearms only, these rates were assumed to apply to the hands as well.

Daily Application Frequency: The number of repellent applications per day would be highly chemical-specific, since it would be dependent on the product's efficacy. However, in the event this information is unknown, the range of 1 application every 2-6 hours (Fradin and Day, 2002) is reasonable.

6.2.4 Combining Post-application Scenarios

Risks resulting from different exposure scenarios are combined when it is likely that they can occur simultaneously based on the use pattern and when the toxicological effects across different routes of exposure are the same (see *Section 1.3.4*). When combining scenarios, it is important to fully characterize the potential for co-occurrence as well as characterizing the risk inputs and estimates. Risks should be combined even if any one scenario or route of exposure exceeds the level of concern because this allows for better risk characterization for risk managers. For insect repellents, the post-application exposure scenarios that should be combined are the dermal and hand-to-mouth scenarios. This combination should be considered a protective estimate of children's exposure from the use of insect repellents.

Section 7 Indoor Environments

This section considers those individuals who are potentially exposed to pesticides from either treating indoor areas with a product available for sale to the general public or after contact with treated indoor surfaces in many settings including homes, schools, and daycares. Before the development of an exposure assessment for this scenario, the assessor should review the pesticide label to determine whether it is appropriate based on the usage of the product.

For the purposes of the indoor SOP, the following definitions are used:

A fogger (or total release aerosol) is a pesticide device designed to automatically release its total content in one operation for the purpose of creating a permeating fog within a confined space to deliver the pesticide throughout the space. Total release aerosols do not need any other application equipment (PR NOTICE 98-6, 1998).

Broadcast application is defined as an application to broad expanses of surfaces such as walls, floors, and ceilings (U.S. EPA, 1996); a coarse spray of liquid insecticide or application of a dust insecticide in a room. Broadcast applications should be evenly distributed (University of Nebraska–Lincoln Extension, 2006).

Perimeter/Spot/Bedbug (Coarse application) is defined as a coarse spray of liquid insecticide or application of a dust insecticide in a wide band or strip (University of Nebraska–Lincoln Extension, 2006) or over a small area (< 2 ft^2) (38 FR 21685, 1973). These applications are typically done with a manually-pressurized handwand or an aerosol can with typical nozzles. Example label language that would indicate this type of application includes:

"Use a coarse, manually-pressurized spray. Treat entry points such as around doors, windows, and eaves. Treat areas where pests normally feed or hide such as baseboards and corners."

"Use a manually-pressurized system with a fan-type nozzle to apply the dilution uniformly."

"Spot treat floor or rugs beneath furniture, in closets, and storage areas, but do not apply to entire floor area."

"…treat mattress, box springs, bed frames, and headboards."

Perimeter/Spot/Bedbug (Pin Stream application) is defined similarly to the coarse perimeter treatment except that the method of application utilizes a pin stream nozzle similar to what is used for crack and crevice applications. However, these types of applications are not made into cracks and crevices and a larger area is treated than would be expected with a crack and crevice application. Example label language that would indicate this type of application includes the language listed above for coarse applications with the exception of the type of nozzle used:

"Use a manually-pressurized system with a pinpoint nozzle."

Crack and crevice application is defined as an application of pesticides with the use of a pin stream nozzle, into cracks and crevices in which pests hide or through which they may enter a

building. Such openings commonly occur at expansion joints, between different elements of construction, and between equipment and floors. These openings may lead to voids such as hollow walls, equipment legs and bases, conduits, motor housings, and junction or switch boxes (U.S. EPA, 1996). Example label language that would indicate this type of application includes:

"Treat areas where pests normally feed or hide such as around water pipes, behind or under refrigerators, cabinets, sinks and stoves."

"Place injector tips into cracks and crevices."

When reviewing proposed labels, the following key items should be considered to determine if an indoor assessment should be conducted, and if so, what type of application should be assessed:

- Look for statements describing or limiting the use of the proposed product. These statements may be on the front panel of the label associated with the brand or trade name or in the use directions section of the label. If a label indicates an indoor residential use, assume that the product is used at residential sites such as daycares, schools, or other sites where children may be present, unless a specific labeling statement indicates use in a non-residential setting. Examples of statements that restrict use in residential sites, and therefore, would preclude a residential assessment, include:

    - For use in commercial sites only; and
    - For use in food handling establishments only.

    A Restricted Use Pesticide (RUP) classification indicates that the product cannot be bought or applied by homeowners (i.e., no residential handler exposure/risk assessment required), but it may be applied by commercial applicators to residential sites; therefore, a post-application risk assessment may be required.

- Determine what type of application is allowed on the label. Check the label for directions for use as a broadcast, perimeter, spot or crack and crevice treatment. Use the definitions and key label language provided above as a guide.

- Determine whether the pesticide label contains directions for use on carpets or hard surfaces, such as walls, countertops, hard floors, or cabinets. If no distinction is made as to what type of surface the product can be applied to, an assessment for both types of surfaces should be conducted.

If an indoor use is possible, the assessment should then characterize and estimate the potential for exposure by route (i.e., dermal, inhalation, non-dietary ingestion) following the methodology outlined in this SOP. The assessor should consider the durations of exposure for each route. Specific considerations include the number of applications allowed per year and the re-treatment interval required between those treatments. Depending on the specific product, this can indicate if intermediate- or long-term assessments are required.

7.1 Handler Exposure Assessment

The residential indoor handler SOP provides a standard method for estimating potential dermal and inhalation doses resulting from applying pesticides indoors. Adults are considered the index lifestage for this scenario as it is assumed that pesticides are applied by adults only (i.e., individuals 16 years or older).

Dermal and Inhalation Handler Exposure Algorithm

As described in *Section 1.3.3*, 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:

$$E = UE * AR * A \qquad (7.1)$$

where:

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

Absorbed dermal and/or inhalation doses normalized to body weight are calculated as:

$$D = \frac{E * AF}{BW} \qquad (7.2)$$

where:

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

Handler exposure for indoor applications is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.3*, such as the product-specific application regimen.

Dermal and Inhalation Handler Exposure Algorithm Inputs and Assumptions

Recommended values for handler exposure (dermal and inhalation) assessments are provided in *Table 7-1* and *Table 7-2*. Following these tables, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 7-1: Indoor Environments – Recommended Unit Exposure (mg/lb ai) Point Estimates				
Formulation	Equipment/ Application Method	Dermal	Inhalation	Appendix Page Reference
		Point Estimate	Point Estimate	
Dusts/Powders	Plunger duster	250	1.7	C-32
	Bulb duster	No exposure data available for this application scenario. Exposure data for plunger duster applications recommended as surrogate data.		
	Electric/power duster	No exposure data available for this application scenario. Exposure data for shaker can applications of dusts/powders recommended as surrogate data.		
	Hand crank duster	No exposure data available for this application scenario. Exposure data for shaker can applications of dusts/powders recommended as surrogate data.		
	Shaker can	4,300	18	C-36
Liquid concentrates	Manually-pressurized handwand (w/ or w/o pin stream nozzle)	No exposure data available for this application scenario. Exposure data for manually-pressurized handwand applications of wettable powder recommended as surrogate data.		
Ready-to-Use (RTU)	Aerosol can (w/ or w/o pin stream nozzle)	370	3.0	C-134
	Trigger-sprayer	85.1	0.061	C-113
	Gels	No exposure data available for this application scenario; however, exposure is considered negligible.		
	Pastes	No exposure data available for this application scenario; however, exposure is considered negligible.		
	Foams	No exposure data available for this application scenario; however, exposure is considered negligible.		
	Bait (granular; hand dispersal)	160	0.38	B-39
	Bait station / trap (enclosed in child resistant packaging)	No exposure data available for this application scenario; however, exposure is considered negligible.		
	Pest Strip	No exposure data available for this application scenario; however, exposure is considered negligible.		
Wettable Powder	Manually-pressurized handwand (w/ or w/o pin stream nozzle)	69	1.1	C-141
Wettable Powder in Water-soluble Packaging	Manually-pressurized handwand (w/ or w/o pin stream nozzle)	No exposure data available for this application scenario. Exposure data for manually-pressurized handwand applications of wettable powders recommended as surrogate data.		

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Table 7-2: Indoor Environments – Recommended Handler Exposure Factor Point Estimates			
Exposure Factor (units)			**Point Estimate(s)**
Amount Applied (see units specified)			
Amount product / /solution used	Manually-pressurized handwand (gallons)	Broadcast	0.5
		Perimeter/Spot/Bedbug (Coarse application)	
	Manually-pressurized handwand (w/pin stream nozzle) (gallons)	Perimeter/Spot/Bedbug (Pin stream application)	
		Crack and crevice	
	Bulb duster (pounds dust)	Perimeter/Spot/Bedbug Crack and crevice	0.25
	Plunger duster (pounds dust)	Broadcast Perimeter/Spot/Bedbug (Coarse application)	0.5
	Electric/power duster (pounds dust)	Broadcast Perimeter/Spot/Bedbug (Coarse application)	
	Hand crank duster pounds dust	Broadcast Perimeter/Spot/Bedbug (Coarse application)	
	Shaker can (#containers)	Broadcast	1
		Perimeter/Spot/Bedbug (Coarse application)	0.5
	Aerosol can (# 16-oz cans)	Broadcast Surface Spray	1
		Perimeter/Spot/Bedbug (Coarse application)	0.5
		Space spray	0.25
	Aerosol can (w/ pin stream nozzle) (# 16-oz cans)	Perimeter/Spot/Bedbug (Pin stream application) Crack and crevice	0.5
	Trigger-pump sprayer (#containers)	Broadcast	1
		Perimeter/Spot/Bedbug (Coarse application)	0.5
Body Weight (kg)			80

Unit Exposures

As described in *Section 1.3.3*, the unit exposure is the ratio between exposure and the amount of active ingredient handled for a given formulation/application method combination, with units of

mass exposure per mass active ingredient handled (e.g., mg ai exposure/lb ai handled). **The recommended point estimate for use in handler dermal and inhalation exposure assessments represents approximately the arithmetic mean of the distribution.** Data summaries can be found in *Appendix C*.

Estimating the Amount of Active Ingredient Handled

The algorithm for estimating handler exposure requires some estimate of the amount of active ingredient handled per day. This factor varies based on the type of equipment or application method used and is estimated based on the application rate specified on the product label. First, the assessor should assemble application rate information in terms of active ingredient per volume of spray (e.g., lb ai/gallon solution). For example, instructions for a liquid formulation might direct application of 0.5 gallons of solution per 100 square feet. For handler indoor assessments, the following are the recommended amounts of active ingredient handled for typical indoor application equipment.

- Manually-pressurized handwand: 0.5 gallons for broadcast, perimeter/spot/bedbug (coarse and pin stream applications) treatments and crack and crevice treatments. These values are supported by data from the Pesticide Handler Exposure Database (PHED), which indicate about 0.5 gallons for a commercial applicator crack/crevice and limited surface treatment in residences.
- Dusters: 0.5 pounds of dust for broadcast and for perimeter/spot/bedbug (coarse application) and 0.25 pounds of dust for perimeter/spot/bedbug (bulb duster application) and crack and crevice treatments. These values are based on best professional judgment since no data are available and may be refined based on label information.
- Shaker can: 1 can for broadcast and 0.5 can for perimeter/spot/bedbug (coarse application) treatments. These values are based on best professional judgment since no data are available and may be refined based on label information.
- Aerosol Can: 1 can for broadcast surface sprays. 0.5 can for perimeter/spot/bedbug (coarse and pin stream applications) treatment surface sprays and crack and crevice surface spray treatments, 0.25 for space sprays. These values are supported by data from the Pesticide Handler Exposure Database (PHED), which indicate one 15-oz can is used to make applications to crack, crevices, baseboards, under sinks, behind appliances, etc, as well as best professional judgment.
- Trigger-pump sprayer: 1 container for broadcast and ½ container for perimeter/spot/bedbug (coarse application) treatments. These values are based on best professional judgment since no data are available and may be refined based on label information.

Future Research/Data Needs

Unavailable information that would refine handler exposure assessments for indoor pesticide applications include:

- Information on the amount handled or area treated for the various scenarios.
- Information on unit exposures for several formulation/equipment combinations.

Exposure Characterization and Data Quality

The uncertainties associated with this assessment stem from the use of assumed amounts of active ingredient handled for typical indoor treatments. The estimated doses are believed to be high-end, conservative estimates.

Unit Exposures

- The exposure data underlying unit exposures are considered reasonable for the purposes of estimating exposure. The data are from actual applications using standardized exposure sampling methodologies and laboratory analyses.
- The underlying assumption of the use of exposure data as unit exposures – proportionality between the amount of active ingredient handled and exposure – is uncertain, though potentially conservative. However, as a prediction mechanism, it is considered practical and useful for the purposes of handler exposure assessment in a regulatory context. It provides a straightforward handler exposure calculation method and enables risk mitigation in the form of formulation comparison and decreased application rates.
- The extent to which an individual's exposure (expressed via unit exposures) varies day-to-day or application-to-application is unknown; therefore, the assumption that there is no variation when assessing longer-term exposure durations is considered conservative.

Amount of active ingredient handled

- Information on the amount of product/formulation (thus, active ingredient) handled per application is lacking, making the estimates highly uncertain. The recommended point estimates are, therefore, intended to be high-end to ensure an appropriately conservative exposure estimate.
- The extent to which the amount an individual will handle per application varies from day-to-day or application-to-application is unknown; therefore, the assumption that there is no variation when assessing longer-term exposure durations is considered conservative.

7.2 Post-application Exposure Assessment

Post-application exposure can result from contact with indoor surfaces following a pesticide application. While exposure may occur for people of all ages, adults and children 1 < 2 years are considered the index lifestages for this exposure scenario based on behavioral characteristics and the strengths and limitations of available data.

This section addresses standard methods for estimating exposure and dose for five individual post-application exposure pathways resulting from exposure to pesticides that have been used to treat indoor areas:

- Section 7.2.1 - Post-application inhalation exposures;
- Section 7.2.2 - Post-application dermal exposures;
- Section 7.2.3 –Non-dietary ingestion via hand-to-mouth activity;
- Section 7.2.4 –Non-dietary ingestion via object-to-mouth activity; and
- Section 7.2.5 –Non-dietary ingestion via dust ingestion.

7.2.1 Post-application Inhalation Exposure Assessment

This SOP provides a standard method for completing post-application inhalation exposure assessments for adults and children after a pesticide treatment indoors (e.g., in a house, school, daycare, etc). The basis for each scenario is that non-handler inhalation exposure occurs while occupying indoor areas after a pesticide treatment. It covers fogger, space spray, and surface-directed applications, as well as foundation/soil injection termiticide applications.

Inhalation exposure primarily occurs through breathing air containing pesticide vapors or aerosols. Aerosols are a spray of fine particles, which tend to settle out of the air after a certain time period depending on the particle size. Some examples of indoor devices that produce aerosols include foggers and aerosol cans. Vapors occur when the pesticide volatilizes from a surface after an application (e.g., broadcast application with a manually-pressurized handwand). Volatilization of a pesticide indoors is dependent on many factors, including the vapor pressure of the chemical, the media on which it has been applied, and air temperature.

For the inhalation route of exposure, there is a possibility that the point of departure (POD) used for risk assessment may be based on the reference concentration (RfC) methodology. In the RfC methodology, air concentrations are not converted to doses, rather, risks are assessed on the basis of comparison of air concentrations with reference concentrations typically determined from animal studies. This approach is not always available for every chemical; therefore, the exposure assessor should discuss the possibility of this approach with a toxicologist.

If the post-application inhalation exposure assessment performed needs to be refined, it is recommended that specialized computer software be used. The computer model currently used by the Agency is the *MCCEM* model or Multi-Chamber Concentration and Exposure Model. The *MCCEM* was peer reviewed in 1998 (Eastern Research Group, 1998). The appendix to this SOP provides standard model inputs for using *MCCEM* in exposure assessments, but the assessor should refer to the *MCCEM* User's Manual for details on the operation of *MCCEM* and for information concerning the underlying assumptions and limitations of each (U.S. EPA, 1995). One notable limitation is that MCCEM treats all emissions as vapor or gas. Therefore, air concentration calculations for aerosols using the MCCEM model will not account for the fact that a certain amount of the pesticide in the air is expected to settle out. All specific model inputs and calculations represented in this SOP are based on *MCCEM* Version 1.2 (available on the EPA website: http://www.epa.gov/opptintr/exposure/pubs/mccem.htm).

Post-application inhalation exposure following applications indoors is generally considered short-term in duration, but is dependent on the use pattern of the specific product being assessed and the dissipation/degradation properties of the active ingredient. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4* such as residue dissipation, product-specific re-treatment intervals, and activity patterns. If longer-term assessments (i.e., intermediate-, long-term, or lifetime exposures) are deemed necessary, similar refinements to more accurately reflect the exposure profile are recommended.

The indoor post-application inhalation exposure assessment section is divided into 3 sections: indoor foggers (*Section 7.2.1.1*), indoor spray applications (*Section 7.2.1.2*; covering both space sprays and surface-directed sprays), and foundation/soil injection termiticide applications (*Section 7.2.1.3*). The following table provides a summary of the possible post-application inhalation scenarios following treatment of indoor areas. More information about each scenario is provided below.

Decision Table for Post-application Inhalation Scenarios				
Possible post-application assessments	***Should an assessment be conducted for the type of applications below?***			
	Fogger (*Section 7.2.1.1*)	Indoor Spray Applications (*Section 7.2.1.2*)		Termiticide Applications (Foundation and Soil Injection) (*Section 7.2.1.3*)
		Space Spray (i.e., Flying Insect Killer)	Surface-directed Spray (e.g., Broadcast/ Spot/Perimeter/Crack and Crevice spray w/ Manually-pressurized Handwand)	
Exposure to pesticide aerosols in air (Algorithm #1)	**No** (reentry restriction and ventilation requirements)	If label has reentry restriction/ventilation requirements – **No** If label does not have reentry restriction/ventilation requirements -- **Yes**	**No**	**No**
Exposure to pesticide vapors in air (Algorithm #2)	**Yes**	**Yes**	**Yes**	**Yes** (using MCCEM model)

7.2.1.1 Indoor Foggers

Fogger devices are designed to spread a fog of pesticide filling a room with aerosols, which will eventually settle out of the air. To address post-application inhalation exposure to pesticide aerosols following fogger applications, most fogger product labels typically require statements such as: "Do Not Reenter Building for Four Hours; then open exterior doors and windows and allow to air for 60 minutes before reoccupying area" with the intention of reducing inhalation exposure. Information provided by manufacturers indicate that the particle size distribution for most total release foggers ranges from 15 micrometers (um) to 60 um. The average settling time for various particle sizes can be calculated based on Stokes Law (see *Section D-1* of *Appendix D*). According to calculations of settling time versus droplet size, it will take 2 hours for a 15 micrometer particle to settle and 8 minutes for a 60 micrometer particle to settle from an eight-foot ceiling height. Therefore, as long as fogger product labels include a statement restricting entry for at least 2 hours, post-application inhalation exposure to pesticide aerosols should be negligible. If there is no reentry time restriction on the product label, the ORE assessor should recommend that the Registration Division (RD) ensure the appropriate restrictions/directions are added to the label.

After pesticide residues from a fogger deposit onto the indoor floor surface, there is the potential for volatilization of those residues into the air. Therefore, an assessment for exposure to pesticide vapors should be conducted according to algorithm #2 below; Exposure to pesticide vapors.

7.2.1.2 Indoor Spray Applications

Indoor spray applications fall into two categories: (1) space sprays (e.g., flying insect killers), and (2) surface-directed sprays (e.g., broadcast applications made with a manually-pressurized handwand).

For space sprays, it is assumed that there may be post-application inhalation exposure to pesticide aerosols that are still airborne after application. It should be noted that some space spray labels have directions similar to those for indoor foggers, where the user is instructed to leave the room for a period of time and to ventilate the room prior to re-entry. Labels include statements such as: "Direct the spray towards the ceiling and upper corners of the room. Keep areas closed for at least 1/2 hour. Do not remain in treated area. Ventilate area thoroughly before re-entry." In those cases, post-application exposure to pesticide aerosols is expected to be negligible considering the re-entry restriction and the ventilation requirement. However, if the label does not contain such directions or requirements, then a post-application inhalation assessment for exposure to pesticide aerosols (algorithm #1 below) should be conducted. Similar to foggers, once the pesticide residues settle out of the air from the space spray application and deposit onto the indoor floor surface, there is the potential for volatilization of those residues into the air. Therefore, an assessment for exposure to pesticide vapors should be conducted according to algorithm #2 below; Exposure to pesticide vapors.

For surface-directed spray applications, it is assumed that there may be post-application inhalation exposure to pesticide vapors emitted after an application to an indoor surface has been made. Therefore, an assessment for exposure to pesticide vapors should be conducted according to algorithm #2 below; Exposure to pesticide vapors.

Post-Application Inhalation Exposure Algorithms

The two post-application inhalation exposure algorithms outlined in this section are:

(1) Exposure to pesticide aerosols, and

(2) Exposure to pesticide vapors.

(1) Exposure to pesticide aerosols

In order to assess post-application inhalation exposure to pesticide aerosols from instantaneous release/aerosol applications (e.g., flying insect killers), the initial air concentration must first be calculated. If chemical-specific data are available, the initial air concentration is the air concentration at time 0 (assuming that individuals could be exposed to the air concentration

immediately after application). If data are not available, then the initial air concentration can be calculated using the following formula:

$$C_0 = AR * CF1 \quad (7.3)$$

where:

C_0 = initial air concentration (mg/m^3);
AR = application rate (lbs ai/m^3); and
CF1 = conversion factor (454,000 mg/lb).

If an application rate is given on the label in terms of unit area, this should be used. The following equation can be used to calculate the application rate if it's not provided:

$$AR = \frac{AI * V_{product} * D_{product} * CF1 * CF2}{V_{room}} \quad (7.4)$$

where:

AR = application rate (lbs ai/m^3);
A.I. = percent active ingredient in product (% ai);
$V_{product}$ = volume of product in 1 can (mL);
$D_{product}$ = density of product (g/mL);
CF1 = conversion factor (1,000 mg/g);
CF2 = conversion factor (2.2x10^{-6} lb/mg); and
V_{room} = volume of room (m^3).

If the POD is based on the RfC methodology, then the calculated air concentration can be compared directly to the reference concentration. However, if the POD is a No-Observed-Adverse-Effect-Level (NOAEL) or Lowest-Observed-Adverse-Effect-Level (LOAEL), inhalation potential doses must be calculated in order to compare to the appropriate POD.

The Instantaneous Release Box Model for aerosols can be used to calculate exposure for this type of application scenario. The basis for this scenario is that post-application inhalation exposure occurs from the airborne aerosols released after an aerosol application. The well-mixed box (WMB) model was used to develop the exposure equation for the instantaneous release/aerosol post-application inhalation scenario.

The WMB model incorporates a number of simplifying assumptions:

(1) fresh air (having no pesticide concentration) enters the box at a constant airflow rate (based on the number of air changes per hour),
(2) a turbulent internal airflow thoroughly mixes the fresh air with the pesticide-laden air resulting in a uniform pesticide air concentration within the box, and
(3) the perfectly mixed air exits the box at the same constant airflow rate (i.e., the inflow rate equals the outflow rate).

Thus, the indoor area where the aerosol is being applied is assumed to be in an enclosed box, which is a reasonable assumption for a walled, indoor space. This scenario assumes instantaneous spray release (i.e., the total amount of aerosol released is modeled to occur instantaneously).

The evacuation of the aerosol from the box depends on airflow. For an indoor scenario, the airflow is the product of the volume of the treated space and the number of air changes per hour, ACH. The WMB model developed for this scenario models the pesticide air concentrations *after* an instantaneous aerosol spray release. **It should be noted that this calculation does not take into account the settling of aerosol droplets. Only dissipation due to airflow into and out of the box is modeled.**

Post-application inhalation exposure for adults/children resulting from space sprays (e.g., flying insect killers) can be calculated using the following equation (See *Section D.3.5* of *Appendix D* for equation description and derivation):

$$E = \frac{C_O * IR}{ACH} * \left[1 - e^{(-ACH*ET)}\right] \qquad (7.5)$$

where:

E	= exposure (mg/day);
C_o	= initial concentration (mg/m^3);
IR	= inhalation rate (m^3/hr);
ACH	= air changes per hour (hour^{-1}); and
ET	= exposure time (hr/day).

Absorbed inhalation dose normalized to body weight is calculated as:

$$D = \frac{E * AF}{BW} \qquad (7.6)$$

where:

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

(2) Exposure to pesticide vapors

The basis for this scenario is that post-application inhalation exposure occurs from the emission of pesticide vapors from a treated surface. The well-mixed box (WMB) model was used to develop the exposure equation for assessing post-application inhalation exposure from vapor emissions. The WMB model was used to model pesticide air concentrations within an enclosed, fixed volume (i.e., a box) over time during the variable emission of a pesticide from a treated surface.

The model incorporates a number of simplifying assumptions:

(1) fresh air (having no pesticide concentration) enters the box at a constant airflow rate (based on the number of air changes per hour),
(2) a turbulent internal airflow thoroughly mixes the fresh air with the pesticide-laden air resulting in a uniform pesticide air concentration within the box, and
(3) the perfectly mixed air exits the box at the same constant airflow rate (i.e., the inflow rate equals the outflow rate).

Thus, the indoor area where the pesticide is being applied is assumed to be in an enclosed box, which is a reasonable assumption for a walled, indoor space. The removal of the pesticide from the box depends on airflow. For an indoor scenario, the airflow is the product of the volume of the treated space and the number of air changes per hour, ACH. The WMB model developed for this scenario models the pesticide air concentrations *after* a surface-directed spray application or after residues have settled onto the floor surface from a fogger or space spray application. Only dissipation due to airflow into and out of the box is modeled.

Post-application inhalation exposure to vapors for adults/children resulting from indoor spray applications can be calculated using the following equation (See *Section D.3.6* of *Appendix D* for equation description and derivation):

$$E = \frac{IR * M_{label}}{ACH * V_{room}} * \left[1 - \left(\frac{\left(ACH * e^{-k*ET}\right) - \left(k * e^{-ACH*ET}\right)}{ACH - k}\right)\right] \qquad (7.7)$$

where:

E = exposure (mg/day);
IR = inhalation rate (m^3/hr);
M_{label} = mass of active ingredient applied, determined from product label (mg);
V_{room} = volume of room (m^3);
ACH = air exchanges per hour (1/hr);
k = first order decay rate (1/hr); and
ET = exposure time (hr).

In the above equation, a mass of pesticide is applied to a surface and the emission of the pesticide from the surface is assumed to decline over time due to dissipation of the pesticide (i.e., emission from the treated surface and removal due to the air exchange rate). The mass of active ingredient applied can be calculated using the following formula:

$$M_{label} = AR * A * CF1 \quad (7.8)$$

where:

M_{label} = mass of active ingredient applied, determined from product label (mg);
AR = application rate (e.g., lb ai/ft^2, lb ai/gal);
A = area treated or amount handled (e.g., ft^2/day, gal/day); and
CF1 = conversion factor ($4.54x10^5$ mg/lb).

The exposure equation models an emission rate that decreases over time, which is based on a first-order decay rate constant (k). Evans (1994) proposed calculating such a decay rate based on work done by Chinn (1981). Chinn developed the following relationship between the volatility, or saturation concentration (C_{sat}), of a chemical and the time required for 90% of the chemical to evaporate (EvapT):

$$EvapT = 10^{[7.3698 - 0.9546 * \log_{10}(C_{sat})]} \quad (7.9)$$

where:

EvapT = evaporation time (sec); and
C_{sat} = saturation concentration (mg/m^3).

Evans proposed the following equation to calculate the decay rate (or dissipation rate) that defines the change in the emission rate based on the evaporation time described by Chinn:

$$E = \left[\frac{\ln(10) * CF1}{EvapT} \right] \quad (7.10)$$

where:

k = first order decay rate (1/hr),
CF1 = conversion factor (sec/hr), and
EvapT = evaporation time (sec).

*****Saturation concentration verification*****

In the vapor emission assessment, post-application inhalation exposure occurs from the release of vapors following a surface treatment indoors. The concentration of pesticide in the air is modeled over time to calculate exposure. **The maximum concentration allowed in the air should be the saturation concentration, calculated as a function of the pesticide's molecular weight and vapor pressure. The equation used to model the air concentration is not bound by the saturation concentration; therefore, the reviewer must perform a check to make sure the exposures being calculated are valid.**

The exposure equation above is based on the mass of pesticide applied, not the concentration of the pesticide in the air; therefore, the reviewer must check that the input for mass applied (M_{label}) is predicting an air concentration less than or equal to the saturation concentration. The following equation can be used to calculate the theoretical mass applied that would result in an air concentration that reaches the saturation concentration for a pesticide (M_{Csat}):

$$M_{Csat} = \frac{C_{sat} * (ACH - k) * V}{k} \quad (7.11)$$

M_{Csat} should be compared to M_{label}.

- If $M_{label} > M_{Csat}$ → M_{label} <u>will</u> predict an air concentration higher than the saturation concentration. Use M_{Csat} in the exposure calculation.

- If $M_{label} < M_{Csat}$, → M_{label} <u>will not</u> predict an air concentration higher than the saturation concentration. Use M_{label} in the exposure calculation.

Once the post-application inhalation exposure is calculated, the inhalation dose normalized to body weight is calculated as:

$$D = \frac{E * AF}{BW} \quad (7.12)$$

where:

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

If not enough information is available to assess post-application inhalation exposure to pesticide vapors from indoor sprays using the approach described above, a screening level assessment can be performed using the saturation concentration (See Section D.3.7 of *Appendix D*).

7.2.1.3 Termiticide Applications (Foundation and Soil Injection)

The basis for this scenario is that post-application inhalation exposure occurs while occupying living spaces within a residence during and after a termiticide treatment. This scenario is specific to foundation and soil injection termiticide treatments as it assumes that only a percentage of the pesticide applied penetrates into a home and is available for inhalation exposure. The scenario is considered a long-term scenario. When possible, chemical-specific air monitoring data should be used to calculate an air concentration; however, if data are not available, MCCEM can be used.

Inputs for MCCEM for calculating air concentrations following termiticide applications are as follows:

House: Select House Code "GN001" which represents a house with two zones (the bedroom and the rest of the house), and an air exchange rate of 0.18/hr to represent summer conditions.

Run Time: Input the length of the model run as 364 days to represent a long-term exposure duration and reporting interval of 1 day steps.

Emissions: The type of emission representative of termiticides is the Chinn-type or long-term emission (e.g., a termiticide treatment is completed, and the pesticide off-gasses from the treated surfaces for several weeks). As described above for surface-directed sprays, the off-gassing emission rate is calculated based on an empirical relationship between evaporation time, vapor pressure, and molecular weight (Chinn, 1981). An additional assumption for foundation/soil injection termiticides is that only 5% of the applied chemical penetrates the home and is available for post-application inhalation exposure. The equations necessary to calculate an emission rate for the model are presented below.

Calculation of Emission Rate for Termiticides

1. Calculate the mass of active ingredient applied in grams during a single application event.

2. Calculate the mass of chemical that penetrates the home (m).
   - Assume 5% penetration into home from treatment area. This is based on the experience and professional judgment of the OPP staff based on the review of company-submitted data.

3. Calculate the Chinn evaporation time using the following formula based on the relationship between a chemical's molecular weight and vapor pressure and the time for evaporation (Chinn, 1981):

$$CET = \frac{145}{(MW * VP)^{0.9546}} \tag{7.13}$$

where:

CET = Chinn evaporation time (hr);
MW = molecular weight of pesticide active ingredient (g/mol); and
VP = vapor pressure (mmHg).

4. Calculate the emission rate (g/hr) using the following formula:

$$ER = \frac{M}{CET} \tag{7.14}$$

where:

ER = emission rate (g/hr);
M = mass of chemical that penetrates house; and
CET = Chinn evaporation time (hr).

Example:

Application rate = 5 lb ai/gal
Vapor pressure of $5x10^{-3}$ mmHg
Molecular weight of 500 g/mol

Amount applied = 5 lb ai/gal * 100 gal/day = 500 lb ai/day * 454 g/lb = 227,000 g ai/day
Amount penetrates home = 227,000 g * 0.05 = 11,350 g

CET = $145/((500 * (5x10^{-3}))^{0.9546})$ = 60.5 hours

and

ER = 11,350/60.5 = 188 grams/hour

This emission rate should be input into the model as a constant rate with an end time of 364 days.

Sinks/Activities/Dose/Monte Carlo: Not used for high-end assessments.

Options: Choose to run a single-chamber model. Other options should stay as defaults.

After all of the inputs have been entered into the model, the assessor should run the model and save the output files for review purposes. The concentration applicable to long-term termiticide applications is the average daily concentration (ADC). This value should be used in the dose equation below.

Post-application inhalation dose normalized to body weight is calculated as:

$$D = \frac{ADC * IR * ET * AF}{BW} \quad (7.15)$$

where:

D = dose (mg/kg-day);
ADC = average daily concentration (mg/m^3);
IR = inhalation rate (m^3/hr);
ET = exposure time (hr);
AF = absorption factor (inhalation); and
BW = body weight (kg).

Post-application Inhalation Exposure Algorithm Inputs and Assumptions

Recommended values for post-application inhalation exposure assessments are provided in *Table 7-3* below. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions, ii) data sources used to derive recommended input values, and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 7-3: Indoor Environments – Recommended Post-application Inhalation Exposure Factor Point Estimates			
Algorithm Notation	**Exposure Factor (units)**		**Point Estimate(s)**
Generic Variables Used in Calculating Post-application Inhalation Exposure			
IR	Inhalation rate (m^3/hour)	Adult	0.64
		Children 1 < 2 years old	0.33
ACH	Air changes per hour (hr^{-1})		0.45
BW	Body weight (kg)	Adult	80
		Children 1 < 2 years old	11
V_{room}	Volume of room (m^3)		33
Variables Specific to Post-application Inhalation Exposure to Pesticide Aerosols			
C_o	Initial air concentration (mg/m^3)		Calculated; concentration at time "0"
AR	Application rate (lb ai/ ft^3)		Product-specific
A.I.	Percent ai in product (%)		Product-specific
$V_{product}$	Volume of product (mL)		Product-specific
$D_{product}$	Product density (g/mL)	Water-based products	1
		Solvent-based products	0.8
ET	Exposure time (hr/day)		2
Variables Specific to Post-application Inhalation Exposure to Pesticide Vapors			
C_{sat}	Saturation concentration (mg/m^3)		Calculated
VP	Vapor pressure (mmHg)		Chemical-specific
MW	Molecular weight (g/mol)		Chemical-specific
R	Gas constant (L-atm/mol-K)		0.0821
T	Temperature of the air (kelvin, K)		298
M_{label}	Mass of active ingredient applied (mg)		Product-specific
k	First order decay rate		Calculated
ET	Exposure time (hr/day)	Adult	16
		Children 1 < 2 years old	18

The following provides a general discussion for each post-application inhalation exposure factor and derivation of recommended distributions and point estimates for use in exposure assessment. Note that recommended body weight and inhalation rate distributions are included under *Sections 2.1* and *2.2*, respectively, since they are not specific to any particular exposure scenarios.

Inhalation Rate (IR)

See *Section 2.2* for discussion of inhalation rates. **The recommended point estimates for use in post-application inhalation exposure assessments are 0.64 m^3/hr for adults and 0.33 m^3/hr for children 1 < 2 years old**.

Air Changes per Hour (ACH)

Air changes per hour is the rate that air within an indoor environment is replaced by outdoor air. An empirical distribution for typical house air changes per hour from the Exposure Factors Handbook 2011 Edition (U.S. EPA, 2011; Table 19-24) should be used for post-application inhalation assessment. The distribution is provided in *Table 7-4.* These values are representative of all seasons and all regions. **The recommended point estimate for use in post-application inhalation exposure assessments is 0.45 ACH.**

Table 7-4: Air Changes per Hour (ACH)

Statistic	ACH (1/hour)
10^{th} percentile	0.18
50^{th} percentile	0.45
90^{th} percentile	1.26
AM (SD)	0.63 (0.65)
GM (SD)	0.46 (2.25)

AM (SD) = arithmetic mean (standard deviation)
GM (SD) = geometric mean (geometric standard deviation)

Volume of a Room (V_{room})

The volume of a room is based on typical dimensions of residential rooms from Exposure Factors Handbook 2011 Edition (U.S. EPA, 2011; Table 19-11). For a 12 foot by 12 foot room, with an 8 foot high ceiling, the **typical volume is 33 m^3**.

Saturation Concentration (C_{sat})

The saturation concentration is a chemical's theoretical maximum air concentration. It represents what would occur if a large amount of chemical were spilled in a non-ventilated room and allowed to evaporate until equilibrium is reached. Calculating post-application inhalation exposure and risk using the saturation concentration should be considered a health protective approach.

Vapor Pressure (VP)

The vapor pressure is a chemical-specific value in units of mmHg.

Molecular weight (MW)

The molecular weight is a chemical-specific value in units of g/mol.

Gas constant (R)

A constant with units of L-atm/mol-K.

Temperature (T)

The temperature of the air in units of Kelvin (K).

Mass of active ingredient applied (M_{label})

The mass of active ingredient applied can be determined from the application rate and the amount handled or area treated assumed for a residential handler (e.g., lb ai/gallon * gallons = lb applied).

First Order Decay Rate (k)

The decay rate, k, defines the change in the emission rate from the treated surface. As proposed by Evans (1994), the **decay rate constant is based on the 90% drying time**. The 90% drying time, in turn, is calculated based on the evaporation time and volatility of the chemical using equations from Chinn (1981) [13].

Exposure Time (ET)

For space sprays (e.g., flying insect killers), it is assumed that after application, the aerosol droplets will settle out of the air and will be dispersed due to air exchange within the house; therefore, based on information regarding particle size and settling time, a **point estimate of 2 hours is used in the SOP**.

For vapor emissions from indoor applications and termiticides, it is assumed that the vapors can continue to emit over time; therefore, exposure time is related to time spent in a residence. Empirical distributions for adults and children are provided in the Exposure Factors Handbook 2011 Edition (U.S. EPA, 2011; Adults -- Tables 16-16 and 16-26; Children – Tables 16-15 and 16-25). The distribution for exposure time for adults and for children 1 < 2 years old is provided in *Table 7-5*. **The recommended point estimates for use in post-application inhalation exposure assessments are 16 hours for adults and 18 hours for children 1 < 2 years old**.

Table 7-5: Exposure Time (ET, hours)

Statistic	Adults	1 to <2 years
5th percentile	9	11
25th percentile	13	15
50th percentile	15	18
75th percentile	19	21
90th percentile	23	24
95th percentile	24	24
AM (SD)	16 (5)	18 (SD not listed)

AM (SD) = arithmetic mean (standard deviation)

[13] Based on information in Guo (2002; Part 2), one method to estimate first order decay rate constants was proposed by Evans (1994). Evans proposed estimating the decay rate constant (k) for solvent emissions (i.e., total volatile organic compounds) from coating materials (i.e., solvent based paint) based on the 90% drying time of the solvent ($t_{0.9}$). This relationship is represented by the following equation: $k = (\ln 10) / t_{0.9}$. The 90% drying time of a chemical can be calculated based on the volatility (or saturation concentration) of a chemical using the following equation: $\log_{10} t_{0.9} = 7.3698 - 0.9546 \log_{10} C_v$. This relationship was determined by Chinn (1981) by measuring the time for 90% evaporation of a number of chemicals and graphing that against the volatility of those chemicals.

Air Concentration (C_o)

The initial concentration is based upon instantaneous release of diluted product and complete mixing into an enclosed space.

Application Rate (AR)

The application rate is the amount of spray applied. The application rate can be determined from product specific factors that are listed on the label.

Percent A.I. in product (A.I.)

The percent of active ingredient (ai) in the product is a product-specific value and should be stated on the label.

Volume of product ($V_{product}$)

The volume of product (mL/can) is a product-specific value and should be stated on the label.

Product Density ($D_{product}$)

The density should represent the product being assessed. If the product is water-based, the assessor should use the density of water (1.0 g/mL). If the product is solvent-based, the assessor should use 0.8 g/mL, an average based on an informal survey of various organic solvents described in CRC (Lide, 1981).

Future Research/Data Needs

Information that would refine post-application inhalation exposure assessments for indoor pesticide applications include:

- Air concentration data collected after space spray and surface-directed applications, both immediately after and over time. Measurements should include differentiation between aerosols, vapors and dusts/resuspension.
- For surface-directed spray applications, air concentration data for various types of application methods, including broadcast, perimeter and crack and crevice.
- More information on fogger particle sizes and settling time.
- Resuspension of pesticide particles after initial application and potential for inhalation exposure.
- More information on the percent of the applied chemical that penetrates a house following a termiticide application.

Exposure Characterization and Data Quality

Air concentration

- The indoor post-application inhalation SOP makes the health protective assumption that all of the applied pesticide is in the air available for inhalation exposure, and then that all of the applied pesticide settles onto the floor and is available for dermal exposure. In addition, dissipation of pesticides indoors is not taken into account for post-application inhalation exposure.
- The well-mixed box model for the instantaneous release/aerosol scenario does not take

into account the settling of aerosol droplets. Only dissipation due to airflow into and out of the box is modeled. In addition, sinks and resuspension activities are not accounted for in the WMB model calculations.

Vapor emission decay rate constant

- The vapor emission from surface sprays model includes an input for a decay rate constant, k, based on work by Chinn (1981) examining the relationship between the volatility, or saturation concentration, of a chemical and the time required for 90% of the chemical to evaporate. Chinn's experiments represent evaporation from a glass plate of pure substances under conditions of mechanical ventilation. Substances in mixtures may behave differently. In addition, the indoor environment features numerous surfaces to which pesticides can partition, possibly leading to slower evaporation. Despite these limitations, the data are considered useful for estimation of decay rate because all of the required inputs are easily obtainable (e.g., molecular weight, vapor pressure and temperature).

7.2.2 Post-application Dermal Exposure Assessment

Post-application dermal exposure can result from pesticide residue transfer to the skin of individuals who contact previously treated indoor surfaces (e.g., carpets, floors, furniture, mattresses and other surfaces) during activities such as recreation, housework or other occupant activities. While exposure may occur for people of all ages, adults and children 1 < 2 years old have been chosen as the index lifestages to assess based on behavioral characteristics and the strengths and limitations of the available data. The indoor post-application dermal SOP is divided into 2 sections: dermal exposure resulting from application to hard surfaces and carpets (*Section 7.2.2.1*) and dermal exposure resulting from application to mattresses (e.g., bedbug treatment) (*Section 7.2.2.2*).

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

Post-application dermal exposure is expected to result from contact with treated indoor surfaces, which, for the purposes of this SOP, are separated into two categories: hard surfaces (e.g., floors) and carpets. Post-application dermal exposure resulting from contact with treated indoor surfaces is dependent on three exposure factors: transferable residue (TR), transfer coefficient (TC), and exposure time (ET). The algorithm to calculate exposure is as follows:

$$E = TR * CF1 * TC * ET \qquad (7.16)$$

where:

E = exposure (mg/day);
TR = indoor surface transferable residue (μg/cm^2);
TC = transfer coefficient (cm^2/hr);

ET = exposure time (hr/day); and
CF1 = conversion factor (0.001 mg/µg).

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:

$$TR = DepR * F_{ai} \quad (7.17)$$

where:

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

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

$$D = \frac{E * AF}{BW} \quad (7.18)$$

where:

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

Post-application dermal exposure following applications indoors is generally considered short-term in duration, but is dependent on the use pattern of the specific product being assessed and the dissipation/degradation properties of the active ingredient. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4*, such as residue dissipation, product-specific re-treatment intervals, and activity patterns. If longer-term assessments (i.e., intermediate-, long-term, or lifetime exposures) are deemed necessary, similar refinements to more accurately reflect the exposure profile are recommended.

Post-application Dermal Exposure Algorithm Inputs and Assumptions (hard surfaces and carpets)

Recommended values for post-application dermal exposure assessments for hard surfaces (e.g., floors) and carpets are provided in *Table 7-6* below. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 7-6: Indoor Environments (Hard Surfaces and Carpets) – Recommended Dermal Exposure Factor Point Estimates				
Algorithm Notation	**Exposure Factor (units)**			**Point Estimate(s)**
TR	Transferable residue ($\mu g/cm^2$)			(1) Chemical-specific transferable residue data OR (2) Estimated: DepR * F_{ai}
DepR	Deposited residue ($\mu g/cm^2$)			(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_{ai}	Fraction of DepR as TR following application	Carpets		0.06[a]
		Hard surfaces		0.08[a]
TC	Transfer Coefficient (cm^2/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

a. These values are screening level point estimates to be used when chemical-specific data are not available. Data are available for certain chemicals; see text and associated tables for chemical-specific data for pyrethrin, permethrin, PBO, chlorpyrifos, and deltamethrin.

Transferable Residue (TR)

Following an application, pesticide residue, which remains on indoor surfaces, can be contacted by an individual and removed. The residue available for transfer is referred to as transferable residue (TR) and is assumed to be the most significant source for dermal exposure in this scenario. If chemical-specific transferable residue data are available for a specific chemical, this is preferred and should be used for the estimation of exposure. The assessor should take into consideration the application rate used in the chemical-specific study and how it compares to the application rate of the proposed use; adjustments should be made, if necessary. If data are not available, the TR can be calculated as a fraction (F_{ai}) of the deposited residue (DepR).

Deposited Residue (DepR)

The deposited residue is the residue that is deposited onto indoor surfaces following an application. It can be based on (1) chemical-specific deposition data (i.e., actual measured residue data), (2) the application rate of the product (e.g., assume that everything that is applied is deposited onto the indoor surface), or (3) default values based on the type of application (e.g., broadcast, crack and crevice, etc). These options should be prioritized as follows, based on the data available for a particular chemical:

1. Chemical-specific deposition data are preferred, if available.
2. If chemical-specific deposition data are not available, then the deposited residue should be estimated based on the label-specified application rate.

3. If neither chemical-specific data nor an application rate is available, default deposited residues should be used based on the type of application.

Figure 7-1 provides a summary of these three options and also shows the approaches for the different types of application methods [e.g., broadcast, perimeter/spot/bedbug (coarse application), perimeter/spot/bedbug (pinstream application), and crack and crevice], which are discussed in more detail below.

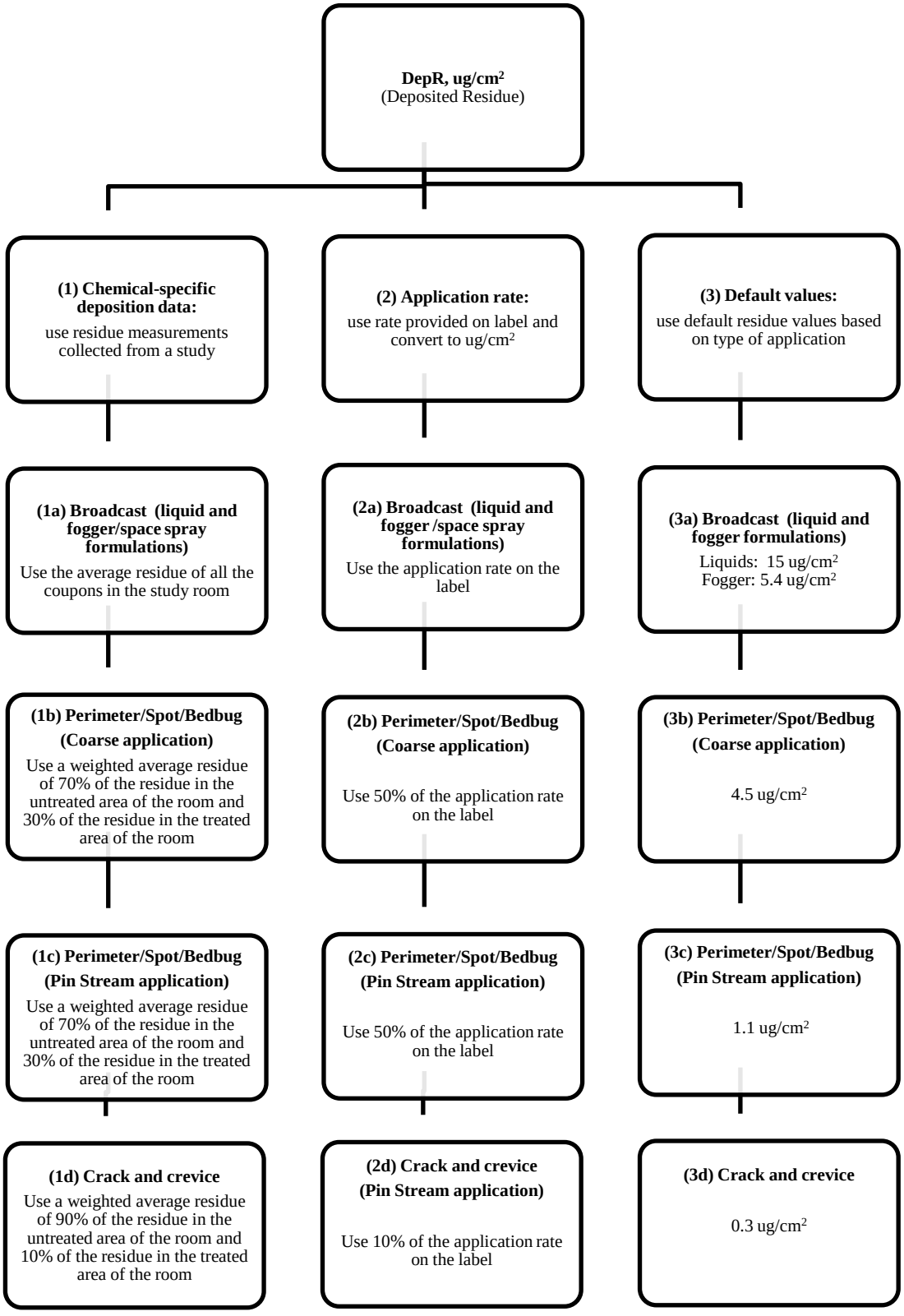


Figure 7-1: Summary of approaches for calculating the deposited residue for use in the dermal post-application exposure calculation.

Approach 1 for calculating deposited residue:

(1) Chemical-specific deposition data -- use residue measurements collected from a study.

For some chemicals, a study may be available in which the pesticide was applied to a room and residue data were collected from the floor using deposition coupons. It should be noted that in October of 2007, the Agency revised the data requirements that pertain to conventional pesticides. As part of these revisions, indoor surface residue studies were classified as required under 40 CFR 158, subpart K (158.1070; post-application exposure data requirements table).

Deposition studies provide not only the magnitude of the deposited residue in a room, but also the distribution of residue in a room. The distribution of residue in a room will differ depending on the type of application made (i.e., broadcast, perimeter, or crack and crevice). For example, it is expected that residues will be evenly distributed throughout a room after a broadcast application, whereas after a perimeter application, residues will be higher near the outer edges of a room than in the center of a room. Both the magnitude and distribution of residues in a room will impact a person's exposure.

An indoor deposition study should collect residue data after an application for a particular pesticide is made. As with chemical-specific transferable residue data, the assessor should take into consideration the application rate used in the chemical-specific study and how it compares to the application rate of the proposed use; adjustments should be made, if necessary. The assessor should also take into consideration the application method used in the study and make sure that it is representative of the proposed use being assessed.

Once the data are analyzed, the following deposited residue values should be calculated using the available data. A discussion of these values is provided below.

(1a) Broadcast (liquid and fogger formulations): Use the average residue of all the coupons in the study room.

DepR = Average of residues measured on all coupons in room

(1b) Perimeter/Spot/Bedbug (Coarse application): Use a weighted average residue of 70% of the residue in the untreated area of the room and 30% of the residue in the treated area of the room.

DepR = (70% * average residue untreated area) + (30% * average residue treated area)

(1c) Perimeter/Spot/Bedbug (Pin Stream application): Use a weighted average residue of 70% of the residue in the untreated area of the room and 30% of the residue in the treated area of the room.

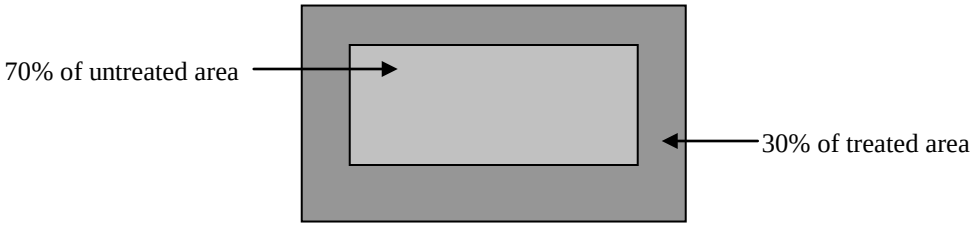
DepR = (70% * average residue untreated area) + (30% * average residue treated area)

(1d) Crack and crevice: Use a weighted average residue of 90% of the residue in the untreated area of the room and 10% of the residue in the treated area of the room.

DepR = (90% * average residue untreated area) + (10% * average residue treated area)

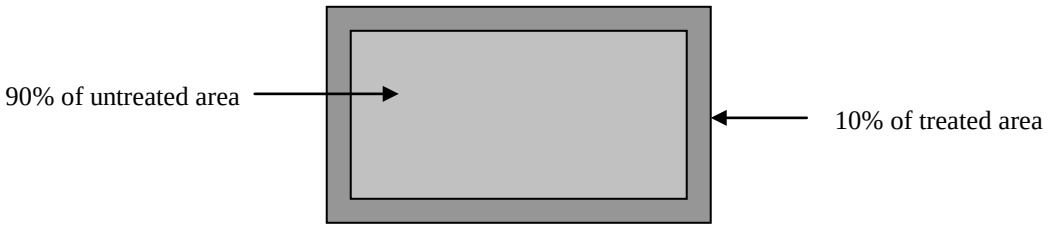
After a broadcast application, the residues in a room should be evenly distributed throughout the room. Therefore, the deposited residue value for use in the exposure assessment should be calculated as the average residue for the entire treated area. Perimeter and crack and crevice applications typically focus on the outer edges of rooms (e.g., along baseboards) and, therefore, result in a distribution of residues with higher levels along the outer edges of a room ("treated area") compared to the center of a room ("untreated area") (Selim, 2008 and U.S. EPA, 1993). It is assumed that a person spends more time in the center of a room than along the outer edges and, thus, is exposed less often to higher levels of residues in the treated area compared to lower levels of residues in the untreated area. An assumption as to how much time a person would come in contact with treated versus untreated areas of the room is used to adjust the estimate of deposited residue. Based on this assumption, a weighted residue value is calculated.

For perimeter/spot/bedbug (coarse and pin stream) applications, it is assumed that a person would come in contact with treated areas 30% of the time and untreated areas 70% of the time (see diagram below). This is based on preliminary information for surface contact probabilities (Brinkman et al., 1999; SHEDS-Multimedia). The average deposited residue for the treated area and untreated area should be calculated separately. Then, the deposited residue for the whole room should be calculated as the sum of 70% of the average deposited residue for the untreated area of the room and 30% of the average deposited residue for the treated area of the room (see equation below).



DepR = (70% * average residue untreated area) + (30% * average residue treated area)

For crack and crevice applications, a similar approach is taken; however, it is assumed that a person would come in contact with treated areas 10% of the time and untreated areas 90% of the time (see diagram below). Again, this is based on preliminary information for surface contact probabilities (Brinkman et al., 1999; SHEDS-Multimedia). The average deposited residue for the treated area and untreated area should be calculated separately. Then, the deposited residue for the whole room should be calculated as the sum of 90% of the average deposited residue for the untreated area of the room and 10% of the average deposited residue for the treated area of the room (see equation below).



DepR = (90% * average residue untreated area) + (10% * average residue treated area)

Approach 2 for calculating deposited residue:

(2) Application Rate -- use rate provided on label and convert to $\mu g/cm^2$.

When the application rate is in terms of mass active ingredient per area (e.g., lb ai/ft^2), the deposited residue can be estimated using the application rate (assuming everything that is applied is deposited onto the floor of the room). A unit conversion can be performed in order to obtain a residue value in terms of $\mu g/cm^2$.

If the label provides an application rate, the recommended deposited residue values are provided below.

(2a) Broadcast (liquid and fogger formulations): Use the application rate on the label.

DepR = Application rate ($\mu g/cm^2$)

(2b) Perimeter/Spot/Bedbug (Coarse application): Use 50% of the application rate on the label.

DepR = 50% * Broadcast-equivalent Application rate

(2c) Perimeter/Spot/Bedbug (Pin Stream application): Use 50% of the application rate on the label.

DepR = 50% * Broadcast-equivalent Application rate

(2d) Crack and crevice: Use 10% of the application rate on the label.

DepR = 10% * Broadcast-equivalent Application rate

It is assumed that broadcast applications (liquid and fogger formulations) evenly distribute the pesticide across the floor of a room; therefore, the deposited residue for the whole room is assumed to be equivalent to the application rate. For fogger formulations, the application rate is not always provided in terms of mass active ingredient per area, but can be calculated from the amount of active ingredient (ai) in the fogger, the volume that the fogger is intended to treat and an assumed ceiling height of 8 feet. If, for example, a six ounce fogger containing 1% ai is used in a 33 cubic meter (1165 cubic foot) room with an eight foot ceiling, the surface residue would be calculated as follows:

Step 1 – Calculate amount of ai applied in μg.

ai applied (μg) = (fogger weight (ounces) * (percent ai/100) * 454,000,000 μg/lb) / 16 ounces/lb = 1,700,000 μg

Step 2 – Calculate Area Treated in cm^2.

Area Treated (cm^2) = 1165 ft^3/8 ft ceiling = 146 ft^2 * 929 cm^2/ft^2 = 135,000 cm^2

Step 3 – Calculate $\mu g/cm^2$.

1,700,000 μg/135,000 cm^2 = 12.6 $\mu g/cm^2$

For perimeter/spot/bedbug (coarse and pinstream) and crack and crevice applications, it is assumed that the pesticide product will not be evenly distributed across the room, but will be directed towards the outer edges of the room. As noted above, for these types of applications, both the magnitude and distribution of residues in a room impact a person's exposure. If it is assumed that broadcast applications result in an average deposited residue for a room that is equivalent to the application rate, then for perimeter/spot/bedbug (coarse and pinstream) and crack and crevice applications, the average deposited residue for a room is expected to be a percentage of the application rate. These percentages were estimated using available residue deposition data from Agency submitted studies and literature studies. For more information on the calculations and further analysis, refer to Section D.5 of *Appendix D*.

For perimeter/spot/bedbug (coarse and pinstream) applications, it is assumed that the deposited residue is equivalent to 50% of the application rate (Selim, 2008, U.S. EPA, 1993). For more information and further analysis, refer to Section D.5 of *Appendix D*.

For crack and crevice applications, it is assumed that the deposited residue is equivalent to 10% of the application rate (Selim, 2008). For more information and further analysis, refer to Section D.5 of *Appendix D*.

Approach 3 for calculating deposited residue:
(3) Default values: use default residue values based on type of application.

If chemical-specific deposition data are not available and no application rate is provided on the product label, then default deposited residue values should be used based on the type of application to be made. The default values provided below are based on an analysis of available residue deposition data from Agency submitted studies and literature studies.

A summary of the recommended values for default residues for broadcast, perimeter and crack and crevice applications is provided in *Table 7-7* and a discussion of these values is provided below.

Table 7-7: Recommended Default Residue Concentrations Based on Type of Application

Type of Application		Percent Spray	Residue concentration ($\mu g/cm^2$)
Broadcast[a]	Liquids	0.5%	15
	Foggers		5.4
Perimeter/Spot/Bedbug (Coarse application)[b]		N/A	4.5

Table 7-7: Recommended Default Residue Concentrations Based on Type of Application		
Type of Application	**Percent Spray**	**Residue concentration ($\mu g/cm^2$)**
Perimeter/Spot/Bedbug (Pin stream application)[b]		1.1
Crack and Crevice[b]		0.3
a. Residue concentration should be proportionately adjusted according to the percent spray of product b. No adjustment of default residue concentration should be made.		

For broadcast applications, residue values appear to be influenced by the percent spray applied (i.e., the higher the percent spray, the higher the residue values). From the available studies where liquid formulations were applied, it was found that for a 0.1% spray, the deposited residue was 2.9 $\mu g/cm^2$, and the range for total deposited residue for 0.5% sprays was approximately 7 to 15 $\mu g/cm^2$. A value of 15 $\mu g/cm^2$ was chosen as a default deposition value for liquid formulation broadcast applications based on the available data. *This value can be proportionately adjusted depending on the percent spray indicated on a particular label.*

For foggers, three studies were available from the Non-Dietary Exposure Task Force: one each for pyrethrin, permethrin and deltamethrin. The deposited residues from those studies were adjusted to a 0.5% spray and averaged to come up with a default value of 5.4 $\mu g/cm^2$. *This value can be proportionately adjusted depending on the percent spray indicated on a particular label.*

Example calculations for adjusting residue value:

Product for specific chemical: 0.25% spray

(0.5% spray ÷ 15 $\mu g/cm^2$) = (0.25% spray ÷ X $\mu g/cm^2$)

X $\mu g/cm^2$ = (15 $\mu g/cm^2$ * 0.25% spray) / 0.5% spray

X $\mu g/cm^2$ = 7.5 $\mu g/cm^2$

For perimeter/spot/bedbug (coarse and pinstream) and crack and crevice applications, the available data did not seem to indicate a trend with percent spray (i.e., a higher percent spray did not necessarily result in a higher residue value for a room). Therefore, for these application methods, a weighted average was calculated for each study and an average residue value based on all the available studies was used as the default for each particular application method. These values should be used as is and should not be adjusted for percent spray. For perimeter/spot/bedbug (coarse) applications, the average residue value from all the studies was 4.5 $\mu g/cm^2$. For perimeter/spot/bedbug (pinstream) applications, the average residue value was 1.1 $\mu g/cm^2$. For crack and crevice applications, the average residue value was 0.3 $\mu g/cm^2$.

For more information and further analysis of the default deposition values, refer to *Section D.5 of Appendix D*.

Fraction of Residue Available For Transfer (F_{ai})

Once the deposited residue is determined for an indoor scenario, the TR can be estimated as a fraction (F_{ai}) of that residue. If chemical-specific fraction transferred data are available, these should be used. This SOP provides information on chemical-specific data that was available for five chemicals, as well as a screening level point estimate to be used in the absence of chemical-

specific data. Fraction transferred values are provided for both carpets and hard surfaces since the type of surface can influence the fraction of deposited residue that can be transferred.

The values for fraction of residue transferred from carpets and hard surfaces are based on information provided from two sources, which examine transferability of a variety of chemicals from both surfaces.

1) Beamer *et. al* (2009): performed an extensive analysis of numerous transfer efficiency studies which covered various methods (including the cloth roller, drag sled, PUF roller, and bare hand press), surfaces (hard surfaces/sheet vinyl and carpets) and various chemicals (chlorpyrifos, pyrethrin and piperonyl butoxide (PBO)).
   Sources included: Camann, 1996; Fortune, 1997; Krieger, 2000; Ross, 1991; Clothier, 2000.
2) Non-Dietary Exposure Task Force (NDETF): examined transferability for bare hand-presses on carpets and vinyl/hard surfaces for deltamethrin, permethrin, PBO and pyrethrin.

Complete datasets (using data from all available sources) were compiled for five chemicals: pyrethrin, permethrin, piperonyl butoxide (PBO), chlorpyrifos and deltamethrin. These datasets were analyzed and the results are provided in *Table 7-8 and Table 7-9*, for carpets and hard surfaces, respectively. **For the chemicals in *Table 7-8* and *Table 7-9*, that have chemical-specific data available, the arithmetic means should be used in post-application dermal exposure assessments.**

For chemicals not included in those tables, chemical-specific data are preferred, but if not available, a screening level value is recommended based on the available data. **For chemicals that do not have chemical-specific data available, the recommended screening level point estimates for use in post-application dermal exposure assessments are 0.06 for carpets and 0.08 for hard surfaces.**

For further information on the fraction transferred factor, see *Section D.6* of *Appendix D*.

Table 7-8: Chemical-specific Fraction transferred (F_{ai}) for Carpets

Statistic	Pyrethrin	Permethrin	PBO	Chlorpyrifos	Deltamethrin
50th percentile	0.02	0.02	0.02	0.01	0.01
75th percentile	0.04	0.02	0.03	0.02	0.02
90th percentile	0.05	0.03	0.04	0.03	0.02
95th percentile	0.07	0.03	0.05	0.03	0.03
99th percentile	0.11	0.04	0.07	0.05	0.04
99.9th percentile	0.19	0.05	0.10	0.08	0.05
AM (SD)	0.03 (0.12)	0.02 (0.06)	0.02 (0.08)	0.02 (0.06)	0.01 (0.05)
GM (GSD)	0.02 (2.00)	0.02 (1.38)	0.02 (1.70)	0.01 (1.72)	0.01 (1.56)
Range	0.002 - 0.086	0.010 - 0.032	0.007 - 0.065	0.003 - 0.045	0.005 - 0.020
N	91	14	105	155	10

AM (SD) = arithmetic mean (standard deviation)
GM (GSD) = geometric mean (geometric standard deviation)

Table 7-9: Chemical-specific Fraction transferred (Fai) for Hard Surfaces					
Statistic	Pyrethrin	Permethrin	PBO	Chlorpyrifos	Deltamethrin
50th percentile	0.04	0.02	0.02	0.06	0.04
75th percentile	0.08	0.03	0.05	0.13	0.06
90th percentile	0.14	0.05	0.10	0.28	0.08
95th percentile	0.20	0.07	0.15	0.45	0.10
99th percentile	0.37	0.11	0.32	1.08	0.15
99.9th percentile	0.75	0.19	0.76	2.85	0.24
Arithmetic mean	0.07 (0.42)	0.03 (0.12)	0.05 (0.42)	0.13 (1.73)	0.05 (0.18)
Geometric Mean	0.04 (2.49)	0.02 (2.06)	0.02 (3.03)	0.06 (3.57)	0.04 (1.80)
Range	0.002 - 0.449	0.006 - 0.049	0.004 - 0.571	0.005 - 0.601	0.017 - 0.124
N	60	14	74	24	10
AM (SD) = arithmetic mean (standard deviation) GM (GSD) = geometric mean (geometric standard deviation)					

Transfer Coefficient (TC)

The transfer coefficient (TC) provides a measure of surface-to-skin residue transfer and is derived from concurrent measurements of exposure and surface residue. Specifically, the TC is the ratio of exposure rate, measured in mass of chemical per time (i.e., μg/hr), to residue, measured in mass of chemical per surface area (i.e., $\mu g/cm^2$).

Table 7-10 provides the distribution for the transfer coefficient factor for indoor surfaces.

Table 7-10: Transfer coefficients (TC; cm^2/hr)		
Statistic	**Adult**	**Children 1 < 2 years old**
50th percentile	4,700	1,300
75th percentile	7,800	2,100
95th percentile	17,000	4,600
99th percentile	28,000	7,600
99.9th percentile	50,000	14,000
AM (SD)	6,800 (8,200)	1,800 (2,200)
GM (GSD)	4,700 (2.16)	1,300 (2.16)
Range	1,200 – 49,000	330 – 13,000
a. A 73% reduction in the adult transfer coefficient is recommended because of the differences of body surface areas between adults and children (1 < 2 years old). AM (SD) = arithmetic mean (standard deviation) GM (GSD) = geometric mean (geometric standard deviation)		

There are no studies available that measure both exposure and surface residue while subjects are performing typical indoor activities. Therefore, the transfer coefficients used for indoor scenarios are derived from information provided in three different studies: (1) two studies which measured exposure and surface residues while subjects performed a Jazzercise™ routine (Krieger, 2000 and Selim, 2004) and (2) a study which measured biomonitoring doses while adults performed scripted activities for 4 hours on carpet (Vaccaro, 1991).

In the Krieger and Selim studies, a Jazzercise™ routine was performed to achieve maximum contact of the entire body with a surface using low impact aerobic movements. All body surfaces (dorsal, ventral, and lateral) contacted the treated surface. The potential dermal

exposure was measured by using whole-body dosimetry. The dosimeters were expected to normalize differences in surface contact and to increase the total sample area relative to patches. The assumption is that the dosimeter represents the skin and that the dose retained by the dosimeter is equivalent to dermal exposure.

In the Vaccaro study, adult males, dressed in bathing suits only, performed different activities over a 4-hour activity period. These activities included: sitting-playing with blocks, on hands and knees crawling, walking on carpet, laying on back, and laying on abdomen. Although activity was minimal during the last 2 activities, considerable surface area was in contact with the carpets during these times.

Using information from these studies on residue transfer, exposure and dose provides an estimated transfer coefficient for indoor activities. It is assumed that the shorter duration of high contact activity (i.e., Jazzercise™) can be used to estimate exposure during longer durations of low contact activity. For more information and full analysis of the transfer coefficient factor, see *Section D.7.3* of *Appendix D*.

For adults, the recommended TC point estimate for post-application dermal exposure assessments is 6,800 cm^2/hr.

The transfer coefficient for children 1 < 2 years old is calculated based on an adjustment of the adult transfer coefficient for differences in body surface area outlined in *Section 2.3*. A factor of 0.27 (i.e., a 73% TC reduction) is used for this lifestage. **For children 1 < 2 years old, the recommended TC point estimate for post-application dermal exposure assessments is 1,800 cm^2/hr.**

Exposure Time (ET)

An empirical distribution based on values from the Exposure Factors Handbook 2011 Edition (U.S. EPA, 2011; Adults -- Tables 16-16 and 16-26; Children – Tables 16-15 and 16-25) should be used for indoor post-application dermal assessments. The distributions for exposure time for adults and for children 1 < 2 years old are provided in *Table 7-11*.

A study which provides information specific to time spent on different types of surfaces indoors is not available. The Exposure Factors Handbook 2011 Edition provides information on total time spent in a residence and time spent in various rooms within a residence. In order to develop inputs for exposure time on carpets and hard surfaces, two assumptions were made: (1) kitchens and bathrooms would represent time spent on hard surfaces and (2) time spent in a residence, less time spent sleeping and napping, would represent time spent on carpets.

For adults, the recommended ET point estimates for post-application dermal exposure assessments are 8 and 2 hours on carpets and hard surfaces, respectively.

For children 1 < 2 years old, **the recommended ET point estimate for post-application dermal exposure assessments are 4 and 2 hours on carpets and hard surfaces, respectively.**

Table 7-11: Exposure Time (ET; hours)				
Statistic	Carpet		Hard surfaces	
	Adult	Children 1 < 2 years old	Adult	Children 1 < 2 years old
5th percentile	4	2	0.25	0
25th percentile	6	4	1	1
50th percentile	7	5	1	2
75th percentile	10	5	3	3
90th percentile	12	6	4	3
95th percentile	12	6	6	4
AM (SD)	8 (3)	4 (--[a])	2 (2)	2(--[a])

a. The Exposure Factor Handbook did not provide these values for children.
AM (SD) = arithmetic mean (standard deviation)

7.2.2.2 Post-Application Dermal Exposure Algorithm (mattresses)

Post-application dermal exposure can occur as a result of pesticide applications to mattresses, such as those directed for the control of bedbugs. Exposure to treated mattresses is dependent on a number of exposure factors. The algorithm to calculate absorbed dose is as follows:

$$D = DR * \frac{SA}{BW} * F * F_{ai} * PF * AF * CF1 \quad (7.19)$$

where:

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

Post-application Dermal Exposure Algorithm Inputs and Assumptions (mattresses)

Recommended values for post-application dermal exposure assessments for mattresses are provided in *Table 7-12* below. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 7-12: Indoor Environments (mattresses) – Recommended Dermal Exposure Factor Point Estimates		
Algorithm Notation	Exposure Factor (units)	Point Estimate(s)

Table 7-12: Indoor Environments (mattresses) – Recommended Dermal Exposure Factor Point Estimates			
Algorithm Notation	**Exposure Factor (units)**		**Point Estimate(s)**
DR	Deposited residue ($\mu g/cm^2$)		(1) Calculated based on information provided on label OR (2) based on default residue values
SA/BW	Surface area / Body Weight Ratio (cm^2/kg)	Adult	280
		Children 1 < 2 years old	640
F	Fraction of body that contacts residue		0.5
F_{ai}	Fraction of DR available for transfer		0.06
PF	Protection Factor		0.5

Deposited Residue (DR)
Following an application to a mattress, pesticide residue deposited onto the surface of the mattress could be contacted by an individual and removed. This residue can be estimated based on information on the product label and high end assumptions or by using default residue values.

If an application rate is provided on the label, assumptions can be made in terms of the size of the mattress and the amount of product applied. It is assumed that an adult or child sleeps on a twin-sized mattress, since it is believed that this scenario would result in the greatest body surface area to treated surface area ratio and, therefore, the highest exposure. The following assumptions can be made to determine a deposited residue:

Percent of mattress treated:

- If the product label includes use directions that indicate the product should be applied to "tufts, seams, folds and edges" of the mattress, a reasonable assumption is that this equates to 20% of the total surface area. This value should be adjusted according to the specific instructions on the label (i.e., if the label use directions indicate application to the entire mattress, the assumption should be 100% of the total surface area).

Volume of product applied to mattress:

- A typical twin-sized mattress has dimensions of 39" x 75"[14], resulting in a total surface area of approximately 3,000 in^2 or 19,000 cm^2.
- To calculate the total *treated* surface area:

$$\text{Total treated surface area } (cm^2) = \text{Percent of mattress treated } (\%) * \text{total surface area } (19{,}000\ cm^2)$$

- Unless specific information is provided on the product label, assume that a reasonable estimate for amount of product used for a twin mattress application is 5 gallons of solution for 1000 square feet (0.005 gal/ft^2).
- To calculate the volume of product applied (gallons) to the mattress:

[14] http://www.mattresssizes.info/

Volume of product applied (gal) = Total treated surface area (cm^2) * 0.005 gal/ft^2 *conversion factor (1.08E-03 ft^2/cm^2)

Using the calculated volume of product applied along with the application rate on the label (in terms of pounds active ingredient per gallon), calculate the pounds active ingredient applied:

Pounds active ingredient applied (lb ai) = Volume of product applied (gallons) * application rate (lb ai/gal)

To estimate the deposited residue for a treated mattress, it is assumed that the pounds of active ingredient applied are applied to the entire surface area of the mattress:

Deposited residue (μg/cm^2) = Pounds of active ingredient applied (lb ai) / total surface area (19,000 cm^2) * 4.5E+08 μg/lb

If an application rate is not provided on the label, the default residue value provided in the Post-application Dermal Exposure section for hard surfaces and carpets for Perimeter/Spot/Bedbug (Coarse application) can be used (4.5 μg/cm^2).

Surface area / Body Weight Ratio (SA / BW)
The **surface area to body weight ratio is 280 cm^2/kg for adults and 640 cm^2/kg for children 1 < 2 years old**. These values represent the mean of the distributions from the U.S. EPA Exposure Factors Handbook 2011 Edition (2011; Table 7-15).

Fraction of body that contacts residue (F)
It is assumed that only **half of the body is in contact with the mattress** at any one time (0.5).

Fraction of Residue Available For Transfer (F_{ai})
The fraction of residue available for transfer from mattresses is assumed to be similar to that for carpets (0.06).

Protection Factor (PF)
A protection factor is included to account for the presence of a single layer of fabric (e.g., bed sheet) between the treated material and the individual (0.5).

Future Research/Data Needs

Information that would refine post-application dermal exposure assessments for indoor pesticide applications include:

- Transferable residue data for a wider variety of chemicals and formulations.
- Further research into the various transfer efficiency methods and linkage to the transfer coefficient factor.
- Distinction between broadcast, perimeter and crack and crevice applications including surface contact probabilities to differentiate exposure potential based on application methods.
- Exposure data representative of participants doing “typical” activities indoors (on both hard surfaces as well as carpets), along with measurements of surface residue that enable calculation of a dermal transfer coefficient.

- For longer-term assessments, chemical-specific information on removal/degradation processes that would allow for better characterization of potential exposure. In the indoor environment, dissipation due to chemical processes (e.g., sunlight) is not expected for most chemicals, although this is chemical dependent; however, there are removal processes that can decrease the amount of residue found. Some factors that can influence a chemical's persistence in the indoor environment include: loss of solvent inerts (which maintain the pesticide in a transferable thin film solution), absorption of the pesticide into the carpet fiber and matting, chemical or electrostatic binding of the pesticide onto the carpet fiber surface, physical removal due to human activity (such as vacuuming), and degradation of the pesticide into non-detectable products.
- Amount of time spent indoors on various surfaces.

Exposure Characterization and Data Quality

Residue

- Reviewers should recognize that factors such as vacuuming, transfer to clothing, re-suspension and impaction into carpet can greatly impact the dissipation rate of pesticides on indoor surfaces when conducting dermal post-application exposure assessments.
- Reviewers should characterize the use of the default residue values for deposited residue (DepR). These defaults are used when no other chemical- or product-specific information is available.

Transfer Coefficient

- Because there are no studies available that measure both exposure and surface residue while subjects are performing typical indoor activities, the indoor transfer coefficient was derived from information provided in three different studies (two Jazzercise™ studies and a biomonitoring study where participants performed "typical" indoor activities). This makes use of the best available data and provides reasonable exposure estimate by utilizing high contact activities and low contact activities in two separate situations.

Fraction Transferred

- In instances where chemical-specific data are not available, estimates of the fraction of residue available for transfer are used generically based on existing data for a wide variety of chemicals. Use of this data generically, including using high-end estimates, may overestimate exposure for some chemicals, but because of the limited data available, there is the possibility of underestimating availability of residues for other chemicals. Additionally, assessors need to be cognizant of using data collected from various methods and linking to a transfer coefficient derived from one specific method.

Exposure Time

- Information on the amount of time spent on carpets and hard surfaces, specifically, is not available. Distributions were available for time spent inside a residence, time spent sleeping, time spent in kitchens, and time spent in bathrooms. The values for different percentiles of each distribution were either added together or subtracted to represent the correct exposure time for a particular surface (e.g., time spent on carpet = time spent in a residence – time spent sleeping) – a reasonable approach given the limitations of the data.

7.2.3 Post-application Non-Dietary Ingestion Exposure Assessment: Hand-to-Mouth

This SOP provides a standard method for estimating the dose for children 1 < 2 years old from incidental ingestion of pesticide residues from previously treated indoor areas. This scenario assumes that pesticide residues are transferred to the skin of children playing on treated indoor surfaces and are subsequently ingested as a result of hand-to-mouth transfer.

Incidental oral exposures resulting from treated mattresses (e.g., treatment for bedbugs) should only be assessed if there are no other indoor uses. Incidental oral exposures from indoor hard surface or carpet applications are considered to be protective of mattress applications for the following reasons: (1) typically a lower application rate is allowed for the mattress application compared to indoor hard surface/carpet applications, (2) a protection factor of 0.5 is assumed for the mattress exposures due to the presence of a bed sheet over the mattress, and (3) the replenishment interval for hand-to-mouth activity is assumed to be less while a child is sleeping than while they are awake.

Post-application Hand-to-Mouth Exposure Algorithm

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

$$E = \left[HR * \left(F_M * SA_H\right) * \left(ET * N_Replen\right) * \left(1 - \left(1 - SE\right)^{\frac{Freq_HtM}{N_Replen}}\right)\right] \qquad (7.20)$$

where:

E	= exposure (mg/day);
HR	= hand residue loading (mg/cm^2);
F_M	= fraction hand surface area mouthed / event (fraction/event);
ET	= exposure time (hr/day);
SA_H	= surface area of one hand (cm^2);
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

$$HR = \frac{Fai_{hands} * DE}{SA_H * 2} \qquad (7.21)$$

where:

HR	= hand residue loading (mg/cm^2);
Fai_{hands}	= fraction ai on hands compared to total surface residue from jazzercise study (unitless);
DE	= dermal exposure (mg); and
SA_H	= typical surface area of one hand (cm^2).

and

Dose, normalized to body weight, is calculated as:

$$D = \frac{E}{BW} \quad (7.22)$$

where:

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

Post-application hand-to-mouth exposure following indoor applications is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4*, such as residue dissipation, product-specific re-treatment intervals, and activity patterns. If longer-term assessments (i.e., intermediate-, long-term, or lifetime exposures) are deemed necessary, similar refinements to more accurately reflect the exposure profile are recommended.

Post-application Hand-to-Mouth Exposure Algorithm Inputs and Assumptions

Recommended values for post-application hand-to-mouth exposure assessments are provided in *Table 7-13* below. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 7-13: Indoor Environments – Recommended Hand-to-Mouth Exposure Factor Point Estimates

Algorithm Notation	Exposure Factor (units)			Point Estimate(s)
Fai_{hands}	Fraction of ai on hands from jazzercise study (unitless)			0.15
DE	Dermal exposure calculated in *Section 7.2.2* (mg)			Calculated
HR	Residue available on the hands (mg/cm^2)			Calculated
SA_H	Surface area of one hand (cm^2)	Children 1 < 2 years old		150
AR	Application rate (mass active ingredient per unit area)			Maximum labeled rate
F_M	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

Table 7-13: Indoor Environments – Recommended Hand-to-Mouth Exposure Factor Point Estimates				
Algorithm Notation	**Exposure Factor (units)**			**Point Estimate(s)**
			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		11.4

Hand Residue (HR)

Hand residue is linked to dermal exposure and it is assumed that the fraction of residue on the hands is equal to the fraction of the residue on the hands from the jazzercise studies used to develop the indoor transfer coefficient.

Fraction of ai on hands from jazzercise study (Fai_{hands})

The fraction of active ingredient available on the hands was based on the jazzercise studies used to calculate the indoor transfer coefficient (Krieger, 2000 and Selim, 2004). This value was determined by taking the average residue measured on the hands (gloves) and comparing that value to the average residue on the entire body. This analysis resulted in **a value of 0.15**.

Fraction of Hand Mouthed per Event (F_M)

See *Section 2.4* of this SOP for discussion of the fraction of hand mouthed. **The recommended point estimate for use in post-application incidental oral exposure assessments is 0.13.**

Hand Surface Area (SA_H)

The hand surface area for children 1 < 2 years old was based on values from the Exposure Factors Handbook 2011 Edition (U.S. EPA, 2011; Table 7-2). This value is **150 cm^2 for one hand**.

Fraction of Pesticide Extracted by Saliva (SE)

See *Section 2.6* of this SOP for discussion of the fraction of pesticide extracted by saliva distribution. **The recommended point estimate for use in post-application incidental oral exposure assessments is 0.48.**

Exposure Time (ET)

An empirical distribution based on values from Exposure Factors Handbook 2011 Edition (U.S. EPA, 2011; Tables 16-15 and 16-25) should be used for indoor post-application hand-to-mouth assessments. The distribution for exposure time for children 1 < 2 years old is provided in *Table 7-14* A study which provides information specific to time spent on different types of surfaces indoors is not available for children; therefore, information in the Exposure Factors Handbook 2011 Edition was used which includes total time spent in a residence and time spent in various rooms within a residence. In order to develop inputs for exposure time on carpets and hard surfaces, two assumptions were made: (1) kitchens and bathrooms would represent time spent on hard surfaces and (2) time spent in a residence, less time spent sleeping and napping, would represent time spent on carpets.

For children 1 < 2 years old, the recommended ET point estimates for post-application incidental oral exposure assessments are 4 and 2 hours on carpets and hard surfaces, respectively.

Table 7-14: Exposure Time (ET; hours) for Children 1 < 2 years old

Statistic	Carpet	Hard surfaces
5th percentile	2	0
25th percentile	4	1
50th percentile	5	2
75th percentile	5	3
90th percentile	6	3
95th percentile	6	4
AM (SD)	4 (--[a])	2(--[a])

a. The Exposure Factor Handbook (U.S. EPA, 2011) did not provide these values for children.
AM (SD) = arithmetic mean (standard deviation)

Replenishment Intervals per Hour (N_Replen)

This SOP assumes an estimate of 4 replenishment intervals per hour (i.e., residues on the hand will be replenished every 15 minutes). This value was selected as a conservative assumption based on the use of 30 minutes in the SHEDS model to coincide with the CHAD diaries.

Hand-to-Mouth Events per Hour (Freq_HtM)

Frequency of hand-to-mouth events is an important variable for hand-to-mouth post-application exposure assessments. The estimates for frequency of hand-to-mouth events in indoor environments are based on the Xue et al. (2007) meta-analysis. *Table 7-15* provides distributions and point estimates of hand to mouth events for use in residential pesticide exposure assessment and *Appendix D.9.2* provides additional analysis.

The recommended point estimate for use in post-application incidental oral exposure assessments is 20 events/hr.

Table 7-15: Frequency of Hand-to-Mouth Events (events/hr)

Statistic	Children 1 < 2 years old

Table 7-15: Frequency of Hand-to-Mouth Events (events/hr)	
Statistic	**Children 1 < 2 years old**
5th percentile	0
25th percentile	6
50th percentile	14
75th percentile	27
95th percentile	63
AM (SD)	20 (20)
GM (GSD)	--[a]
Range	--[a]
N	245

Weibull distribution – Scale: 18.79 and Shape: 0.91
AM (SD) = arithmetic mean (standard deviation)
GM (GSD) = geometric mean (geometric standard deviation)
[a] Not provided

Future Research/Data Needs

Information that would refine post-application incidental oral hand-to-mouth exposure assessments for indoor pesticide applications include:

- Application intervals (i.e., how often products are applied indoor) – either chemical-specific or generic intervals.
- Survey information (preferably longitudinal) detailing:
  - General pesticide use to obtain, on a per capita basis, the probability of treating indoor surfaces with pesticides;
  - Product-specific application rates to obtain the likelihood that the maximum rate is used; and,
  - Daily activity patterns specific to hand-to-mouth activities indoors (e.g., replenishment interval, hand-to-surface contacts).

Exposure Characterization and Data Quality

Residue

- Reviewers should recognize that factors such as vacuuming, transfer to clothing, re-suspension and impaction into carpet can greatly impact the dissipation rate of pesticides on indoor surfaces when conducting dermal post-application exposure assessments.

Fraction of Pesticide Extracted by Saliva

- Though based on limited data, the determination of the fraction of pesticide extracted by saliva from the hand is considered reasonable.

7.2.4 Post-application Non-Dietary Ingestion Exposure Assessment: Object-to-Mouth

This SOP provides a standard method for estimating the dose for children 1 < 2 years old from incidental ingestion of pesticide residues from previously treated indoor surfaces. This scenario assumes that pesticide residues are transferred to a child's toy and are subsequently ingested as a result of object-to-mouth transfer.

Post-application Object-to-Mouth Exposure Algorithm

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

$$E = \left[OR * CF1 * SAM_O * (ET * N_Replen) * \left(1 - (1 - SE)^{\frac{Freq_OtM}{N_Replen}}\right)\right] \quad (7.23)$$

where:

E	=	exposure (mg/day);
OR	=	chemical residue loading on an object (μg/cm^2);
CF1	=	weight unit conversion factor (0.001 mg/μg);
SAM_O	=	area of the object surface that is mouthed (cm^2/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

$$OR = DepR * F_O \quad (7.24)$$

where:

OR	=	chemical residue loading on the object (μg/cm^2);
DepR	=	deposited residue (μg/cm^2); and
F_O	=	fraction of residue transferred to an object (unitless).

and

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

$$D = \frac{E}{BW} \quad (7.25)$$

where:

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

Post-application object-to-mouth exposure following indoor applications is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4*, such as residue dissipation, product-specific re-treatment intervals, and

activity patterns. If longer-term assessments (i.e., intermediate-, long-term, or lifetime exposures) are deemed necessary, similar refinements to more accurately reflect the exposure profile are recommended.

Post-application Object-to-Mouth Exposure Algorithm Inputs and Assumptions

Recommended values for post-application object-to-mouth exposure assessments are provided in *Table 7-16* below. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 7-16: Indoor Environments – Recommended Object-to-Mouth Exposure Factor Point Estimates

Algorithm Notation	Exposure Factor (units)			Point Estimate(s)
AR	Application rate (mass active ingredient per unit area)			Maximum labeled rate
F_O	Fraction of residue transferred to an object	Carpets		0.06[a]
		Hard surfaces		0.08[a]
SAM_O	Surface area of object mouthed (cm^2/event)			10
N_Replen	Replenishment intervals per hour (intervals/hour)			4
SE	Saliva extraction factor			0.48
ET	Exposure Time (hours per day)	Children 1 < 2 years old	Carpets	4
			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		11.4

a. These values are screening level point estimates to be used when chemical-specific data are not available. Data are available for certain chemicals; see text and associated tables for chemical-specific data for pyrethrin, permethrin, PBO, chlorpyrifos, and deltamethrin.

Fraction of Residue to an Object (F_O)

Following an application, some pesticide residue remains on indoor surfaces. Some of this residue may be transferred to a child's toy and subsequently ingested via object-to-mouth activities. For this SOP, it is assumed that the residue that could be transferred to the object is the same as what is available for dermal transfer. As a result, the fraction of residue available for transfer assumed for dermal exposure for both carpets and hard surfaces (see discussion above in *Section 7.2.2* for more detail) should be used as a conservative estimate for the fraction of residue transferred to an object.

For carpets and hard surfaces, the recommended point estimates for use in post-application incidental oral exposure assessments are 0.06 and 0.08, respectively.

Surface Area of Object Mouthed (SAM_O)

See *Section 2.5* of this SOP for discussion of surface area of object mouthed. **The recommended value for use in exposure assessments is 10 cm^2/event.**

Fraction of Pesticide Extracted by Saliva (SE)

See *Section 2.6* of this SOP for discussion of fraction of pesticide extracted by saliva distribution. T**he recommended point estimate for use in post-application incidental oral exposure assessments is 0.48.**

Exposure Time (ET)

An empirical distribution based on values from the Exposure Factors Handbook 2011 Edition (U.S. EPA, 2011; Tables 16-15 and 16-25) should be used for indoor post-application object-to-mouth assessments. The distribution for exposure time for children 1 < 2 years old is provided in *Table 7-17*. A study which provides information specific to time spent on different types of surfaces indoors is not available for children; therefore, information in the Exposure Factors Handbook 2011 Edition was used which includes total time spent in a residence and time spent in various rooms within a residence. In order to develop inputs for exposure time on carpets and hard surfaces, two assumptions were made: (1) kitchens and bathrooms would represent time spent on hard surfaces and (2) time spent in a residence, less time spent sleeping and napping, would represent time spent on carpets.

For children 1 < 2 years old, the recommended point estimates for use in post-application incidental oral exposure assessments are 4 and 2 hours on carpets and hard surfaces, respectively.

Table 7-17: Exposure Time (ET; hours) for Children 1 < 2 years old

Statistic	Carpet	Hard surfaces
5th percentile	2	0
25th percentile	4	1
50th percentile	5	2
75th percentile	5	3
90th percentile	6	3
95th percentile	6	4
AM (SD)	4 (--[a])	2(--[a])

a. The Exposure Factor Handbook (U.S. EPA, 2011) did not provide these values for children.
AM (SD) = arithmetic mean (standard deviation)

Replenishment Intervals per Hour (N_Replen)

This SOP assumes an estimate of 4 replenishment intervals per hour (i.e., residues on the hand will be replenished every 15 minutes). This value was selected as a conservative assumption based on the use of 30 minutes in the SHEDS model to coincide with the CHAD diaries.

Object-to-Mouth Events per Hour (Freq_OtM)

Frequency of object-to-mouth events is an important variable for object-to-mouth post-application exposure assessments. The estimates for frequency of object-to-mouth events in indoor environments are based on the Xue et al. (2010) meta-analysis. *Table 7-18* provides distributions and point estimates of object-to-mouth events for use in residential pesticide exposure assessment.

The recommended point estimate for use in post-application incidental oral exposure assessments is 14 events/hr.

Table 7-18: Frequency of Object-to-Mouth Events (events/hr)

Statistic	Children 1 < 2 years old
5th percentile	2
25th percentile	7
50th percentile	12
75th percentile	19
95th percentile	34
AM (SD)	14 (10)
GM (GSD)	--[a]
Range	--[a]
N	137

Weibull distribution – Scale: 15.5 and Shape: 1.4
AM (SD) = arithmetic mean (standard deviation)
GM (GSD) = geometric mean (geometric standard deviation)
[a] Not provided

Future Research/Data Needs

Information that would refine post-application incidental oral object-to-mouth exposure assessments for indoor pesticide applications include:

- Application intervals (i.e., how often chemicals are applied indoors) – either chemical-specific or generic intervals.
- Survey information (preferably longitudinal) detailing:
  - General pesticide use to obtain, on a per capita basis, the probability of treating indoor surfaces with pesticides;
  - Product-specific application rates to obtain the likelihood that the maximum rate is used; and,
  - Daily activity patterns specific to object-to-mouth activities indoors (e.g., typical surface area of object that is mouthed).
- Data on the amount of residue transferred from treated indoor surfaces to both hard and soft children's toys.

Exposure Characterization and Data Quality

<u>Residue</u>

- Reviewers should recognize that factors such as vacuuming, transfer to clothing, re-suspension and impaction into carpet can greatly impact the dissipation rate of pesticides on indoor surfaces when conducting dermal post-application exposure assessments. The assumption that the entire available indoor transferable residue is transferred to the object should be considered very conservative.

Fraction of Pesticide Extracted by Saliva

- Though based on limited data, the determination of the fraction of pesticide extracted by saliva from the hand is considered reasonable.

7.2.5 Post-application Non-Dietary Ingestion Exposure Assessment: Dust Ingestion

House dust is a heterogeneous mixture of various particles with varying sizes, shapes, and densities. The basic composition of house dust varies throughout a home as well as between homes, across seasons, and across regions. In the indoor environment, it is known that pesticides can partition into house dust and persist for periods of time, but assessing exposure to house dust from a particular application of a pesticide product is difficult for several reasons.

In order to do an assessment of incidental oral ingestion exposure to house dust, information on the pesticide concentration in dust is needed. There is uncertainty surrounding the ability to estimate pesticide concentrations in dust from a single application. Pesticide concentrations in house dust reported in the literature are not typically related to a single application event. Pesticide residues in house dust can originate from either recent or historical applications and from either indoor or outdoor sources; therefore, available measurements of dust concentrations in house dust are unlikely to be representative of concentrations resulting from a particular application.

Additionally, for measured concentrations in dust, there is difficulty in ensuring that the sampling method utilized would be able to collect dust material that would be available for human exposure. Most vacuum methods employed for the collection of household dust collect the material from all depths of the carpet; whereas, incidental oral exposure to house dust would primarily be to dust located on the surface of the carpet.

At this point in time, knowledge of dust ingestion patterns is somewhat limited due to the fact that only a few researchers have attempted to quantify dust ingestion patterns in children. Values are available in the Exposure Factors Handbook 2011 Edition (EFH, 2011); however, the dust ingestion recommendations include treated soil from the outdoor environment tracked into the indoor setting, indoor settled dust and air-suspended particulate matter that is inhaled and swallowed. The EFH notes that the confidence rating for the dust ingestion recommendation is low due to limitations in the studies available.

A SOP for assessing incidental oral exposure to indoor house dust is not being proposed at this time due to the issues discussed above; however, HED believes that the current method of hand-to-mouth exposure assessment for indoor pesticide residues is protective of exposure to indoor house dust. The current approach accounts for exposure to residues immediately after application, which are assumed to be available in much higher concentrations than concentrations found in house dust. Therefore, this approach is considered a conservative measure of incidental oral exposure to a pesticide after application indoors and would be protective of exposure to any partitioning of the pesticide into house dust.

Future Research/Data Needs
Information that would useful for understanding the potential for exposure to house dust would include:

- Identifying best practices for house dust collection; and
- Collection of longitudinal measurements of surface residues and house dust concentrations after a pesticide application.

7.2.6 Combining Post-application Scenarios

Risks resulting from different exposure scenarios are combined when it is likely that they can occur simultaneously based on the use pattern and when the toxicological effects across different routes of exposure are the same. When combining scenarios, it is important to fully characterize the potential for co-occurrence as well as characterizing the risk inputs and estimates. Risks should be combined even if any one scenario or route of exposure exceeds the level of concern because this allows for better risk characterization for risk managers. The following issues should be considered when combining scenarios for the residential indoor SOP:

- There are a number of non-dietary ingestion exposure scenarios that could potentially be combined with the dermal exposure scenario. These non-dietary ingestion scenarios should be considered inter-related and it is likely that they occur interspersed amongst each other across time. For example, a child may place his hand in his mouth "X" number of times as well as place an object in his mouth "Y" number of times during a certain period of time. The potential combinations of co-occurrence of the hand-to-mouth/object-to-mouth scenarios across a particular period of time are limitless. Combining both of these scenarios with the dermal exposure scenario would be overly-conservative because of the conservative nature of each individual assessment. Based on this discussion, it is recommended that the dermal and hand-to-mouth scenarios be combined for short-term exposure durations and this combination should be considered a protective estimate of children's exposure to pesticides used on indoor surfaces.

Section 8 Treated Pets

This section provides the methods for estimating potential exposure that individuals may receive from dermal, inhalation and/or hand-to-mouth exposure resulting from the treatment of pets with a pesticide product. Products in this marketplace include liquid concentrates (dips, shampoos and sponges), liquid ready-to-use (RTU) formulations (aerosol cans, collars, spot-ons and trigger pump sprayers) and solid RTU formulations (dusts and powders). Exposure from treated pets is anticipated to occur through dermal and inhalation routes when handling or applying the treatment (adults). Further, exposure is anticipated to occur from the dermal (adults and children) and hand-to-mouth routes (children only) from contact with treated pets.

This SOP updates the algorithms and inputs previously used to estimate handler and post-application dermal and post-application hand-to-mouth exposure. While the SOP builds on methods previously developed by the Agency, it relies mainly upon review of data submitted to EPA in support of specific pet pesticide product registrations. The submitted data were used to estimate potential exposure from 1) the application of pet pesticide treatments and 2) post-application activity with treated pets. The Agency also used data from open literature when available, though few sources were identified.

The exposure assessor should check the label language for directions on pet use. Look for statements describing or limiting the use of the product (e.g., some dust/powder products marketed for use indoors also allow for use on pets). These statements may be on the front panel of the label associated with the brand or trade name or in the use-directions section of the labeling. Restricted Use Pesticide (RUP) classification indicates that the product cannot be bought or applied by pet owners and, therefore, a residential handler exposure assessment is not applicable. However, because pets often return to residential sites following professional treatments, a residential post-application exposure assessment is required. Label language such as such as "for use by veterinarians or veterinary assistants only" or “only available from veterinarians” is considered unenforceable and does not preclude use in residential settings. In this case, therefore, both a residential handler and post-application exposure assessment is required.

The following definitions of common pet product formulations should be applied for use of the Treated Pet SOP:

Liquid Formulations -

An aerosol product is a can formulation packaged under pressure for the dispersion of pesticide to the hair coat of the treated animal.

A pet collar is a product formulated to be worn around the neck of a treated pet. Collars are designed so that the pesticide is impregnated into the material of the collar and acts by slowly releasing over the product active lifetime onto the hair coat of the pet.

A dip is a product that is applied to pets via dipping or immersion in a concentrated liquid solution.

A shampoo is a product formulation that is applied to the wetted coat of the animal to be lathered or shampooed into the hair coat of the treated pet.

A spot-on is a product formulated for application to pets via tube or vial to one or more small, localized areas on the body of the animal. The products work by means of spreading from the application site over the dermal surface of the treated pet.

A trigger pump sprayer is a product formulated to be distributed onto the hair coat of the treated animal by means of pump spray applicator.

Solid Product Formulations –

Dust and powder formulations are RTU products applied to the treated pet by means of direct application to the hair coat of the animal.

8.1 Handler Exposure Assessment

As described in *Section 1.3.3,* handler exposure refers to an adult individual exposed during mixing, loading, and applying of a pesticide. The Agency assumes that dermal and inhalation pesticide handler exposure can occur while applying pesticides to pets. This SOP provides unit exposures for each formulation/application equipment combination that are relevant to calculating handler exposure to pet pesticide products in the absence of chemical-specific handler data.

The unit exposures in this section are based on a review of 6 studies of varying formulations which provided information on the amount of active ingredient applied and resulting exposure to the handler. Formulations for which data have been identified include dips, dusts, trigger-pump spray, shampoo and spot-on. No formulation-specific data were identified for pet collar, powder or aerosol spray formulations; however, surrogate unit exposures that closely approximate these types of exposures have been recommended for the assessment of these formulations. More information can be found in *Section C.1* of *Appendix C.*

Label information is important for selecting appropriate data inputs for the handler exposure assessment. The maximum application rate specified on the label should be used. Additional information provided by the label such as use directions, application-specific animal weight ranges and re-treatment intervals should be considered as a part of the exposure assessment.

Prior to the development of a handler exposure assessment for a pet treatment scenario, the assessor should review the pesticide label to determine whether the scenario is appropriate based upon the pesticide formulation and usage characteristics of the product. Specific labeling considerations for pet treatment products are as follows:

- Determine whether the labeling contains directions for use on pets.
- Identify from product labeling the formulation of the pet pesticide.
- Determine maximum rate(s) of application for differing ranges of animal weight.
- For formulations of pet pesticides which specify application rate as it corresponds to animal weight (i.e., spot-ons), labeled weight ranges should be used to determine application rate. The weight range which corresponds to the greatest amount of active ingredient applied should be used for the assessment of handler exposure. Many application methods of pet products (i.e., dips, shampoos and aerosol/trigger-pump sprays) do not specify application rate as it corresponds to pet weight ranges. When not specified it should be assumed that 1/2 of the contents of the can or bottle of product is applied per animal treated based on best professional judgment. The majority of pet collar formulations are registered as a single collar for use on all animal weight ranges with directions to fit the collar to the treated animal and trim off the excess length. Because the trimmed length and corresponding active ingredient loss cannot be determined, the maximum application rate of the collar as labeled should be assumed for assessment of applicator risk.
- Only adults (individuals 16 years and older) are assumed to handle/apply pesticides to 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 formula-application method-specific unit exposure by an estimate of the amount of active ingredient handled in a day, using the equation below:

$$E = UE * AR * A \qquad (8.1)$$

where:

E	= exposure (mg/day);
UE	= unit exposure (mg/lb ai);
AR	= application rate (lb ai/pet); and
A	= number of animals treated per day.

Absorbed dermal and/or inhalation dose normalized to body weight is calculated as:

$$D = \frac{E * AF}{BW} \qquad (8.2)$$

where:

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

Handler exposure for applications to pets is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term, multi-day exposure

profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.3* such as the product-specific application regimen.

Dermal and Inhalation Handler Exposure Algorithm Inputs and Assumptions

Recommended values for handler exposure (inhalation and dermal) assessments are provided in *Table 8-1*. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 8-1: Pet Treatments – Recommended Unit Exposure (mg/lb ai) Point Estimates

Formulation	Equipment/ Application Method	Dermal	Inhalation	Appendix Page Reference
		Point Estimate	Point Estimate	
Liquid-Concentrate	Dip	100	0.027	C-71
	Sponge	1,600	0.21	C-75
Ready-to-Use (RTU) - Liquid	Trigger-pump sprayers	820	3.3	C-113
	Shampoo	2,000	0.29	C-124
	Spot-on	120	Inhalation exposure is considered negligible.	C-130
	Collar	No exposure data available for this application scenario. Exposure data for spot-on applications recommended as surrogate data.		
	Aerosol Can	No exposure data available for this application scenario. Exposure data for trigger sprayer applications recommended as surrogate data.		
Dusts/Powder	Shaker Can	4,300	18	C-36

Unit Exposures

As described in *Section 1.3.3*, the unit exposure is the ratio of exposure and the amount of active ingredient handled for a given formulation/application method combination, with units of mass exposure per mass active ingredient handled (e.g., mg exposure/lb ai handled). The recommended point estimates shown in *Table 8-1* represent the arithmetic mean. Data summaries for all UE inputs can be found in *Section C.1* of *Appendix C*.

Number of Animals Treated

It is assumed that residential handlers of pet treatment products will treat **2 animals per application** (N). This estimate is based upon information available from The Humane Society of the United States[15] which references data from the American Pet Products Manufacturers Association (APPA) 2011-2012 National Pet Owners Survey that reports pet owners have an average of 1.7 dogs and 2.2 cats.

[15] http://www.humanesociety.org/issues/pet_overpopulation/facts/pet_ownership_statistics.html

8.2 Post-application Exposure Assessment

Post-application exposure can result from conducting physical activities such as petting or otherwise interacting with pets following pesticide applications. While exposure may occur for people of all ages, adults and children 1 < 2 years old are considered the index lifestage for this exposure scenario based on behavioral characteristics and the strengths and limitations of available data. An analysis of index lifestages for the Treated Pet section can be found in *Appendix A*.

It is assumed that individuals contact previously treated pets on the same day the pesticide treatment is applied. Therefore, the assessment of post-application exposure must be representative of the day of application residues (i.e., Day 0). However, the assessment can be refined to reflect exposure over longer periods of time (e.g., several months) if post-application exposure (transferable residue) data, toxicological endpoint, or activity information is available to allow for such calculations.

This section addresses standard methods for estimating exposure and dose for three individual post-application scenarios resulting from exposure to pesticides that have been used to treat pets:

- Section 8.2.1 – Post-application inhalation exposures;
- Section 8.2.2 – Post-application dermal exposures; and
- Section 8.2.3 – Non-dietary ingestion via hand-to-mouth activity.

8.2.1 Post-application Inhalation Exposure Assessment

Post-application inhalation exposure is generally not assessed for pets and should be handled on a case-by-case basis. The combination of low vapor pressure for chemicals typically used as active ingredients in pet pesticide products and the small amounts of pesticide applied to pets is expected to result in negligible inhalation exposure.

8.2.2 Post-application Dermal Exposure Assessment

This SOP provides a revised standard method for estimating potential dermal pesticide exposure among adults and/or children that contact pets previously treated with pesticide products. The method for determining post-application dermal exposure is based on the relationship between the amount of pesticide applied and contact activities. It was developed to incorporate chemical-specific data; however, standard values and assumptions are included that can be used in the absence of data as described below in the sub-Section, *Post-application Dermal Exposure Algorithm Inputs and Assumptions.*

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:

$$E = TC * TR * ET \quad (8.3)$$

where:

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

$$TR = \frac{AR * F_{AR}}{SA} \quad (8.4)$$

where:

TR = transferable residue (mg/cm^2);
AR = application rate or amount applied to animal (mg);
F_{AR} = fraction of the application rate available as transferable residue; and
SA = surface area of the pet (cm^2).

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

$$D = \frac{E * AF}{BW} \quad (8.5)$$

where:

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

As described previously, post-application exposure must include an estimated dose based on day of application residues (i.e., Day 0). However, due to temperate climates in some parts of the country, the potential exists for pet pest pressures and resulting treatment to extend beyond a short-term duration (i.e., to intermediate- and long-term). Post-application exposure estimates can be refined to reflect a multi-day exposure profile by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4* such as dissipation, product-specific re-treatment intervals (i.e., monthly, bi-monthly), and activity patterns. A description of the methodology recommended for refinement of longer term post-application exposure to treated pets can be found in *Appendix D.*

Post-application Dermal Exposure Algorithm Inputs and Assumptions

Recommended values for post-application dermal exposure assessments are provided in *Table 8-2* below. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 8-2: Residential Post-application Scenario – Pet Treatment SOP Dermal Exposure Factors: Recommended Point Estimates

Algorithm Notation	Exposure Factor Units		Point Estimates
AR	Application rate (mg)		Labeled Rate for Each Weight Range Specified (Small, Medium, Large)
SA	Surface Area of Animal (cm^2)	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_{AR}	Fraction of AR Available for Transfer		0.02
TC	Transfer Coefficient – Liquids (cm^2/hr)	Adult	5,200
		Children 1 < 2 years old	1,400
	Transfer Coefficient – Solids (cm^2/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

Transfer Coefficient (TC)

Post-application dermal exposure can be predicted using estimates for residue transfer to individuals contacting treated pets during certain activities and exposure times. Exposure rates resulting from residue transfer associated with a given formulation and activity is an empirical value, known as the transfer coefficient (TC). For the purpose of determining exposure to treated pets, TC can be defined as animal surface area contact per unit time (cm^2/hr). It is the ratio of exposure rate, measured in mass of chemical per time (e.g., µg/hr), to residue, measured in mass of active ingredient per surface area of the animal (e.g., µg/cm^2).

The transfer coefficients used for pet exposure were derived from two studies representing application and grooming activities with dogs, one using a carbaryl shampoo product (Mester, 1998) and the other using a carbaryl dust product (Merricks, 1997); these are used to represent

TCs for liquid and solid formulations, respectively. Data were gathered while human volunteers applied pet pesticide products to various dogs of differing sizes and fur lengths. The information identified best approximates the exposures that could occur from interactions with treated pets because these studies included the direct measurement of exposures to applicators or pet groomers. Since these individuals directly handled pesticide products and had direct contact with treated pets, it is expected that their resulting exposures are a reasonable approximation of upper bound estimates of contact with a treated animal. In the absence of direct exposure data for this scenario (e.g., homeowner activity with a treated pet), the Agency assumes that the application and grooming activities are likely to result in a protective estimate of exposure than just the evaluation of petting, hugging or sleeping with a pet.

Because TCs were established from studies using adult volunteers, they have been scaled to adjust for assessment of children 1 < 2 years old exposure as outlined in *Section 2.3* using a factor of 0.27 (i.e., a 73% reduction in the adult TC).

A TC of 5,200 cm^2/hr for adults and 1,400 cm^2/hr for children (based on the arithmetic mean) is recommended for addressing all durations of post-application exposure for all liquid formulations (or formulations that behave as liquids) including RTU liquid formulations (i.e., aerosol/trigger sprays, dips, pet collars, shampoos and spot-ons). *Table 8-3* provides a statistical summary of dermal exposure TCs derived for liquid formulations. A transfer coefficient of 140,000 cm^2/hr for adults and 38,000 cm^2/hr for children (based on the arithmetic mean) is recommended for assessing post-application exposure for RTU solid formulations (i.e., dust and powder). *Table 8-4* provides a statistical summary of dermal exposure TCs derived for solid formulations. A description of these studies and statistical derivations can be found in *Section* D.7.4 of *Appendix* D.

Table 8-3: Dermal Exposure Transfer Coefficients - Liquid Formulations

Statistic	Transfer Coefficient (cm^2/hr) [a, b]	
Liquids (Dips, Shampoos, Aerosol/Trigger Sprays, Collars and Spot-Ons)		
	Children 1 < 2 years old	**Adult**
50th Percentile	980	3,600
75th Percentile	1,700	6,400
95th Percentile	3,900	15,000
99th Percentile	7,000	26,000
AM (SD)	1,400 (1,400)	5,200 (5,300)
GM (GSD)	980 (2.3)	3,600 (2.3)
Range	NA [c]	522-12,846
N	NA [c]	16

a. Representative of individuals wearing short-sleeve shirts, shorts, and no gloves
b. Dermal liquid formulation TC based on a lognormal distribution fit with data from MRID 46658401 (*See Section D.7.4 of Appendix D*).
c. NA = Not applicable. Child values were derived by scaling adult data.

Table 8-4: Dermal Exposure Transfer Coefficients - Solid Formulations

Statistic	Transfer Coefficient (cm^2/hr) [a, b]	
Solids (Dusts/Powders)		
	Children 1 < 2 years old	**Adult**
50th Percentile	31,000	120,000
75th Percentile	47,000	170,000

Table 8-4: Dermal Exposure Transfer Coefficients - Solid Formulations		
Statistic	**Transfer Coefficient (cm^2/hr) [a, b]**	
95th Percentile	84,000	310,000
99th Percentile	130,000	470,000
AM (SD)	38,000 (25,000)	140,000 (92,000)
GM (GSD)	31,000 (1.8)	120,000 (1.8)
Range	NA [c]	28,754 – 318,503
N	NA [c]	20
a. Representative of individuals wearing short-sleeve shirts, shorts, and no gloves b. Dermal solid formulation TC based on a lognormal distribution fit with data from MRID 44439901 (*See Section D.7.4 of Appendix D*). c. NA = Not applicable. Child values were derived by scaling adult data.		

Transferable Residue (TR)

Transferable residue (TR) is a measure of the concentration of pesticide active ingredient per surface area of the treated pet that is anticipated to transfer to the exposed person. The concentration of pesticide residue per surface area of animal is determined by normalizing the maximum amount of residue deposited on the pet from a single treatment to the surface area (SA) of the treated animal and multiplying by the fraction of application rate (F_{AR}) anticipated to transfer from the hair coat of the treated animal to the exposed individual. The following selection criteria should be used to determine TR.

1) Use the measure of TR by means of a chemical-specific exposure study (e.g., pet wipe study), if submitted. Notably, the Agency recently revised the data requirements that pertain to conventional pesticides. As part of these revisions, residue studies were classified as required for residential uses under 40 CFR 158, subpart K (158.1070; post-application exposure data requirements table).

2) In the absence of a chemical-specific study, the fraction of the application rate (F_{AR}) should be used.

Fraction Application Rate (F_{AR})

If chemical specific TR measurements are not available, then a standard value for the fraction of active ingredient available (F_{AR}) for transfer is used. In this SOP, a screening level F_{AR} was recommended based on the review of 8 pet residue transfer, or "petting," studies (9 data sets total) submitted to the Agency. Measurements of residue transfer were derived by taking the ratio of the amount of active ingredient on a bare or gloved hand (on the day of highest observed transfer) to the amount of active ingredient applied. Five residue transfer studies were performed by means of volunteers "petting" or "stroking" animals treated with a known amount of active ingredient. Three additional residue transfer studies were conducted using a gloved mannequin hand. For each study the amount of residue transferred to the hands was determined. F_{AR} studies varied in the number, location and intensity of petting/stroking actions. All 8 pet residue transfer studies were reviewed for ethical conduct and no barriers were identified in law or regulation for their being relied upon by the Agency. *Appendix D.6.2* provides more detailed analysis.

Based on the available pet residue transfer studies, the **recommended screening level F_{AR} point estimate for use in post-application dermal exposure assessment is 0.02 (equivalent to 2%)**.

Exposure Time (ET)

The exposure time (ET) for adults and children were derived from Tsang and Klepeis, 1996 (as presented in 1997 Exposure Factors Handbook Table 15-77). Animal care is defined in the 1997 Exposure Factors Handbook as "care of household pets including activities with pets, playing with the dog, walking the dog and caring for pets of relatives, and friends." The data identified the time spent with an animal while performing household activities as recorded in 24 hour diaries by study volunteers. While the activities defined do not necessarily represent the time volunteers were actively engaged in constant contact with the animal as is implicit in the post-application dermal and incidental oral algorithms, the data are the most accurate representation of time spent with pets available and, therefore, it is assumed that contact is continual throughout the timed activity. The distribution for exposure time for children 1 < 2 years old is provided in *Table 8-5* and adults in *Table 8-6*. **The recommended point estimate for use in post-application dermal exposure assessments, 1.0,** represents approximately the arithmetic mean. A description of the input and study can be found in *Section D.7.4 Appendix D*.

Table 8-5: Daily Exposure Time (ET) with Pets (Children 1 < 2 years old)

Statistic	Time (hours)
5th percentile	0.05
25th percentile	0.5
50th percentile	1.0
75th percentile	1.5
90th percentile	2.3
95th percentile	2.3
AM (SD)	1.0 (0.74)

AM (SD) = arithmetic mean (standard deviation)

Data presented for children 1 < 4 years old from Tsang and Klepeis, 1996 (as presented in the 1997 Exposure Factors Handbook).

Table 8-6: Daily Exposure Time (ET) with Pets (Adults)

Statistic	Time (hours)
5th percentile	0.05
25th percentile	0.17
50th percentile	0.5
75th percentile	1.0
90th percentile	1.8
95th percentile	2.5
AM (SD)	0.77 (1.1)

AM (SD) = arithmetic mean (standard deviation)

Data presented for adults 18-64 years old from Tsang and Klepeis, 1996 (as presented in the 1997 Exposure Factors Handbook).

Application Rate (AR)

The pesticide label should be used to determine the amount of active ingredient used during each treatment. The maximum application rates allowed by labels are always considered in risk assessments. For pet pesticide formulations which specify application rate in relation to animal weight (i.e., spot-ons), a rate should be quantified for small, medium and large weight classifications as assigned by the Agency. The weight ranges are as follow:

- Cats – Small (up to 5 lbs), Medium (6 to 12 lbs), Large (13 lbs and up).
- Dogs - Small (up to 20 pounds), Medium (21 to 50 lbs) and Large (51 lbs and up).

Many application methods of pet pesticides (i.e., dips, shampoos and aerosol/trigger sprays) are not specific about application rate in relation to pet weight. **If not specified, then it should be assumed that 1/2 of the contents of the can or bottle of product is applied** to the pet based on professional judgment. The majority of pet collar formulations are registered as a single collar for use on all animal weight ranges with directions to fit the collar to the treated animal and trim off the excess length. Because the trimmed length and corresponding active ingredient loss cannot be determined, the maximum application rate of the collar as labeled should be assumed for assessment of post-application risk.

Surface Area (SA)

Animal surface area (SA) is determined by inputting animal weight (lbs) into an algorithm (12.3*((animal body weight (lbs)*454)^0.65)) as referenced from U.S. EPA (1993) Wildlife Exposure Factors Handbook. Representative surface areas have been calculated for the assigned cat and dog weight ranges. The surface areas for assessment are as follows:

- Cats – Small (1500 cm^2), Medium (2500 cm^2) and Large (4000 cm^2).
- Dogs – Small (3000 cm^2), Medium (7000 cm^2) and Large (11000 cm^2).

Future Research/Data Needs

Areas of research and data needs for the assessment of post-application dermal exposure from treated pets include:

- Product survey data could be useful in refinement of the Agency's current, high-end assumptions for use patterns of particular pet pesticide application methods.
- Studies conducted to determine residue transfer occurring from actual adult and child activities with treated pets could provide a more realistic estimate of transfer (TC)
- Activity durations and pet contacts (either video or reported recordings) would help the Agency to refine its exposure time assumption.

Exposure Characterization and Data Quality

- Information on the amount of product applied to the animal for particular application methods (e.g., aerosol and trigger sprays, powders/dusts and shampoos) is largely unavailable. Due to the lack of specific product labeling and the lack of data to inform typical application method use patterns, the Agency assumes that ½ of the can or bottle can be applied for each animal based on best professional judgment. This estimate is

considered a high-end assumption resulting in a health-protective exposure estimate.

- The Agency did not identify any studies which were conducted to capture the range of exposures which could occur as a result of normal residential interactions with a treated pet. While studies were conducted to determine the fraction of the application rate transferred from the treated pet to an exposed person, these data are limited in that they used scripted activity patterns (i.e., petting) and only measured exposure to the hands of the study participants. Thus, these studies are limited for assessing exposure from actual activities to the whole body of people contacting treated pets. As a result of these limitations, EPA recommended the use of applicator and groomer studies that are assumed to represent vigorous contact with an animal. These activities are likely to result in higher, more consistent and reliable contact factors than petting, hugging or sleeping with a pet and, therefore, were used to derive a TC assumed to be health-protective.
- The exposure time (ET) assumed by the Agency represents daily contact associated with pet care (i.e., feeding, playing, walking, etc.). The NCEA data include the entirety of time spent daily, including high, as well as low contact activities. Therefore, the Agency believes that the recommended point estimates for children and adults (1.0 and 0.77 hours per day of continual exposure, respectively) in conjunction with high-end TCs derived from groomer studies, represents a health-protective estimate of adult and child exposure to a treated pet. Furthermore, the study was the only identified by the Agency which specifically monitored human activity duration, as well as contact with pets and is therefore the best available source of data.

8.2.3 Post-application Non-Dietary Ingestion Exposure Assessment: Hand-to-Mouth

This SOP provides a standard method for estimating the potential dose from incidental ingestion of pesticide residues from previously treated pets. Considering the strengths and limitations of available data and behavioral characteristics of potentially exposed lifestages, exposure for children is calculated in this scenario. This scenario assumes that pesticide residues are transferred to the skin of children contacting treated pets and are subsequently ingested as a result of hand-to-mouth transfer.

Post-application Hand-to-Mouth Exposure Algorithm

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

$$E = \left[HR * \left(F_M * SA_H\right) * \left(ET * N_Replen\right) * \left(1 - \left(1 - SE\right)^{\frac{Freq_HtM}{N_Replen}}\right)\right] \qquad (8.6)$$

where:

E	= exposure (mg/day);
HR	= hand residue loading (mg/cm^2);
SA_H	= surface area of one child hand (cm^2);
F_M	= 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

$$HR = \frac{Fai_{hands} * DE}{SA_H * 2} \quad (8.7)$$

where:

HR = hand residue loading (mg/cm^2);
DE = dermal exposure (mg);
Fai_{hands} = fraction of a.i. on hands compared to total residue from dermal transfer coefficient study (unitless); and
SA_H = surface area of one child hand (cm^2).

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

$$D = \frac{E}{BW} \quad (8.8)$$

where:

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

Post-application Hand-to-Mouth Exposure Algorithm Inputs and Assumptions

Recommended values for post-application hand-to-mouth exposure assessments are provided in *Table 8-7* below. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 8-7: Pet Treatments – Recommended Hand-to-Mouth Exposure Factor Point

Algorithm Notation	Exposure Factor (units)		Point Estimate(s)
Fai_{hands}	Fraction of a.i. on hands from transfer coefficient studies (unitless)		Solid = 0.37 Liquid = 0.040
F_M	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	Mean = 20

Table 8-7: Pet Treatments – Recommended Hand-to-Mouth Exposure Factor Point			
SA_H	Typical surface area of one child hand (cm^2)	Children 1 < 2 years old	150
BW	Body Weight (kg)	Children 1 < 2 years old	11.4

Fraction Active Ingredient on the Hands (Fai_{hands})

The fraction of active ingredient available on the hands was based on the two dermal pet transfer coefficient studies that represent application and grooming activities with dogs and used to derive dermal TCs. One study used a carbaryl shampoo product (Mester, 1998) and the other a carbaryl dust product (Merricks, 1997). These values were determined for liquid and solid formulations, respectively, by taking the average fraction of active ingredient on the hands and comparing that value to the average fraction of active ingredient on the entire body. This analysis resulted in **values of 4% for liquid formulations and 37% for solid formulations**.

Hand Residue Loading (HR)

Link hand loading to dermal exposure and assume the percent on the hands is equal to the percent of the residue on the hands from dermal transfer coefficient studies.

Fraction Hand Surface Area Mouthed (F_M)

See *Section 2.4* for discussion of fraction hand surface area mouthed. The **recommended F_M value for use in post-application non-dietary ingestion exposure assessments, 0.13**, represents approximately the arithmetic mean.

Hand Surface Area (SA_H)

The hand surface area for **children 1 < 2 years old of 150 cm^2**, for one hand, was based on values from the Exposure Factors Handbook 2011 Edition (U.S. EPA, 2011).

Exposure Time (ET)

The exposure time (ET) for children exposed to pesticide treated pets is assumed to be the same as described in *Section 8.2.2* for post-application dermal exposure. The **recommended point estimate for use in post-application non-dietary ingestion exposure assessment 1.0** represents approximately the arithmetic mean.

Replenishment Intervals per Hour (N_Replen)

This SOP assumes an estimate of 4 replenishment intervals per hour (i.e., residues on the hand will be replenished every 15 minutes). This value was selected as a conservative assumption based on the use of 30 minutes in the SHEDS model to coincide with the CHAD diaries.

Fraction of Pesticide Extracted by Saliva (SE)

See *Section 2.6* of this SOP for discussion of fraction of pesticide extracted by saliva distribution. The **recommended value for use in post-application non-dietary ingestion exposure assessments, 0.48**, represents approximately the arithmetic mean.

Hand-to-Mouth Events per Hour (Freq_HtM)

Frequency of hand-to-mouth events is an important variable for post-application non-dietary ingestion exposure assessments. However, there are currently no data available that specifically address the number of hand-to-mouth events that occur relative to the amount of time a child spends with a pet. As a result, the estimates for frequency of hand-to-mouth events in indoor environments from the Xue et al. (2007) meta-analysis were used as a surrogate. The indoor data were selected, even though child exposure to treated pets can occur either indoors or outdoors, because the indoor data result in a greater frequency of contacts. Therefore, using these data are the most conservative and thus the most health protective estimate of exposure. The pet SOP uses hand-to-mouth frequency data for the children 1 < 2 years old lifestage. *Table 8-8* provides distributions and point estimates of hand to mouth events for use in residential pesticide exposure assessment and *Appendix D.10.1*. The **recommended point estimate for use in post-application non-dietary exposure assessments, 20**, represents the arithmetic mean for children 1 < 2 years old.

Table 8-8: Frequency of Hand-to-Mouth Events (events/hr)

Statistic	Children 1 < 2 years old
5th percentile	0
25th percentile	6
50th percentile	14
75th percentile	27
95th percentile	63
AM (SD)	20 (20)
GM (GSD)	--[a]
Range	--[a]
N	245

AM (SD) = arithmetic mean (standard deviation)
GM (GSD) = geometric mean (geometric standard deviation)
[a] Not provided

Future Research/Data Needs

Information that would help refine the incidental ingestion scenario includes

- Additional videography data could be collected focusing on the number of hand-to-mouth events which occur in relationship to the amount of time a child spends with a pet.

Exposure Characterization and Data Quality

- While not specific to child activity with treated pets, the inputs used for incidental oral exposure estimates from contact with pets are reasonable. The inputs identified for the estimation of child incidental ingestion of pesticides from exposure to a treated pet reflect general activity and behavior patterns exhibited by children and are unlikely to vary based on the object being contacted (i.e., frequency of hand to mouth events per hour and the surface area of the hand mouthed).
- The Agency currently assumes that children are exposed to a treated pet for 1.0 hours per day based on a study conducted to analyze the behaviors of adults and children in residential, household settings. As described in *Section 8.2.2*, the Agency believes that this represents a health-protective estimate of child exposure to a treated pet since it is based upon assumptions of continual contact and is paired with high-end TCs from

applicator and groomer studies.

8.2.4 Combining Post-application Scenarios

Risks resulting from different exposure scenarios are combined when it is likely that they can occur simultaneously based on the use pattern and when the toxicological effects across different routes of exposure are the same. When combining scenarios, it is important to fully characterize the potential for co-occurrence as well as characterizing the risk inputs and estimates. Risks should be combined even if any one scenario or route of exposure exceeds the level of concern because this allows for better risk characterization for risk managers.

It is likely that children could be exposed to a treated pet via post-application dermal and non-dietary ingestion (hand-to-mouth) routes and that these scenarios could occur simultaneously. Therefore, these exposure scenarios should be combined when toxicological effects are the same across these routes of exposure.

Section 9 Impregnated Materials

This section provides methodologies for assessing pesticide exposures from pesticide impregnated materials, including textiles (e.g. clothing, mattress linings, upholstery, etc.), carpets, flooring, and plastic materials. The exposure assessment methodologies provide a general approach and conceptual framework for evaluating a broad range of impregnated materials. Therefore, it is recommended that exposure assessors evaluate whether the methods outlined in this section represent the specific type of impregnated materials under assessment and review exposure assessment methodologies established by the World Health Organization's International Programme on Chemical Safety for treated bednets and other appropriate regulatory agencies (WHO/IPCS, 2004).

When assessing pesticide exposure from impregnated materials, the primary exposure routes that may need to be addressed include post-application dermal absorption and non-dietary ingestion. Exposure from these routes may result in pesticide exposures in the general population. However, some population groups, such as military personnel, outdoor workers, and children, may display activity patterns that have the potential to result in higher levels of exposure (e.g., military personnel and outdoor workers who wear impregnated clothing for extended periods of time, children who display hand-to-mouth activity), which may need to be addressed more explicitly when performing exposure assessments.

Before developing an exposure assessment for an impregnated material, the appropriate exposure scenarios should be identified using information on the product's pesticide label. Specific label information that should be considered is described below.

- **Impregnated Materials with Pesticidal Claims:** Some impregnated materials contain conventional pesticides and have a pesticide label. The labels of such products make claims about pest control, such as "repels fleas and ticks" or "repels flying insects." These labels contain information on the active ingredient and should be used when performing exposure assessments using the methods described in this chapter.

- **Impregnated Materials with No Pesticidal Claims:** Many impregnated materials (e.g., mattress covers, shower curtains, paper, and adhesives) contain biocide pesticides and do not require a pesticide label. The pesticide in these products is present as a biocide, which is added during the manufacturing process. Biocides are more routinely assessed by OPP's Antimicrobial Division (OPP/AD) and are not addressed in this chapter.

- **Limiting and Descriptive Statements:** It should be assumed that impregnated products may be used in non-occupational settings, unless otherwise indicated on the label. Examples of labels that may appear on products that are intended for non-occupational settings include:

    - Insect repellent apparel;

- For treatment of nets, tents, sleeping bags; and
- For fabric product on and around beds.

9.1 Handler Exposure Assessment

For impregnated materials treated with non-biocide pesticides (e.g. insecticides and repellents), exposure during the manufacturing process is not typically assessed by EPA.[16] There are some situations following the treatment process, however, where individuals may contact large volumes of impregnated material. The handling of impregnated materials following the treatment process is addressed in the post-application dermal exposure scenario described in *Section 9.2.3*.

9.2 Post-Application Exposure Assessment

Post-application exposure can result from contacting impregnated materials, such as wearing pesticide impregnated clothing and hand- or object-to-mouth behavior. Depending on the application of the impregnated material, potential exposed populations include both adults and children. While exposure may occur for people of all ages, adults and children 1 < 2 years old are considered the index lifestages based on behavioral characteristics and the strengths and limitations of available data.

This section addresses standard methods for estimating exposure and dose for four post-application scenarios resulting from pesticide impregnated materials:

- Section 9.2.1 – inhalation exposures;
- Section 9.2.3 – adult/children 1 < 2 years old dermal exposures;
- Section 9.2.4 – children 1 < 2 years old non-dietary ingestion via object-to-mouth activity; and
- Section 9.2.5 – children 1 < 2 years old non-dietary ingestion via hand-to-mouth activity.

9.2.1 Post-Application Inhalation Exposure Assessment

In most cases inhalation exposure from impregnated materials is expected to be negligible, since many pesticides that are used in impregnated materials have relatively low vapor pressures. As a result, inhalation exposure is not expected to result in appreciable exposure when compared with dermal and non-dietary ingestion exposure, and is not explicitly addressed in these SOPs.

9.2.2 Post-Application Surface Residue Concentration

When assessing dermal and non-dietary ingestion scenarios, the product label and registrant should be consulted to obtain information on the surface residue concentration in terms of active

[16] Safety issues associated with potential chemical exposure during the manufacturing process are more typically addressed by the Occupational Safety and Health Administration, but may also be addressed in the occupational pesticide exposure assessment.

ingredient (a.i.) that is present on the surface area of the impregnated material (e.g. mg a.i./ cm^2). In some cases, however, information on surface residue concentration may only be available in terms of percent a.i. in terms of total product mass (e.g. Fraction of a.i. in treated material). In these cases, surface residue concentration can be estimated by finding the product of the weight fraction of a.i. in treated material and the material's weight:surface area density (See *Table 9-1*), as illustrated in the equation below.

$$SR = WF * MD \quad (9.1)$$

where:

SR = Surface residue concentration (mg a.i./cm^2);
WF = Weight fraction of a.i. in treated material (% a.i. w/w); and
MD = Material weight:surface area density (mg material/cm^2).

Table 9-1: Recommended weight-to-surface area values for selected fabrics/materials

Material	Material Weight:Surface Area	Source
Textiles		
Cotton [a]	20 mg/cm^2	Unpublished Henkel data from HERA (2005)
Light Cotton/Synthetic Mix [a]	10 mg/cm^2	Unpublished Proctor & Gamble data from HERA (2005)
Heavy Cotton/Synthetic Mix	24 mg/cm^2	Nylon/cotton battle dress uniform data published in Snodgrass (1987)
All Synthetics	1 mg/cm^2	Unpublished Proctor & Gamble data from HERA (2005)
Carpets		
Household Carpets	120 mg/cm^2	USAF (2003)
Hard Surfaces and Plastics		
Plastic Polymers	100 mg/cm^2	OPP/AD information on a polyethylene highchair
Vinyl Flooring	390 mg/cm^2	OPP/AD information on the density (1300 mg/cm^3) and thickness (0.3 cm) of polyvinyl chloride tiling

[a] Comparable weight:surface area ratio values are also reported for cotton and cotton/synthetic sheets analyzed in a submitted study (Rudenko, L. (2000), EPA MRID 45256001).

Regardless of how residue concentration is reported, the value used in post-application exposure assessments should always be based on the maximum concentration reported on a product's label. This approach may overestimate potential exposure since the concentration of pesticide residue is expected to decrease over time due to laundering (textiles only) and dissipation over time. With regard to textiles, for example, it has been demonstrated that 20 – 30 percent of pesticide can be removed after first laundering (Snodgrass, 1992) and as high as 90 percent of pesticide residue is removed after twenty launderings (Faulde et al., 2003).[17] Similarly, some pesticide residue in impregnated materials, including both textiles and hard surfaces (e.g. flooring, linings, and plastics), may dissipate through decay and weathering over time. Since laundering and dissipation are not specifically incorporated, or otherwise accounted for, in the post-application exposure assessment methods, the approach used to estimate surface residue

[17] These percent changes were approximated from a graphical chart presented in Faulde et al. (2003).

concentration is believed to be health protective because it is assumed that no pesticide residue is lost due to laundering or dissipation and individuals are always exposed to the maximum concentration listed on the label.

9.2.3 Post-Application Dermal Exposure Assessment

This SOP provides methods for estimating adult and children 1 < 2 years old post-application dermal exposure. In contrast to the SOPs for other exposure scenarios, the method for determining post-application dermal dose is based on the amount of pesticide that may be transferred to the skin during continuous contact with an impregnated material, such as wearing impregnated clothing or sleeping on a bed with an impregnated mattress liner.

Post-Application Dermal Exposure Algorithm

Post-application dermal exposure is calculated as follows:

$$E = SR * SA / BW * F_{Body} * TE * PF \quad (9.2)$$

where:

- E = Daily exposure rate (mg/kg-day);
- SR = Surface residue concentration (mg/cm^2);
- SA/BW = total body surface area to body weight ratio (cm^2/kg);
- F_{Body} = clothing-dependent fraction of body exposed (fraction exposed);
- TE = Daily material-to-skin transfer efficiency (fraction/day); and
- PF = Protection factor to account for the presence of a single layer of fabric (e.g. clothing, bed sheet, etc.) between the impregnated material and individual (unitless).

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

$$D = E * AF \quad (9.3)$$

where:

- D = Dose rate (mg/kg-day);
- E = Daily exposure rate (mg/kg-day); and
- AF = Dermal absorption factor.

Post-application dermal exposure from impregnated materials is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4*, such as residue dissipation, product-specific re-treatment intervals, and activity patterns. If longer-term assessments (i.e., intermediate-, long-term, or lifetime exposures) are deemed necessary, such as in cases where the impregnated material may be routinely replaced or re-treated, or used on a continuous basis, similar refinements to more accurately reflect the exposure profile are recommended.

Post-Application Dermal Exposure Assessment Inputs and Assumptions

Recommended values for post-application dermal exposure assessments of impregnated materials are provided in *Table 9-2*. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 9-2: Summary of recommended values for post-application dermal exposure assessment.

Algorithm Notation	Exposure Factor (Units)		Recommended Input Values
SR	Residue Concentration (mg a.i. /cm^2)		Label
WF	Percent A.I. by Weight (% w/w)		Label
MD	Material weight:surface area density (mg/cm^2)	Textile: Cotton	20
		Textile: Light Cotton/Synthetic Mix	10
		Textile: Heavy Cotton/Synthetic Mix	24
		Textile: All Synthetics	1
		Household Carpets	120
		Plastic Polymers	100
		Vinyl Flooring	390
SA/BW	total body surface area to body weight ratio (cm^2/kg)	Adult	280
		Children 1 to < 2 years old	640
F_{Body}	Fraction of body exposed	Pants, Jacket, or Shirts	0.50
		Total Body Coverage	1.0
		Mattresses, Carpets, or Flooring	0.50
		Handlers	0.11
TE	Daily Material-to-Skin Transfer Efficiency (fraction/day)	Textiles or Carpeting	0.06
		Flooring or Hard Surfaces	0.08
PF	Protection Factor	Protective layer present (Mattresses)	0.50
		Protective layer not present	1.0

Surface Residue Concentration (SR)

Surface residue concentration is the concentration of pesticide residue on the surface of an impregnated material. Product-specific information, such as weight fraction of a.i., should be used to estimate the residue concentration. This information may be found on labels or other information provided by the registrant/manufacturer. After obtaining this information, the surface residue concentration can be estimated using the methods described in *Section 9.2.2*.

Fraction of Body Exposed (F)

Fraction of body that contacts residue should be representative of the parts of the body that are expected to frequently contact the impregnated material. *Table 9-3* provides the recommended inputs for assessing exposures from impregnated textiles, including jackets/shirts, total body coverage, and garment workers who may handle large volumes of clothing during their workday, and exposures from impregnated carpets, flooring, and hard surfaces. The recommended values are based on the surface area of different parts of the body and judgment about the fraction of the body that could potentially be exposed to different garments and surfaces. An impregnated shirt

or pants, for example, contacts roughly half of the body. Similarly, it is assumed that no more than half of the body contacts a mattress, carpet, or flooring. This assumption recognizes that the entire surface of the body has the potential to contact an impregnated surface. It is believed to be a reasonable assumption because it is unlikely that more half the body can contact a surface at a given time (e.g. roughly half of the body is in contact with a mattress when sleeping).

Table 9-3: Recommended input values for fraction of body surface area that contacts residue.		
Exposure Scenario (s)	**Representative Body Part**	**Fraction of Body**
Pants, Jacket, or Shirts	50 percent of total body	0.50
Mattresses, Carpets, or Flooring	50 percent of total body	0.50
Total Body Coverage	Complete upper and lower torso	1.0
Handlers	Hands and Forearms [a]	0.11

[a] Derived using percent of body surface area exposed for hands and forearms from *Table 6- 7.*

Daily Material-to-Skin Transfer Efficiency (TE)

Daily material-to-skin transfer efficiency is the percent of pesticide residue that is transferred from an impregnated material to an individual's skin during a one-day period. There is currently only limited data available to characterize the daily material-to-skin pesticide transfer efficiency for impregnated materials. In the absence of application-specific data, the amount of material-to-skin transfer can be determined using a worst-case screening where it is assumed that all of the a.i. that is available on the surface of an impregnated material is transferred to the skin.

For refinement a lower fraction of residue is assume transferred, based on data on the fraction of a.i. that is available for transfer after carpet or hard surface pesticide treatment. Based on this approach, daily material-to-skin transfer efficiency values have been estimated using more recent data on the fraction of a.i. that is available for transfer from carpets and hard surfaces, which is described in the indoor exposure assessment SOPs provided in *Section 7.2.2* of the *Indoor Environments Section*. **Based on the data, the recommended values for textiles/carpets and hard surfaces are 0.06 and 0.08 per day, respectively.**

Table 9-4: Recommended daily material-to-skin transfer efficiency values for textiles and hard surfaces.	
Material	**Daily Material-to-Skin Transfer Efficiency**
Textiles or Carpeting	0.06/day
Flooring or Hard Surfaces	0.08/day

While this approach has its limitations, it is expected to overestimate dermal exposure to impregnated materials. This is because the default material-to-skin transfer efficiency rates are based on data from carpets and hard surfaces that have had a pesticide applied to their external surface only. A lower fraction of pesticide is expected to be available for transfer because the pesticide compound is impregnated to the material and believed to have a lower potential for transfer. Additionally, the limited data that are available suggest that the material-to-skin transfer rate may more typically be an order of magnitude lower than the recommended values. Specifically, data that are available to characterize material-to-skin transfer efficiency from impregnated materials are described in more detail below.

- **Permethrin-Treated Clothing:** Snodgrass (1992) characterized the material-to-skin transfer rate for permethrin-treated battle-dress uniforms (BDUs). In this study, which

was subsequently incorporated into the National Research Council's assessment of permethrin-impregnated BDUs (National Research Council, 1994), radiolabeled (^{14}C) permethrin-treated fabric patches were applied to the backs of 22 male New Zealand white rabbits in four treatment groups based on environment (temperate vs. subtropical) and fabric type (cotton vs. 50:50 nylon/cotton blend). After seven days, the average percent migration to skin for each treatment group was estimated using the recovery of ^{14}C from excreta and skin. Based on this approach, the overall fraction of a.i transferred per day was 0.005 and ranged from an average ± standard deviation of 0.004 ± 0.09 fraction a.i. transferred per day in the subtropical/NYCO group to 0.0065 ± 0.10 fraction of a.i. transferred per day in the subtropical/cotton treatment group.

- **TBTM-Treated Carpets:** In a leaching study (MRID 45746802), tri-n-butyltin maleate (TBTM)-treated carpets swatches were immersed in alkaline and acidic simulated sweat solutions to determine the maximum amount of TBTM that may leach from treated carpets in 2-hour and 24-hour periods. In the study, the highest percent leaching was observed in saline and alkaline (pH 9.2) simulated sweat solutions and the overall average leaching during the 24-hour period (9.0%) was approximately 1.8 times greater than the overall average leaching during the 2-hour period (5.1%). However, the continuous 24-hour immersion method used in the study is likely to overestimate exposure from dermal contact with an impregnated material, since it represents the amount of residue that leaches from a material when placed in solution (Evans, 2005).

Table 9-5: Summary statistics for 24-hour material-to-skin transfer rates for Impregnated Clothing (Snodgrass, 1992) and Mattresses/Bedding (MRID 45256001).

Source	Treatment Group	n	24-hour material-to-skin transfer efficiency (fraction/day)					
			Mean ± SD	Percentile				Range
				50th	75th	90th	95th	
Permethrin BDUs (Snodgrass, 1992)	All Groups	18	0.005± 0.006	0.005	0.006	0.007	0.008	0.003 – 0.008
TBTM Carpets (MRID 45746802)	2-Hour	12	0.05± 0.02	0.05	0.07	0.07	0.08	0.02 – 0.10
	24-Hour	12	0.09 ± 0.04	0.09	0.11	0.14	0.15	0.05 – 0.15

When compared to the limited available transfer data, the recommended generic inputs result in conservative estimates of exposure. The range of 24-hour transfer efficiency values from Snodgrass (1992), for example, ranged from 0.003 – 0.008 fraction a.i. transferred per day and are around an order of magnitude lower than values recommended in *Table 9-4*.[18] Therefore, in the absence of chemical-specific data, it is believed that the recommended approach provides a conservative estimate of transfer efficiency.[19]

Exposure assessors should note that the recommended default values may not be appropriate for all type of impregnated materials. If it is determined that the default values may not be

[18] The study on TBTM-treated carpets found an average 24-hour leaching fraction of 9.0%. As previously indicated, however, the study was an extraction study which is likely to overestimate exposure from dermal contact (Evans, 2005).

[19] While it is emphasized that the available data are not sufficient to derive a generic transfer fraction for all possible chemicals, it is also acknowledged that it may be appropriate to derive transfer efficiency values from the summarized data sources when assessing materials impregnated with permethrin.

appropriate and underestimate exposure, additional data may need to be requested to refine the estimate of the transfer efficiency value.

Body Weight and Surface Area

The exposure algorithm uses surface area (SA) and body weight (BW) as a ratio instead of as two separate factors. **The recommended point estimate ratio for adults is 280 cm^2/kg and 640 cm^2/kg for children 1 < 2,** from the Exposure Factors Handbook 2011 Edition, Table 7-15 (U.S. EPA, 2011).

Protection Factor (PF)

Bed sheets and other fabrics can act as a protective barrier when placed between an impregnated surface and an exposed individual's skin. The protection factor, therefore, accounts for a decrease in pesticide residue transfer that is expected when bed sheets or other protective barriers are present. In these cases, the recommended input value is 0.50- meaning that it is assumed that only 50% of the available pesticide residue is transferred from the material to the potentially exposed individual's skin. This default value is based on the PHED protection factor for a single layer of clothing and is also used by OPP/AD when conducting biocide exposure assessments involving mattresses. In cases other than mattresses, it should generally be assumed that no protective barrier is present. When no protective barrier is present, the recommended input value is 1.0.

Future Research/Data Needs

- There is currently only limited data available to characterize the daily material-to-skin pesticide transfer efficiency for impregnated materials. While recommended methods are believed to provide health-protective estimates of exposure, additional research is needed to more fully characterize the dermal transfer of pesticide residue from impregnated materials.
- Survey data on the use patterns of impregnated materials could also help further characterize exposure.

Exposure Characterization and Data Quality

- Due to insufficient exposure data on impregnated materials, the exposure assessment scenarios presented in this chapter are based on data on externally treated surfaces that may not be completely representative of impregnated materials. As a consequence, the methods rely on conservative assumptions that cannot be completely characterized quantitatively. These assumptions include: 1) laundering and dissipation are not accounted for in the algorithm, so it is assumed that individuals are continually exposed to the maximum surface residue concentration; and 2) daily material-to-skin transfer efficiency was characterized using data on residue transfer from treated surfaces, rather than impregnated materials.

9.2.4 Post-Application Non-Dietary Ingestion Exposure Assessment: Object-to-Mouth (Textiles Only)

This SOP provides the methods for assessing non-dietary object-to-mouth ingestion of pesticide residues from impregnated materials by children. In general, object-to-mouth exposure assessments should be used to assess non-dietary exposure to impregnated textiles (e.g. clothing and other impregnated fabrics), but not other impregnated materials, such as carpeting and flooring, which are less likely to be mouthed.

Non-Dietary Object-to-Mouth Ingestion Algorithm

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

$$E = \left[OR * CF1 * SAM_O * \left(ET * N_Replen \right) * \left(1 - \left(1 - SE \right)^{\frac{Freq_OtM}{N_Replen}} \right) \right] \quad (9.4)$$

where:

E	= exposure (mg/day);
OR	= chemical residue loading on an object (µg/cm^2);
CF1	= weight unit conversion factor (0.001 mg/µg);
SAM_O	= area of the object surface that is mouthed (cm^2/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

$$OR = SR * F_O \quad (9.5)$$

where:

OR	= chemical residue loading on the object (µg/cm^2);
SR	= surface residue (µg/cm^2); and
F_O	= fraction of residue available on the object (unitless).

Non-dietary oral dose, normalized to body weight, is then calculated as:

$$D = \frac{E * AF}{BW} \quad (9.6)$$

where:

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

Post-application object-to-mouth exposure from impregnated materials is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4*, such as residue dissipation, product-specific re-treatment intervals, and activity patterns. If longer-term assessments (i.e., intermediate-, long-term, or lifetime exposures) are deemed necessary, similar refinements to more accurately reflect the exposure profile are recommended.

Non-Dietary Object-to-Mouth Exposure Assessment Inputs and Assumptions

Recommended values for non-dietary object-to-mouth ingestion exposure assessments are provided in *Table 9-6*. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 9-6: Summary of recommended values for non-dietary object-to-mouth ingestion exposure assessment.

Algorithm Notation	Exposure Factor (units)		Recommended Value
SR	Residue Concentration ($\mu g/cm^2$)		Maximum labeled rate
WF	Percent A.I. by Weight (WF) (% w/w)		Maximum labeled rate
MD	Material weight:surface area density (mg/cm^2)	Cotton	20
		Light Cotton/Synthetic Mix	10
		Heavy Cotton/Synthetic Mix	24
		All Synthetics	1
F_O	Fraction of AR as OR following application	Carpets	0.06
		Hard surfaces	0.08
SAM_O	Surface area of object mouthed per event (cm^2/event)		10
N_Replen	Replenishment intervals per hour (intervals/hour)		4
SE	Saliva extraction factor		0.48
ET	Exposure Time (hours per day)	Indoor Environments (Children 1 < 2 years old)	4
		Outdoor Environments (Children 1 < 2 years old)	1.5
Freq_OtM	Object-to-mouth events per hour (events/ hour)	Indoor Environments (Children 1 < 2 years old)	14
		Outdoor Environments (Children 1 < 2 years old)	8.8
BW	Body Weight (kg)	Children 1 < 2 years old	11.4

Surface Residue Concentration (SR)

Surface residue concentration is the concentration of pesticide residue on the surface of an impregnated material. Product-specific information, such as weight fraction of a.i., should be used to estimate the residue concentration. This information may be found on labels or other information provided by the manufacturer. After obtaining this information, the surface residue concentration can be estimated using the methods described in *Section 9.2.2*.

Fraction of Residue Available on the Object (F_O)

For this SOP, it is assumed that the residue that could be transferred to the object is the same as what is available for dermal transfer. As a result, the fraction of residue available for transfer assumed for dermal exposure for both carpets and hard surfaces should be used, which is provided in *Section 7.2.2*.

Surface area of object mouthed (SAM_O)

Surface area of object mouthed (SAM_O) is the area of an impregnated object that may contact a child's mouth during mouthing behavior. SAM_O is a universal exposure factor that is described in more detail in *Section 2.5*. **The recommended value for use in exposure assessments is 10 cm^2/event.**

Replenishment interval (N_Replen)

This SOP assumes an estimate of 4 replenishment intervals per hour (i.e., residues on the hand will be replenished every 15 minutes). This value was selected as a conservative assumption based on the use of 30 minutes in the SHEDS model to coincide with the CHAD diaries.

Fraction of Pesticide Extracted by Saliva (SE)

See *Section 2.6* of this SOP for discussion of the fraction of pesticide extracted by saliva distribution. **The recommended point estimate for use in post-application incidental oral exposure assessments is 0.48.**

Exposure Time (ET)

Exposure time is the amount of time that a child is an environment where they may contact a surface containing an impregnated material. There is currently no data available to characterize the amount of time that children spend in indoor and outdoor environments where they may contact impregnated materials. In the absence of scenario-specific data, recommended exposure time value for exposures that may occur in indoor environments is based on the children 1 < 2 years old exposure time values discussed in *Section 7.2.4* of the Indoor Environment SOPs. Similarly, the recommended exposure time for outdoor environments is based on the children 1 < 2 years old exposure time values discussed in *Section 3.2.4* of the Lawn/Turf SOP.

Object-to-Mouth Events (Freq_OtM)

Frequency of object-to-mouth events is the number of mouthing events that occur per hour. There is currently no data available that specifically address the number of object-to-mouth events that occur relative to the amount of time a child is in contact with an impregnated material. As a result, the estimate for frequency of object-to-mouth events in outdoor

environments is based on the Xue et al. (2007) meta-analysis of object-to-mouth behavior that has previously been summarized in *Section 3.2.4* of the Lawns/Turf SOPs. Similarly, the estimate for frequency of object-to-mouth events in indoor environments is based on the Xue et al. (2010) meta-analysis of object-to-mouth behavior that is summarized in *Section 7.2.4* of the Indoor Environment SOPs.

Future Research/Data Needs

Future research priorities should include:

- Developing a database of studies which characterize pesticide transfer from impregnated materials to skin and objects that could mouthed by toddlers. An important focus should be on charactering the transfer of pesticide residue from impregnated materials following mouthing behavior by young children and toddlers. Collecting this transfer data is important because mouthing behavior and saliva extraction is believed to be the most important drivers of non-dietary ingestion from object-to-mouth exposure.

Exposure Characterization and Data Quality

- Due to insufficient exposure data on impregnated materials, the exposure assessment scenarios presented in this chapter are based on data on externally treated surfaces that may not be completely representative of impregnated materials. As a consequence, the methods rely on conservative assumptions that cannot be completely characterized quantitatively. These assumptions include: 1) laundering and dissipation are not accounted for in the algorithm, so it is assumed that individuals are always exposed to the maximum surface residue concentration; and 2) daily material-to-skin transfer efficiency was characterized using data on residue transfer from treated surfaces, rather than impregnated materials.

9.2.5 Post-Application Non-Dietary Ingestion Exposure: Hand-to-Mouth (Carpets, Flooring, and Hard Surfaces Only)

This SOP provides the methods for assessing non-dietary hand-to-mouth ingestion of pesticide residues from impregnated materials by toddlers. In general, hand-to-mouth exposure assessment should be performed when assessing impregnated carpets, flooring, and hard surfaces, since infants may routinely contact these objects with their hands.

Non-Dietary Hand-to-Mouth Ingestion Exposure Algorithm

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

$$E = \left[HR * \left(F_M * SA_H\right) * \left(ET * N_Replen\right) * \left(1 - \left(1 - SE\right)^{\frac{Freq_HtM}{N_Replen}}\right)\right] \qquad (9.7)$$

where:

E = exposure (mg/day);
HR = hand residue loading (mg/cm^2);
F_M = fraction hand surface area mouthed / event (fraction/event);

SA_H = surface area of one hand (cm^2);
ET = exposure time (hr/day);
N_Replen = number of replenishment intervals per hour (intervals/hour);
SE = saliva extraction factor (ie, mouthing removal efficiency); and
Freq_HtM = number of hand-to-mouth contacts events per hour (events/hour).

In this algorithm, hand residue concentration is calculated as:

$$HR = SR * F_H \quad (9.8)$$

where:
HR = hand residue concentration (mg/cm^2);
SR = surface residue ($\mu g/cm^2$); and
F_H = fraction ai transferred to hands.

After calculating exposure, oral dose, normalized to body weight, is calculated as:

$$D = \frac{E}{BW} \quad (9.9)$$

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

Post-application hand-to-mouth exposure from impregnated materials is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4*, such as residue dissipation, product-specific re-treatment intervals, and activity patterns. If longer-term assessments (i.e., intermediate-, long-term, or lifetime exposures) are deemed necessary, such as in cases where the impregnated material may be routinely replaced or re-treated, similar refinements to more accurately reflect the exposure profile are recommended.

Non-Dietary Hand-to-Mouth Exposure Assessment Inputs and Assumptions

Recommended values for non-dietary hand-to-mouth ingestion exposure assessments are provided in *Table 9-7*. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 9-7: Summary of recommended values for non-dietary hand-to-mouth ingestion exposure assessment.

Algorithm Notation	Exposure Factor (units)	Point Estimate(s)
SR	Surface Residue Concentration (mg a.i. /cm^2)	Product-Specific

Table 9-7: Summary of recommended values for non-dietary hand-to-mouth ingestion exposure assessment.				
				Label
WF	Percent A.I. by Weight (WF) (% w/w)			
MD	Material weight:surface area density (mg/cm^2)	Cotton		20
		Light Cotton/ Synthetic Mix		10
		Heavy Cotton/ Synthetic Mix		24
		All Synthetics		1
F_H	Fraction ai transferred to hands	Carpets		0.06
		Hard Surfaces		0.08
F_M	Fraction of hand mouthed per event (fraction/event)			0.13
SA_H	Typical surface area of one toddler hand (cm^2)			150
N_Replen	Replenishment intervals (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/hour)	Children 1 < 2 years old		20
BW	Body Weight (kg)	Children 1 < 2 years old		11.4

Surface Residue Concentration (SR)

Surface residue concentration is the concentration of pesticide residue on the surface of an impregnated material. Product-specific information, such as weight fraction of a.i., should be used to estimate the residue concentration. This information may be found on labels or other information provided by the manufacturer. After obtaining this information, the surface residue concentration can be estimated using the methods described in *Section 9.2.2*.

Fraction ai transferred to hands (F_H)

For this SOP, it is assumed that the residue that could be transferred to the object is the same as what is available for dermal transfer. As a result, the fraction of residue available for transfer assumed for dermal exposure for both carpets and hard surfaces should be used, which are provided in *Section 7.2.2* of the *Indoor Environments Section*.

Fraction of Hand Mouthed per Event (F_M)

See *Section 2.4* of this SOP for discussion of the fraction of hand mouthed. **The recommended point estimate for use in post-application incidental oral exposure assessments is 0.13.**

Hand Surface Area (SA_H)

The hand surface area for children 1 < 2 years old was based on values from the Exposure Factors Handbook 2011 Edition (U.S. EPA, 2011; Table 7-2). This value is **150 cm^2 for one hand**.

Replenishment Intervals per Hour (N_Replen)

This SOP assumes an estimate of 4 replenishment intervals per hour (i.e., residues on the hand will be replenished every 15 minutes). This value was selected as a conservative assumption based on the use of 30 minutes in the SHEDS model to coincide with the CHAD diaries.

Exposure Time (ET)

Exposure time is the amount of time that a child is an environment where they may contact a surface containing an impregnated material. There is currently no data available to characterize the amount of time that children spend in environments where they may contact impregnated materials. In the absence of scenario-specific data, recommended exposure time values are based on *Section 7.2.4* of the Indoor Environment SOPs. **For children 1 < 2 years old on carpets and hard surfaces, the recommended ET point estimates for post-application incidental oral exposure assessments are 4 and 2 hours, respectively.**

Fraction of Pesticide Extracted by Saliva (SE)

See *Section 2.6* of this SOP for discussion of the fraction of pesticide extracted by saliva distribution. **The recommended point estimate for use in post-application incidental oral exposure assessments is 0.48.**

Hand-to-mouth events (Freq_HtM)

Frequency of hand-to-mouth events refers to the number of hand-to-mouth events per hour. There is currently no data available to characterize children's hand-to-mouth behavior that is associated with impregnated materials. In the absence of scenario-specific data, recommended frequency of hand-to-mouth events is based on *Section 7.2.4* of the Indoor Environment SOPs. The estimates for frequency of hand-to-mouth events in indoor environments from the Xue et al. (2007) meta-analysis were used as a surrogate. **The recommended point estimate for use in post-application incidental oral exposure assessments is 20 events/hr.**

Future Research/Data Needs

Future research priorities should include:

- Developing a database of studies which characterize pesticide transfer from impregnated materials to skin and objects that could mouthed by toddlers. An important focus should be on charactering the transfer of pesticide residue from impregnated materials following mouthing behavior by young children and toddlers. Collecting this transfer data are important because mouthing behavior and saliva extraction is believed to be the most important drivers of non-dietary ingestion from object-to-mouth exposure.

Exposure Characterization and Data Quality

- Due to insufficient exposure data on impregnated materials, the exposure assessment scenarios presented in this chapter are based on data on externally treated surfaces that may not be completely representative of impregnated materials. As a consequence, the methods rely on conservative assumptions that cannot be completely characterized quantitatively. These assumptions include: 1) laundering and dissipation are not accounted for in the algorithm, so it is assumed that individuals are always exposed to the maximum surface residue concentration; and 2) daily material-to-skin transfer efficiency

was characterized using data on residue transfer from treated surfaces, rather than impregnated materials.

9.2.6 Combining Post-application Scenarios

Risks resulting from different exposure scenarios are combined when it is likely that they can occur simultaneously based on the use pattern and when the toxicological effects across different routes of exposure are the same. When combining scenarios, it is important to fully characterize the potential for co-occurrence as well as characterizing the risk inputs and estimates. Risks should be combined even if any one scenario or route of exposure exceeds the level of concern because this allows for better risk characterization for risk managers.

For impregnated materials, there is potential for exposure from both dermal and non-dietary ingestion exposure assessment pathways. When assessing impregnated textiles, including impregnated clothing and other textiles, exposure assessments should only combine dermal and non-dietary object-to-mouth ingestion exposure pathways. Similarly, when assessing impregnated surfaces, including carpets and flooring, exposure assessments should only combine dermal and non-dietary hand-to-mouth ingestion exposure pathways.

Section 10 Treated Paints & Preservatives

This chapter provides the standard operating procedures (SOPs) for assessing pesticide exposures from pesticide-treated paints and wood preservatives. The sources of pesticide exposure that are addressed in this chapter include pesticide-treated paints and wood preservatives and materials containing pesticide-treated paints and preservatives. Exposure assessment scenarios that are addressed in this chapter include residential handler exposure during mixing and application activities, post-application dermal and non-dietary incidental ingestion exposure, and potential inhalation of volatile pesticide compounds.[20]

Before the development of an exposure assessment of a paint/preservative, the appropriate exposure scenarios should be identified using information on the product's pesticide label. Specific label information that should be considered is described below.

- **Paints/Preservatives with Pesticide Claims:** Paints/preservatives may be treated with conventional pesticides and contain a pesticide label that makes claims, such as "kills mildew," "prevents wood rot," or "kills algae." These labels contain information on the active ingredient and should be used when performing exposure assessments using the methods described in this chapter.

- **Paints/Preservatives without Pesticide Claims:** Many paints/preservatives do not have a pesticide label on their container and their labels do not make claims about pest control. The pesticide in these paints/preservatives is present as a biocide, which is added during the manufacturing process. Biocides are more routinely assessed by OPP's Antimicrobial Division (OPP/AD) and are not addressed in this chapter.

- **Limiting and Descriptive Statements:** Assume that a pesticide-containing paint/preservative is used in residential settings and/or applied by homeowners, unless specific label language indicates otherwise. Examples include labels that specify paints/preservatives for commercial use only (e.g., warehouses, shipyards, etc.). Additionally, "Restricted Use Pesticide" classification indicates that the product cannot be bought or applied by homeowners (i.e., no residential handler exposure/risk assessment required), but it may be applied by commercial applicators to residential sites; therefore, a post-application risk assessment may be required.

10.1 Residential Handler Exposure Assessment

This SOP provides the standard methods for assessing dermal and inhalation exposures that can result from mixing and applying treated paints and preservatives by residential handlers. There

[20] In the past, exposure assessment procedures have been provided for ingestion of paint chips. There procedures are no longer provided, since it is believed that children would have to ingest an unreasonably high quantity of pesticide-containing paint chips to have an exposure that represents an unacceptable risk.

are currently limited exposure data on treated paint and preservative activities, so it is assumed that they are similar to other handler activities as described below:

- Aerosol spray cans handler activities are represented by pesticide aerosol data;
- Paints brush handler activities are represented by paint brush data;
- Roller painting handler activities are represented by paint roller data;
- Painting/staining with a manually-pressurized sprayer handler activities are represented by mixer/loader/applicator manually-pressurized sprayer data; and
- Painting/staining with an airless sprayer handler activities are represented by mixer/loader/applicator airless sprayer data.

When assessing risks associated with dermal exposure, the methods described in the remainder of this section are recommended. Since this approach relies on surrogate data, it is recommended that it should only be used in the absence of, or as a supplement to adequate existing chemical-specific data.

Dermal and Inhalation Handler Exposure Algorithm

Residue concentration is most commonly reported as percent a.i. in terms of total paint/preservative mass (e.g. Weight fraction of a.i. in treated paint/preservative). In these cases, residue concentration can be estimated and subsequently used to determine the potential daily dose rate, as shown below.

$$AR = V * \rho * WF * CF1 \tag{10.1}$$

where:

AR = Mass of active ingredient applied per paint can (lbs a.i./can);
V = Volume of paint contained in each can (mL/can);
ρ = Paint density (g/mL);
WF = Weight fraction of a.i. in treated paint/preservative (% a.i. w/w); and
CF1 = Gram-to-pound conversion factor ($2.2*10^{-3}$ lbs/g).

$$E = UE * AR * N \tag{10.2}$$

where:

E = Daily exposure rate (mg/day);
UE = unit exposure (mg/lb a.i. applied);
AR = Mass of active ingredient applied per paint can (lbs a.i./can); and
N = number of cans paint used per exposure day (cans/day).

After calculating exposure, absorbed dose, normalized to body weight, is calculated as:

$$D = \frac{E * AF}{BW} \tag{10.3}$$

where:

D = Dose (mg/kg-day);
E = Exposure (mg/day);
AF = absorption factor (dermal and/or inhalation); and
BW = Body weight (kg).

Handler exposure for paint or wood preservative applications is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.3* such as the product-specific application regimen. If longer-term assessments (i.e., intermediate-, long-term, or lifetime exposures) are deemed necessary, similar refinements to more accurately reflect the exposure profile are recommended.

Dermal and Inhalation Handler Exposure Algorithm Inputs and Assumptions

Recommended values for handler exposure (inhalation and dermal) assessments are provided in *Table 10-1* and *Table 10-2*. Following these tables, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 10-1: Paints and Stains – Recommended Unit Exposure (mg/lb ai) Distributions and Point Estimates

Formulation	Equipment/ Application Method	Dermal Unit Exposure	Inhalation Unit Exposure	Appendix Page Reference
Ready-to-Use (RTU)	Aerosol can	370	3.0	C-134
Paints and Stains	Airless Sprayer	160	0.56	C-42
	Brush	450	0.20	C-48
	Manually-pressurized sprayer	63	0.018	C-48
	Roller	No exposure data available for this application scenario. Exposure data for brush applications of paints/stains recommended as surrogate data.		

Table 10-2: Paints and Stains – Recommended Handler Exposure Factors Distributions and Point Estimates

Exposure Factor (Units)		Recommended Value
Application Rate mass ai per unit area		Maximum labeled rate
Amount of active ingredient (AR) (lbs a.i./can)		Maximum labeled rate
Number of cans applied per day (N)	Aerosol Spray Cans	3 twelve-ounce cans
	Paints with Brush	2 one-gallon cans
	Roller Painting	2 one-gallon cans
	Manually-pressurized sprayer	3 one-gallon cans
	Airless sprayer	3 five-gallon cans
Body Weight (BW) (kg)	Adult	80

Unit Exposure (UE)

Unit exposure values for paints/preservatives are summarized in *Appendix B.* As indicated, there are some exposure data on painting with a brush or roller, but limited exposure data on paint/preservative exposure scenarios involving aerosols, manually-pressurized sprayers, and airless sprayers. In these cases, data for conventional pesticide application activities are assumed to be reasonable surrogates of exposure.

Amount of Active Ingredient (AR)

The amount of a.i. applied per paint/preservative container should be determined using label information on the maximum concentration of a.i. that is mixed with a paint/preservative. In some cases, this information may not be directly reported on the label. When this information is not directly available, however, data on the volume of paint per container, specific gravity of paint/preservative solution, and weight fraction of a.i. in paint/preservative can be used to estimate the amount of active ingredient applied per container

Number of Paint Cans (N)

The number of paint cans is the amount of paint that is handled during a residential application. The recommended input values for each handler exposure scenario are based on data presented in U.S. EPA's Exposure Factors Handbook (2011) and summarized in *Table 10-3*.

Table 10-3: Recommended number of gallon input values for paint and wood preservative exposure scenarios.

Exposure Scenario	Paint Cans Number	Justification
Aerosol Spray Cans	3 twelve-ounce cans	Upper-percentile assumption for the amount handled is 3 cans (12 ounces each) used per event (the 90th percentile amount of spray paint used per event is 36.11 oz/use (U.S. EPA Exposure Factors Handbook ,2011, Table 17-18).
Paints with Brush	2 one-gallon cans	90th percentile value of 8 gallons of latex paint used per year divided by the mean frequency of 4 painting events per year (U.S. EPA Exposure Factors Handbook, 2011, Table 17-6).
Roller Painting	2 one-gallon cans	90th percentile value of 8 gallons of latex paint used per year divided by the mean frequency of 4 painting events per year (U.S. EPA's Exposure Factors Handbook, 2011, Table 17-6).
Manually-pressurized sprayer painting/staining	3 one-gallon cans	Professional judgment assuming that more products would be used with a manually-pressurized sprayer than with a roller or brush, but less than that used with a high pressure sprayer.
Airless sprayer painting/staining	3 five-gallon cans	A homeowner is assumed to use three 5-gallon cans of ready-to-use product or of finished spray prepared from a concentrated product and water. This is based on a coverage rate of 200 ft^2/gallon and a house size with a surface area of 2,800 ft^2.

Future Research/Data Needs

Iinformation that could refine the handler exposure assessment methods include:

- General use information on treated paints;

- Frequency of treated paint/preservative applications;
- Location of treated paint/preservatives in residential environments; and
- Typical surface of area of treated areas.

Exposure Characterization and Data Quality

Unit Exposures

- The exposure data underlying unit exposures are considered reasonable for the purposes of establishing distributions and estimating exposure. The data are from actual applications using standardized exposure sampling methodologies and laboratory analyses.
- The underlying assumption of the use of exposure data as unit exposures – proportionality between the amount of active ingredient handled and exposure – is uncertain, though potentially conservative. However, as a prediction mechanism, it is considered practical and useful for the purposes of handler exposure assessment in a regulatory context. It provides a straightforward handler exposure calculation method and enables risk mitigation in the form of formulation comparison and decreased application rates.
- The extent to which an individual's exposure (expressed via unit exposures) varies day-to-day or application-to-application is unknown; therefore, the assumption that there is no variation when assessing longer-term exposure durations is considered conservative.

Amount of active ingredient handled

- Information on the amount of product/formulation (thus, active ingredient) handled per application is largely unavailable. The approach used is believed to provide conservative estimates of exposure because the amount of paint/preservative handled is based on information on the use of non-treated painted that is more commonly used. The recommended point estimates are, therefore, intended to be conservative to ensure an appropriately health protective exposure estimate.
- The extent to which the amount an individual will handle per application varies from day-to-day or application-to-application is unknown; therefore, the assumption that there is no variation when assessing longer-term exposure durations is considered conservative.

10.2 Post-Application Exposure Assessment

Post-application exposure can result from contacting surfaces that have been painted with treated paint or wood preservative. Potential exposed populations include both adults and children. While exposure may occur for people of all ages, adults and children 1 < 2 years old are considered index lifestages based on behavioral characteristics and the strengths and limitations of available data.

This section addresses standard methods for estimating exposure and dose for three individual post-application scenarios resulting from exposure to pesticide-containing paints, stains, or wood preservatives:

- Section 10.2.1 - adult/children 1 < 2 years old dermal exposures;

- Section 10.2.2 – children 1 < 2 years old non-dietary ingestion via hand-to-mouth activity; and
- Section 10.2.3 - adult/children 1 < 2 years old inhalation exposures.

10.2.1 Post-Application Dermal Exposure Assessment

This SOP provides the standard methods for assessing dermal exposure scenarios following the application of pesticide-treated paint or wood preservatives on indoor and outdoor surfaces, such as home walls, outdoor decks, and play-sets. The exposure assessment methods presented in this section are based primarily on the approach developed for an exposure assessment of children who contact chromated copper arsenate treated playsets using the EPA/ORD Stochastic Human Exposure and Dose Simulation Model for the Wood Preservative Scenario (SHEDS-WOOD) (U.S. EPA, 2005).

Post-Application Dermal Exposure Algorithm

The algorithm to calculate post-application dermal exposure is calculated as follows:

$$E = SR * SA / BW * F_{Body} * TE * PF \quad (10.4)$$

where:

E = Daily exposure rate (mg/kg-day);
SR = Surface residue concentration (mg/cm^2);
SA/BW = total body surface area to body weight ratio (cm^2/kg);
F_{Body} = Fraction of total body skin surface area that is unclothed (unitless); and
TE = Daily material-to-skin transfer efficiency (fraction/day).

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

$$D = E * AF \quad (10.5)$$

where:

D = Dose rate (mg/kg-day);
E = Daily Exposure (mg/kg-day); and
AF = Dermal absorption factor.

Post-application dermal exposure from paints or wood preservatives containing pesticides is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4*, such as residue dissipation, product-specific re-treatment intervals, and activity patterns. If longer-term assessments (i.e., intermediate-, long-term, or lifetime exposures) are deemed necessary, such as in cases where the impregnated material may be routinely replaced or re-treated, similar refinements to more accurately reflect the exposure profile are recommended.

Post-Application Dermal Exposure Assessment Assumptions and Recommendations

A summary table of the recommended values for post-application dermal exposure assessment of paints/preservatives is provided in *Table 10-4.* Following this summary table, each scenario-specific input parameter, excluding the universal body surface area and bodyweight inputs, is described in more detail. This description includes a summary of i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 10-4: Summary of recommended values for post-application dermal absorption.

Algorithm Notation	Exposure Factor (Units)		Recommended Input Values
SR	Surface Residue Concentration (mg a.i. /cm^2)		Maximum Labeled Rate
WF	Percent A.I. by Weight (% w/w)		Label
F_{body}	Fraction of body that contacts residue		0.31
TE	Material-to-skin transfer efficiency (fraction/day)		0.14
SA/BW	total body surface area to body weight ratio (cm^2/kg)	Adult	280
		Children 1 < 2 years old	640

Surface Residue Concentration (SR)

Surface residue concentration is the concentration of pesticide residue on the surface of a painted/treated surface. Whenever possible, product-specific information should be used to estimate the surface residue concentration. This information may be found on labels or other information provided by the manufacturer.

Material-to-Skin Transfer Efficiency (TE)

Surface-to-skin transfer efficiency is the fraction of pesticide residue that is transferred from a painted/treated surface to the skin. Whenever possible, product -specific information should be used to estimate the surface-to-skin transfer efficiency. In the absence of product-specific information, the recommended transfer efficiency is based on warm weather data on the transfer of arsenic from chromated copper arsenate treated wood (American Chemistry Council, 2003). This data was incorporated into the SHEDS-CCA assessment and used to obtain a lognormal distribution with a geometric mean and geometric standard deviation of 0.143 and 2.33, respectively.

Fraction of Total Body Exposed (F_{body})

This term refers to the fraction of the body that is unclothed. The recommended default value for this input was derived using information presented previously in *Table 6-7.* Specifically, the recommended input value of 0.31 represents the fraction of surface area of the torso and arms, lower thighs, shins, feet, hands, and neck. This value is believed to be representative of the fraction of the body that may be exposed in warm weather.

Future Research/Data Needs

Specific information that could help refine the exposure assessment methods include:

- Additional research/ data on the transfer of non-preservative pesticide additives, as available data are limited to transfer of arsenic from chromated copper arsenate.
- Information on how treated paints/preservatives are used by residential home owners could help improve the exposure assessment methods.
- General use information on treated paints;
- Frequency of treated paint/preservative applications;
- Location of treated paint/preservatives in residential environments; and
- Typical surface of area of treated areas.

Exposure Characterization and Data Quality

- Many of the methods presented in this section are based on the approach used to assess chromated copper arsenate treated playsets. Therefore, an important limitation of the exposure assessment methods presented is that they are based on a single chemical that is used a wood preservative, rather than conventional pesticide (e.g. insecticide, herbicide, fungicide, etc.).

10.2.2 Post-Application Non-Dietary Ingestion Exposure Assessment: Hand-to-Mouth

This SOP provides the dose estimation methods for assessing incidental ingestion from hand-to-mouth behavior following contact with treated paint/preservative surfaces.

Non-Dietary Hand-to-Mouth Ingestion Exposure Algorithm

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

$$E = \left[HR * \left(F_M * SA_H\right) * \left(ET * N_Replen\right) * \left(1 - \left(1 - SE\right)^{\frac{Freq_HtM}{N_Replen}}\right)\right] \qquad (10.6)$$

where:

E	= exposure (mg/day);
HR	= hand residue loading (mg/cm^2);
F_M	= fraction hand surface area mouthed / event (fraction/event);
SA_H	= surface area of one hand (cm^2);
ET	= exposure time (hr/day);
N_Replen	= number of replenishment intervals per hour (intervals/hour);
SE	= saliva extraction factor (ie, mouthing removal efficiency); and
Freq_HtM	= number of hand-to-mouth contacts events per hour (events/hour).

In this algorithm, hand residue concentration is calculated as:

$$HR = SR * TE \qquad (10.7)$$

where:

HR = hand residue concentration (mg/cm^2);
SR = surface residue (µg/cm^2); and
TE = transfer Efficiency.

After calculating exposure, oral dose, normalized to body weight, is calculated as:

$$D = \frac{E}{BW} \quad (10.8)$$

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

Post-application hand-to-mouth exposure from paints or wood preservatives containing pesticides is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4*, such as residue dissipation, product-specific re-treatment intervals, and activity patterns. If longer-term assessments (i.e., intermediate-, long-term, or lifetime exposures) are deemed necessary, such as in cases where the impregnated material may be routinely replaced or re-treated, similar refinements to more accurately reflect the exposure profile are recommended.

Non-dietary Hand-to-Mouth Ingestion Exposure Assessment Assumptions and Recommendations

Recommended values for non-dietary hand-to-mouth ingestion exposure assessments are provided in *Table 10-5*. Following this table, each scenario-specific input parameter is described in more detail. This description includes a summary of i) key assumptions; ii) data sources used to derive recommended input values; and iii) discussion of limitations that should be addressed when characterizing exposure.

Table 10-5: Summary of recommended values for post-application hand-to-mouth incidental ingestion.

Algorithm Notation	Exposure Factor (units)		Point Estimate(s)
SR	Surface Residue Concentration (mg a.i. /cm^2)		Maximum Labeled Rate
TE	Material-to-skin transfer efficiency		0.14
F_M	Fraction of hand mouthed per event (fraction/event)		0.13
SA_H	Typical surface area of one hand, children 1 < 2 years old (cm^2)		150
N_Replen	Replenishment intervals (intervals/hr)		4
ET	Exposure Time (hours per day)	Indoor Environments (Children 1 < 2 years old)	4
		Outdoor Environments (Children 1 < 2 years old)	1.5
SE	Saliva extraction factor (fraction)		0.48
Freq_HtM	Hand-to-mouth events (events/hour)	Indoor Environments (Children 1 < 2 years old)	20

Table 10-5: Summary of recommended values for post-application hand-to-mouth incidental ingestion.			
		Outdoor Environments (Children 1 < 2 years old)	13.9
BW	Body Weight (kg)	Children 1 < 2 years old	11.4

Surface Residue Concentration (SR)

Surface residue concentration is the concentration of pesticide residue on the surface of an impregnated material. Product-specific information, such as weight fraction of a.i., should be used to estimate the residue concentration. This information may be found on labels or other information provided by the manufacturer. After obtaining this information, the surface residue concentration can be estimated using the methods described in *Section 9.2.2*.

Material-to-Skin Transfer Efficiency (TE)

Surface-to-skin transfer efficiency is the fraction of pesticide residue that is transferred from a painted/treated surface to the skin. Whenever possible, product -specific information should be used to estimate the surface-to-skin transfer efficiency. In the absence of product-specific information, the recommended transfer efficiency is based on warm weather data on the transfer of arsenic from chromated copper arsenate treated wood (American Chemistry Council, 2003). This data was incorporated into the SHEDS-CCA assessment and used to obtain a lognormal distribution with a geometric mean and geometric standard deviation of 0.143 and 2.33, respectively.

Fraction of Hand Mouthed per Event (F_M)

See *Section 2.4* of this SOP for discussion of the fraction of hand mouthed. **The recommended point estimate for use in post-application incidental oral exposure assessments is 0.13.**

Hand Surface Area (SA_H)

The hand surface area for **children 1 < 2 years old of 150 cm^2**, for one hand, was based on values from the Exposure Factors Handbook 2011 Edition (U.S. EPA, 2011).

Replenishment Intervals (N_Replen)

This SOP assumes an estimate of 4 replenishment intervals per hour (i.e., residues on the hand will be replenished every 15 minutes). This value was selected as a conservative assumption based on the use of 30 minutes in the SHEDS model to coincide with the CHAD diaries.

Exposure Time (ET)

Exposure time is the amount of time that a child is an environment where they may contact a surface containing an impregnated material. There is currently no data available to characterize the amount of time that children spend in environments where they may contact surfaces with treated paints and preservatives. In the absence of scenario-specific data, recommended exposure time value for exposures that may occur in indoor environments is based on the children 1 < 2 years old exposure time values discussed in *Section 7.2.4* of the Indoor Environment SOPs. Similarly, the recommended exposure time for outdoor environments is

based on the children 1 < 2 years old exposure time values discussed in *Section 3.2.2* of the Lawns/Turf SOPs.

Fraction of Pesticide Extracted by Saliva (SE)

See *Section 2.6* of this SOP for discussion of the fraction of pesticide extracted by saliva distribution. **The recommended point estimate for use in post-application incidental oral exposure assessments is 0.48.**

Hand-to-mouth events per hour (Freq_HtM)

Frequency of hand-to-mouth events refers to the number of hand-to-mouth events per hour. There is currently no data available that specifically address the number of hand-to-mouth events that occur relative to the amount of time a child is in contact surfaces containing treated paints/preservatives. In the absence of scenario-specific data, the frequency of hand-to-mouth events in indoor environments is based on *Section 7.2.4* of the Indoor Environment SOPs, which provides a summary of data from a meta-analysis performed by Xue et al. (2007). Similarly, the frequency of hand-to-mouth events in outdoor environments is based on *Section 3.2.3* of the Lawns/Turf SOPs, which provides a summary of the outdoor hand-to-mouth data from the same Xue et al. (2007) meta-analysis.

Future Research/Data Needs

Specific information that could help refine the exposure assessment methods include:

- Additional research/ data on the transfer of non-preservative pesticide additives, as available data are limited to transfer of arsenic from chromated copper arsenate.
- Information on how treated paints/preservatives are used by residential home owners could help improve the exposure assessment methods.
- General use information on treated paints;
- Frequency of treated paint/preservative applications;
- Location of treated paint/preservatives in residential environments; and
- Typical surface of area of treated areas.

Exposure Characterization and Data Quality

- Many of the methods presented in this section are based on the approach used to assess chromated copper arsenate treated playsets. Therefore, an important limitation of the exposure assessment methods presented is that they are based on a single chemical that is used a wood preservative, rather than conventional pesticide (e.g. insecticide, herbicide, fungicide, etc.).

10.2.3 Post-Application Inhalation Exposure Assessment

In many cases, inhalation exposure from impregnated paints is expected to be negligible, since many non-preservative pesticides have low vapor pressures and would be designed to be incorporated into the treated surface. When treated paints/wood preservatives contain more volatile pesticide chemicals, however, it may be necessary to assess post-application inhalation exposures. The recommended methodology is described in the remainder of this section.

Wall Paint Exposure Model

EPA's Wall Paint Exposure Model (WPEM) version 3.2 is used estimate post-application air concentrations resulting from the use of paint preserved with *volatile* chemicals (2001). WPEM was developed under a contract by Geomet Technologies for EPA OPPT to provide estimates of potential air concentrations and consumer/worker exposures to chemicals emitted from wall paint which is applied using a roller or a brush. WPEM uses mathematical models developed from small chamber data to estimate the emissions of chemicals from oil-based (alkyd) and latex wall paint. The emission data can then be combined with detailed use, workload and occupancy data (e.g., amount of time spent in the painted room, etc,) to estimate exposure. Specific input parameters include: the type of paint (latex or alkyd) being assessed, density of the paint (default values available), and the chemical weight fraction, molecular weight, and vapor pressure. Detailed information and the executable model can be downloaded from http://www.epa.gov/opptintr/exposure/pubs/wpem.htm.

It should be noted that WPEM's emission models are based on a limited set of chemicals and an associated range of molecular weights and vapor pressures. The models may not be valid for chemicals outside of these ranges. The valid vapor pressure ranges are 0.4 to 18.7 torr (or mmHg) for chemicals in alkyd paint and 0.002 to 0.2 torr (or mmHg) for chemicals in latex paint.

For volatile chemicals, use WPEM and chemical specific data (i.e., vapor pressure and molecular weight) to determine air concentrations. For the do-it-yourself residential painter, use the default WPEM scenario "RESDIY" to estimate chemical specific air concentrations. This WPEM default scenario assumes that a do-it-yourself painter is exposed to a chemical in paint while applying one coat paint to the bedroom of a house. For a detailed description of the default RESDIY scenario, see the WPEM User's Guide.

The model provides several dose measures (i.e., LADD, ADD), air concentration measures (i.e., peak, 15-min, 8hr), and a comma-separated (.csv) file as outputs. The comma-separated file contains details on time-varying concentrations within the modeled building (i.e., conc in zone 1, conc in zone 2) as well as concentrations to which the individual is exposed (i.e., Conc@person). This file can be read directly into spreadsheet software (e.g., Excel) for calculating additional summary statistics. The output data in comma-separated file should be used to estimate air concentrations over time durations that are in comparable time-durations to the toxicity endpoints. For the adult DIY painter, a 4-hr average air concentration (i.e., the time it takes to paint the bedroom) should be used in the following equation used for calculating the absorbed inhalation dose:

$$D = \frac{C * IR * ET * AF}{BW} \quad (10.9)$$

where:

D = Potential Daily Dose (mg/kg-day);
C = 4-Hour Average Air concentration (mg a.i./m^3);
IR = Inhalation rate (Standard Value= m^3/hour);
ET = Exposure time (Standard Value= hours/day);
AF = Absorption Factor; and
BW = Bodyweight (kg).

For the adult and child bystander and post-application exposure scenario, use the default WPEM scenario "RESADULT" to estimate chemical specific air concentrations. This WPEM default scenario assumes that a resident located in the non-painted part of the house (i.e., zone 2) is exposed to the chemical in the paint while a bedroom is painted with one coat of primer and one coat of paint by a professional. This resident then moves in, out, and throughout the house following the paint application. For a detailed description of the default RESADULT scenario, see the WPEM User's Guide. The "RESCHILD"scenario should be used to assess child exposure even though the application scenario is the same as in the adult assessment because WPEM moves the person around in the home (i.e., in the painted room, in non-painted rooms, and outdoors) based on activity patterns and the activity patterns for the child and adult are different.

The output data in comma-separated file should be used to estimate air concentrations over time durations that are in comparable time-durations to the toxicity endpoints. For the bystander/post-application exposure the data in the "Conc@person" column of the output file should be used to estimate 24-hr average and subsequently used in the following equation for calculating the post-application absorbed inhalation dose is:

$$D = \frac{C * IR * ET * AF}{BW} \quad (10.10)$$

where:

D = Potential Daily Dose (mg/kg-day);
C = 24-Hour Average Air concentration (mg a.i./m^3);
IR = Inhalation rate (m^3/hour);
ET = Exposure time (hours/day);
AF = Absorption Factor; and
BW = Bodyweight (kg).

Post-application inhalation exposure from paints or wood preservatives containing pesticides is generally considered short-term in duration. Refinement of this dose estimate to reflect a more accurate short-term multi-day exposure profile can be accomplished by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4*, such as residue dissipation, product-specific re-treatment intervals, and activity patterns. If longer-term assessments (i.e., intermediate-, long-term, or lifetime exposures) are deemed necessary, such as in cases where the impregnated

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Appendix A Health Effects Division Residential Standard Operating Procedures "Index Lifestage" White Paper

Introduction

In the beginning phase of an exposure and risk assessment, exposure assessors must first identify the relevant lifestages for each exposure scenario (i.e., adults, children 1 < 2 years old, children 3 < 6 years old, etc.). In most cases, there are multiple lifestages that could be potentially exposed within a particular exposure scenario. To simplify the exposure and risk assessment process, an exposure assessor generally focuses the exposure assessment towards the lifestage (or lifestages) of highest concern due to unique behavioral characteristics that may lead to higher levels of exposure. This process is referred to as "selecting an index lifestage". The index lifestage approach utilizes quantitative assessments of the index lifestage to protect for the exposures and risks for all potentially exposed lifestages. This approach simplifies and streamlines the assessment process and allows risk managers to focus on the area(s) of highest concern.

Children engage in behaviors and consumption that can increase their risk of pesticide exposures compared to adults. In the 1997 version of the Health Effects Division's (HED's) Residential Standard Operating Procedures (ResSOPs), the children 3 < 6 years old lifestage was used to represent children's exposure to pesticides in residential environments. At the time, the Agency believed that this lifestage was the appropriate index lifestage for children based mainly on behavioral aspects (e.g., mobility, mouthing characteristics). In the 2011 revised version of HED's ResSOPs, different index lifestage were selected for each individual SOP based on behavioral aspects (e.g., mobility, mouthing characteristics) as well as the types and quality of data used in the individual SOPs.

In October 2009, the Agency presented the revised ResSOPs to the Federal Insecticide Fungicide and Rodenticide Act (FIFRA) Science Advisory Panel (SAP). The FIFRA SAP provided a number of comments on the revised ResSOPs specifically related to the issue of the selection of index lifestages for children. The SAP agreed with the Agency's use of the index lifestage approach but recommended that additional explanation be included in the ResSOPs regarding the selection of the specific index lifestage for the individual SOPs.

Based on the FIFRA SAP's comments, the Agency decided to further analyze the index lifestage issue. The Agency analyzed this issue using both quantitative exposure assessments as well as qualitative considerations. Quantitative exposure assessments were performed for a variety of younger lifestages as defined in the Agency's *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures for Environmental Contaminants*[21]. This analysis was performed for each individual SOP and it includes the following lifestages: 6 < 12 months, 1 < 2 years, 2 < 3 years, and 3 < 6 years. While children younger than 6 months may potentially have exposure in the residential setting, it is believed that exposure for children older than 6 months will be equivalent, if not greater, due to behavioral and anatomical/physiological development; therefore, the focus of the quantitative assessment was on children older than 6 months.

[21] http://www.epa.gov/raf/publications/guidance-on-selecting-age-groups.htm

Where appropriate, dermal, inhalation, and non-dietary exposures (e.g., hand-to-mouth, object-to-mouth) were considered for all individual SOPs. The results of this analysis can be found in Attachment 1, *Table AA-1 to Table AA-14* which can be found at the end of this document. Selection of an index lifestage for an individual SOP cannot solely be based on this quantitative analysis. The selection requires a holistic examination and discussion of the underlying data utilized in these assessments, which is critical to this selection. Further discussion of the issues to consider in the selection of an index lifestage is included below.

Exposure Data Considerations

- Exposure data based on monitoring of children are not typically available. The exposure data used in all of the individual SOPs were developed via monitoring of adults and not children. In order to use this data to more accurately represent children, the data were adjusted to take into account the differences in body surface area between adults and children. It is unclear how exposure studies performed with children would compare to the available adjusted adult exposure data. However, the Agency does believe factors such as force of contact (adults vs. children) and scripted vs. unscripted play could impact the study results. *Table A-1* below presents the adjustment factors utilized in the ResSOPs.

Table A-1: Surface Area Adjustment Factors

Lifestage	Surface Area (m^2) [Mean: Combined Males and Females[1]]	Adjustment Factor[2]
6 < 12 months	0.45	0.23
1 < 2 years	0.53	0.27
2 < 3 years	0.61	0.31
3 < 6 years	0.76	0.39
6 < 11 years	1.08	0.55
11 < 16 years	1.59	0.82

[1] U.S. EPA, 2011; Table 7-9

[2] Derived as ratio of adult surface area (1.95 m^2; average of male and female means) to combined male and female mean surface area for specified lifestage (e.g., 0.76 m^2 ÷ 1.95 m^2 = 0.39)

- In some cases, the dermal exposure studies represent activities that younger lifestages do not perform or are unable to perform. In addition, the dermal exposure studies may represent activities that involve a more vigorous or consistent contact with treated surfaces than would be expected for young children. For example, the outdoor Turf SOP is based on exposure data representing a combined routine of various outdoor turf activities (some of which are relevant to the younger lifestages and some of which are not). These exposure data can be considered a reasonable representation of younger lifestage behaviors; however, it does not represent an exact match. One example of this issue can be seen if the activities in the turf exposure study are examined. Many of these activities (e.g., playing Frisbee, playing football) are unlikely to be performed by younger lifestages, such as the 6 < 12 month old, the 1 < 2 year old, and the 2 < 3 year old lifestages. These activities are also performed with older individuals and represent a higher intensity contact with the treated surfaces (e.g., an adult being tackled on the lawn versus a child crawling on the lawn). In another example, interaction with treated pets is based on exposure monitoring of professional pet grooming activities. Groomers in the study exhibited a more consistent and vigorous contact with the treated dogs than is

expected from a child's casual contact with a pet. These exposure data may not be a good representation of younger lifestage behaviors related to pets; however, the data have been used in the Pet SOP as a surrogate for a child's contact with a treated pet in lieu of a more representative pet exposure study. In general, using these exposure studies to represent younger lifestages who wouldn't be performing those activities is not expected to underestimate exposure for younger lifestages.

- For some scenarios, assessment of some of the younger lifestages is not appropriate because it is not expected that these lifestages will engage in the activities represented in the scenario. For example, in the Outdoor Fogger SOP, the 6 < 12 month old, the 1 < 2 year old, and the 2 < 3 year old lifestages are not expected to spend any significant length of time in horse or animal barns. As a result, these lifestages are not assessed for this exposure scenario.

- When selecting an index lifestage, developmental milestones for different lifestages need to be considered. *Table A-2* below clearly shows that from 6 months to 2 years, floor mobility increases, which increases the likelihood of contacting different surfaces. Among the younger lifestages, the 1 < 2 year old lifestage is likely the youngest lifestage that is highly mobile and can potentially cover a large area indoors and outdoors.

Table A-2: Developmental Milestones Relevant to Oral and Dermal Exposure

Lifestage	Milestones
Birth < 3 months	Breast and bottle feeding. Hand-to-mouth activities.
3 < 6 months	Solid food may be introduced. Contact with surfaces increases. Object/hand-to-mouth activities increase.
6 < 12 months	Food consumption expands. Children's floor mobility increases (surface contact). Children are increasingly likely to mouth nonfood items.
12 < 24 months	Children consume full range of foods. They participate in increased play activities, are extremely curious, and exercise poor judgment. Breast and bottle feeding cease.
2 < 6 years	Children begin wearing adult-style clothing. Hand-to-mouth activities begin to moderate.
6 < 11 years	There is decreased oral contact with hands and objects as well as decreased dermal contact with surfaces.

- Developmental milestones, in particular floor mobility, are important because the underlying assumption used in the dermal and incidental oral scenario equations is that children are continuously contacting areas of with fresh (i.e., untouched) residue. The SOPs do not take into account the fact that touching the same treated area over and over again results in less total residue being transferred than if each touch is to a previously uncontacted treated area. The Non-Dietary Exposure Task Force (NDETF) has performed multiple studies examining the impacts on the amount of residue transferred to the hand resulting from these two very different surface contact patterns (i.e., contacting the same piece of flooring for every hand-to-surface contact versus contacting a new piece of flooring for each hand-to-surface contact). For example, a study performed with permethrin showed that approximately 17% of the deposited residue was transferred to the hand after four hand-to-surface contacts were made, with each contact occurring on a new piece of treated flooring (i.e., fresh residue for every contact). In contrast,

approximately 6% of the total deposited residue was transferred to the hand after four hand-to-surface contacts were made, with each contact occurring on the same piece of treated flooring. The NDETF data clearly show that, all other things being equal (e.g., exposure time, hand-to-mouth frequency, etc), repeated exposure to the same treated surface will result in a lower overall exposure than repeated exposure to uncontacted treated surfaces. Based on this data, assuming repeated contact with areas of fresh residue is not expected to underestimate exposure.

Activity Data Considerations

- The data available describing exposure time for young children in various environments do not typically distinguish between the specific younger lifestages. The data are typically presented for all children or subsets of children (e.g., 3-12 years old or 1-4 and 5-11 years old). As a result, the exposure times used as an input in the individual SOPs are identical across many lifestages. This is likely a health protective use of these data as it is unlikely the exposure time to treated turf or a treated pet would be the same for the 6 < 12 month old lifestage vs. the 1 < 2 year old lifestage vs. the 2 < 3 year old lifestage.

- Frequency of hand-to-mouth events is an important variable for hand-to-mouth post-application exposure assessments. Data on the frequency of hand-to-mouth events are limited and difficult to collect. The meta-analysis presented in Xue et al. (2007) examined hand-to-mouth frequency data from 9 studies representing 429 subjects and more than 2,000 hours of behavior observation. This meta-analysis shows that mouthing activity across the younger lifestages is very similar (see *Table A-3*); particularly for the 6 < 12 months and 1 < 2 years old lifestages.

Table A-3: Hand-to-Mouth Activity Data Summary

Scenario	Lifestage	Mean HTM events	95th percentile HTM events
Indoor	6 < 12 months (N=119)	18.9	52
	1 < 2 year old (N=245)	19.6	63
	2 < 3 year old (N=160)	12.8	37.5
	3 < 6 year old (N=160)	14.3	56.5
Outdoor	6 < 12 months (N=10)	14.5	46.7
	1 < 2 year old (N=32)	13.9	42.2
	2 < 3 year old (N=46)	5.3	20
	3 < 6 year old (N=55)	8.5	36

It is believed that a majority of the hand-to-mouth activity observed in the studies included in the Xue, et al. 2007 meta-analysis occurred during eating intervals. Some research supporting this belief has already been performed (AuYeung et. al, Poster presented at 15th Annual Meeting of the International Society of Exposure Analysis; 2005) but more work needs to be done. Thus, the use of these hand-to-mouth activity data is unlikely to underestimate exposure because hand contact with treated surfaces (and thus transfer of residues) is likely limited during the time a child is eating.

In addition, it should be noted that hand-to-mouth events in these studies are defined as when a child's hand touches anywhere near the mouth (i.e., each event did not necessarily result in the hand entering the mouth). For example, if a child brought their

hand up to their mouth and only touched the outside of the mouth, this was counted as a hand-to-mouth event. In the ResSOPs, all hand-to-mouth events are assumed to be mouthing events, where part of the hand is mouthed and residues are transferred via saliva extraction. Using the data in this manner is not expected to underestimate exposure.

It should also be acknowledged that the SOPs assume even spacing of the hand-to-mouth events across replenishment intervals; however, in actuality, the hand-to-mouth events observed in the studies are not evenly spaced out over the observation period. The assumption of evenly spaced hand-to-mouth events is also unlikely to underestimate exposure as it assumes a certain amount of hand-to-mouth events occur during each replenishment interval, resulting in greater total exposure than if all the hand-to-mouth events occurred after a single replenishment of residues.

- Frequency of object-to-mouth events is an important variable for object-to-mouth post-application exposure assessments. Data on the frequency of object-to-mouth events are limited and difficult to collect. The meta-analysis presented in Xue et al. (2009) examined object-to-mouth frequency data from 7 studies representing 438 subjects and ~1500 hours of behavior observation. The object-to-mouth activity data available from the Xue, et al. 2009 meta-analysis show that mouthing activity across the younger lifestages is very similar (see *Table A-4*). It is acknowledged that object mouthing does occur for children younger than 6 months of age; however, data are not available for these younger lifestages.

Table A-4: Object-to-Mouth Activity Data Summary

Scenario	Lifestage	Mean OTM events	95th percentile OTM events
Indoor	6 < 12 months (N=82)	20.3	37.9
	1 < 2 year old (N=137)	14.2	34.0
	2 < 3 year old (N=94)	10.0	24.4
	3 < 6 year old (N=158)	10.2	40.0
Outdoor	6 < 12 months	No data available.	
	1 < 2 year old (N=21)	8.8	21.3
	2 < 3 year old (N=29)	8.1	40.0
	3 < 6 year old (N=53)	8.3	30.3

Similar to the hand-to-mouth scenario, the SOPs assume even spacing of the object-to-mouth events across replenishment intervals; however, in actuality, the object-to-mouth events observed in the studies are not evenly spaced out over the observation period. The assumption of evenly spaced object-to-mouth events is unlikely to underestimate exposure as it assumes a certain amount of object-to-mouth events occur during each replenishment interval, resulting in greater total exposure than if all the object-to-mouth events occurred after a single replenishment of residues.

Also similar to the hand-to-mouth scenario, it should be noted that object-to-mouth events in these studies are defined as whenever an object touched anywhere near the mouth (i.e., each event did not necessarily result in the object entering the mouth). For example, if a child brought an object up to their mouth and only touched the outside of

the mouth, this was counted as a object-to-mouth event. In the ResSOPs, all object-to-mouth events are assumed to be mouthing events where part of the object is mouthed and residues are transferred via saliva extraction. Using the data in this manner is not expected to underestimate exposure.

- Body weights outlined in the EPA's Exposure Factors Handbook 2011 Edition (U.S. EPA, 2011) show that mean male/female combined body weights for the younger lifestages are similar (see *Table A-5*).

Table A-5: Body Weight Summary

Lifestage	Mean Body Weight (kg)	95th percentile Body Weight (kg)
6 < 12 months	9.2	11.3
1 < 2 year old	11.4	14.0
2 < 3 year old	13.8	17.1
3 < 6 year old	18.6	26.2

- Inhalation rates outlined in the EPA's Exposure Factors Handbook 2011 Edition (U.S. EPA, 2011) show that rates for the younger lifestages are very similar (see *Table A-6*).

Table A-6: Inhalation Rate Summary

Lifestage	Mean Inhalation Rate (m^3/hr)	95th percentile Inhalation Rate (m^3/hr)
6 < 12 months	0.23	0.33
1 < 2 year old	0.33	0.53
2 < 3 year old	0.37	0.57
3 < 6 year old	0.42	0.58

Aggregate Exposure Considerations

As a result of the Food Quality Protection Act (FQPA), exposures from food, drinking water and residential uses of a single pesticide are combined when completing an aggregate exposure assessment. For pesticides with residential uses, residential exposures to children are an important part of the Agency's consideration of aggregate exposure. As described above, in the past the Agency has focused on assessing the 3 < 6 year old lifestage for residential exposures. These residential assessments were then combined with the most sensitive lifestage from the dietary assessment (food + water). For example, an aggregate assessment might combine dietary exposure for infants less than 1 year old with the residential exposure for the 3< 6 year old lifestage. As the Agency has analyzed the index lifestage issue for the ResSOPs, it was determined that aggregating dietary and residential exposures from the same lifestage is most appropriate. Aggregating exposures from the same lifestage will result in aggregate assessments more reflective of real world exposures.

Selection of an Index Lifestage

As described above, there are a number of factors to consider in the selection of an index lifestage for the ResSOPs. The Agency's quantitative analysis (see *Table AA-1* to *Table AA-14* in Attachment 1) showed that, for the most part, either the 6 < 12 month old lifestage or the 1 < 2 year old lifestage results in the highest quantitative estimate of exposure/dose for the younger lifestages. However, as noted above, this quantitative analysis cannot be considered alone, as

there are also a number of qualitative factors that impact the selection of an index lifestage for the ResSOPs. Based on the combined quantitative and qualitative analysis of the index lifestage issue, the Agency has determined that the 1 < 2 year old lifestage represents the most appropriate index lifestage for children for most of the exposure scenarios. There are some exceptions to this selection within the ResSOPs. For example, as mentioned above, in some of the individual SOPs, selecting some of the younger lifestages (e.g., the 6 <12 month old lifestage in horse or animal barns) is inappropriate because children in that age range are not expected to engage in the activities represented in the scenario.

Attachment 1: Quantitative Sensitivity Analysis

Turf SOP

Table AA-1: Turf Dermal Index Lifestage Analysis							
TTR Calculations when Chemical Specific TTR Data are Not Available							
	Application Rate (lb ai/acre)	F [a]	F_D	t	Weight unit conversion factor	Area unit conversion factor	TTR_t (ug/cm2)
Liquid Product	0.87	0.01	0.1	0	450000000	0.0000000247	0.097
Granular Product	0.67	0.002	0.1	0	450000000	0.0000000247	0.015
Dermal Exposure for High Contact Lawn Activities							
Exposure Scenario	Lifestage	TTR_t (ug/cm2)	Weight unit conversion factor	Transfer Coefficient (cm2/hr)	Hours of Exposure (hr)	Exposure (mg/day)	Average Daily Dose (mg/kg/day)
High Contact Lawn Activities (Liquids)	Adult	0.097	0.001	180,000	1.5	26.11	0.33
	11 <16 years	0.097	0.001	150,000	1.5	21.76	0.38
	6 <11 years	0.097	0.001	99,000	1.5	14.36	0.45
	3 <6 years	0.097	0.001	70,000	1.5	10.15	0.55
	2 <3 years	0.097	0.001	56,000	1.5	8.12	0.59
	1 <2 years	0.097	0.001	49,000	1.5	7.11	0.62
	6 <12 months	0.097	0.001	41,000	1.5	5.95	0.65
High Contact Lawn Activities (Granulars)	Adult	0.015	0.001	200,000	1.5	4.47	0.06
	11 <16 years	0.015	0.001	160,000	1.5	3.57	0.06
	6 <11 years	0.015	0.001	110,000	1.5	2.46	0.08
	3 <6 years	0.015	0.001	78,000	1.5	1.74	0.09
	2 <3 years	0.015	0.001	62,000	1.5	1.39	0.10
	1 <2 years	0.015	0.001	54,000	1.5	1.21	0.11
	6 <12 months	0.015	0.001	46,000	1.5	1.03	0.11

a. The screening level value was selected for the F value in this example. This value would be refined if chemical specific turf transferable residue data are available.

Table AA-2: Turf Hand-to-Mouth Lifestage Analysis

Hand Residue Calculations

Exposure Scenario	Lifestage	Fai_{hands}	Children Dermal Exposure	SA_H (cm2)	HR_t (mg/cm2)
Hand Residue Liquid Product	3 <6 years	0.06	10.154	225	0.0014
	2 <3 years	0.06	8.123	160	0.0015
	1 <2 years	0.06	7.107	150	0.0014
	6 <12 months	0.06	5.947	120	0.0015
Hand Residue Granular Product	3 <6 years	0.027	1.743	225	0.00010
	2 <3 years	0.027	1.385	160	0.00012
	1 <2 years	0.027	1.206	150	0.00011
	6 <12 months	0.027	1.028	120	0.00012

Hand-to-Mouth Exposure for Lawn Activities

Exposure Scenario	Lifestage	HRt	F_M	SA_H (cm2)	Exposure Time (hours/day)	N_Replen	SE	Freq_HtM	Exposure (mg/day)	Average Daily Dose (mg/kg/day)
		Hand Residue (mg/cm2)	Fraction of Hand Surface Area Mouthed / Event			Number of replenishment intervals per hr (intervals/hr)	Extraction by Saliva	H-t-M events per hour		
HtM Exposure Liquid Product	3 <6 years	0.00135	0.127	225	1.5	4	0.5	8.5	0.18	0.0096
	2 <3 years	0.00152	0.127	160	1.5	4	0.5	5.3	0.11	0.0081
	1 <2 years	0.00142	0.127	150	1.5	4	0.5	13.9	0.15	0.013
	6 <12 months	0.00149	0.127	120	1.5	4	0.5	14.5	0.12	0.014
HtM Exposure Granular Product	3 <6 years	0.00010	0.127	150	1.5	4	0.5	8.5	0.0092	0.0005
	2 <3 years	0.00012	0.127	150	1.5	4	0.5	5.3	0.0080	0.0006
	1 <2 years	0.00011	0.127	150	1.5	4	0.5	13.9	0.011	0.0010
	6 <12 months	0.00012	0.127	150	1.5	4	0.5	14.5	0.012	0.0013

Table AA-3: Turf Object-to-Mouth Lifestage Analysis

Object Residue Calculations

Exposure Scenario	Application Rate (lb ai/acre)	F_O	Weight unit conversion factor	Area unit conversion factor	OR_t (ug/cm2)
Object Residue Liquid Product	0.87	0.0	450000000	0.0000000247	0.097
Object Residue Granular Product	0.67	0.0	450000000	0.0000000247	0.074

Object-to-Mouth Exposure for Lawn Activities

Exposure Scenario	Lifestage	ORt: Object Residue (mg/cm2)	Weight unit conversion factor	SAM_O: Object Surface Area Mouthed / Event (cm2/event)	Exposure Time (hours/day)	N_Replen: Number of replenishment intervals per hr (intervals/hr)	SE: Extraction by Saliva	Freq_OtM: O-t-M events per hour	Exposure (mg/day)	Average Daily Dose (mg/kg/day)
OtM Exposure Liquid Product	3 <6 years	0.097	0.001	10	1.5	4	0.5	8.3	0.0044	0.00024
	2 <3 years	0.097	0.001	10	1.5	4	0.5	8.1	0.0044	0.00032
	1 <2 years	0.097	0.001	10	1.5	4	0.5	8.8	0.0045	0.00040
	6 <12 months	Data on outdoor object-to-mouth event per hour are not available for this lifestage.								
OtM Exposure Granular Product	3 <6 years	0.074	0.001	10	1.5	4	0.5	8.8	0.0035	0.00019
	2 <3 years	0.074	0.001	10	1.5	4	0.5	8.8	0.0035	0.00025
	1 <2 years	0.074	0.001	10	1.5	4	0.5	8.8	0.0035	0.00031
	6 <12 months	Data on outdoor object-to-mouth event per hour are not available for this lifestage.								

Indoor SOP

Table AA-4: Indoor Dermal Lifestage Analysis									
Indoor Surface Residue Calculations when Chemical Specific Data are Not Available									
Type of Application	Application Rate (lb ai/acre)	Conversion Factor (ug/lb)	Conversion Factor (ft2 to cm2)	Percent of application rate deposited	Deposited residue (ug/cm2)				
Broadcast	0.0001	4.5E+08	1.08E-03	100%	49.03				
Dermal Exposure for Indoor Activities									
Exposure Scenario	Lifestage	Deposited Residue (ug/cm2)	Conversion Factor (mg/ug)	Fraction transferred	Transfer Coefficient (cm2/hr)	Hours of Exposure (hr)	Exposure (mg/day)	Body Weight (kg)	Average Daily Dose (mg/kg/day)
Carpet	Adult	49.03	0.001	0.06	6,800	8	160.0	79.5	2.0
	11 <16 years	49.03	0.001	0.06	5,500	5	80.9	56.8	1.4
	6 <11 years	49.03	0.001	0.06	3,800	5	55.9	31.8	1.8
	3 <6 years	49.03	0.001	0.06	2,700	5	39.7	18.6	2.1
	2 <3 years	49.03	0.001	0.06	2,200	4	25.9	13.8	1.9
	1 <2 years	49.03	0.001	0.06	1,800	4	21.2	11.4	1.9
	6 <12 months	49.03	0.001	0.06	1,600	5	23.5	9.2	2.6
Hard surfaces	Adult	49.03	0.001	0.08	6,800	2	53.3	79.5	0.7
	11 <16 years	49.03	0.001	0.08	5,500	1	21.6	56.8	0.4
	6 <11 years	49.03	0.001	0.08	3,800	2	29.8	31.8	0.9
	3 <6 years	49.03	0.001	0.08	2,700	2	21.2	18.6	1.1
	2 <3 years	49.03	0.001	0.08	2,200	2	17.3	13.8	1.3
	1 <2 years	49.03	0.001	0.08	1,800	2	14.1	11.4	1.2
	6 <12 months	49.03	0.001	0.08	1,600	2	12.6	9.2	1.4

Table AA-5: Indoor Inhalation (Aerosols) Lifestage Analysis									
Lifestage	Application rate (lb ai/m^3)	CF (mg/lb)	Co (mg/m^3)	IR (m^3/hr)	ACH (1/hr)	ET (hr)	Exposure (mg/day)	Body Weight (kg)	Inhalation Dose (mg/kg/day)
Adult	0.000158	4.54E+05	71.58	0.64	0.45	2	60.41	79.5	0.8
11 <16 years	0.000158	4.54E+05	71.58	0.63	0.45	2	59.47	56.8	1.0
6 <11 years	0.000158	4.54E+05	71.58	0.5	0.45	2	47.20	31.8	1.5
3 <6 years	0.000158	4.54E+05	71.58	0.42	0.45	2	39.65	18.6	2.1
2 <3 years	0.000158	4.54E+05	71.58	0.37	0.45	2	34.93	13.8	2.5
1 <2 years	0.000158	4.54E+05	71.58	0.33	0.45	2	31.15	11.4	2.7
6 <12 months	0.000158	4.54E+05	71.58	0.23	0.45	2	21.71	9.2	2.4

Table AA-6: Indoor Inhalation (Vapors) Lifestage Analysis									
Lifestage	Inhalation Rate (m^3/hr)	Mass of active ingredient applied (mg)	Hours of Exposure (hr)	k (first order decay rate)	Air exchange rate (1/hr)	Volume of room (m^3)	Exposure (mg/day)	Body Weight (kg)	Inhalation Dose (mg/kg/day)
Adult	0.64	454	16	2.08E-05	0.45	33	0.006	79.5	0.00007
11 <16 years	0.63	454	15	2.08E-05	0.45	33	0.005	56.8	0.00009
6 <11 years	0.5	454	15	2.08E-05	0.45	33	0.004	31.8	0.00012
3 <6 years	0.42	454	16	2.08E-05	0.45	33	0.004	18.6	0.00020
2 <3 years	0.37	454	16	2.08E-05	0.45	33	0.003	13.8	0.00024
1 <2 years	0.33	454	18	2.08E-05	0.45	33	0.003	11.4	0.00029
6 <12 months	0.23	454	18	2.08E-05	0.45	33	0.002	9.2	0.00025

Table AA-7: Indoor Hand-to-Mouth Lifestage Analysis

Hand Residue Calculations

Exposure Scenario	Lifestage	Fai_{hands}	Children Dermal Exposure	SA_H (cm2) Surface area of one hand	HR_t (mg/cm2)
Carpets	3 <6 years	0.15	39.7	225	0.0132
	2 <3 years	0.15	25.9	160	0.0121
	1 <2 years	0.15	21.2	150	0.0106
	6 <12 months	0.15	23.5	120	0.0147
Hard surfaces	3 <6 years	0.15	21.2	225	0.0071
	2 <3 years	0.15	17.3	160	0.0081
	1 <2 years	0.15	14.1	150	0.0071
	6 <12 months	0.15	12.6	120	0.0078

Hand-to-Mouth Exposure for Indoor Activities

Exposure Scenario	Lifestage	HR_t (mg/cm2)	F_M Fraction of Hand Surface Area Mouthed / Event	SA_H (cm2) Surface area of one hand	Exposure Time (hours/day)	N_Replen Number of replenishment intervals per hr (intervals/hr)	SE Extraction by Saliva	Freq_HtM H-t-M events per hour	Exposure (mg/day)	Body Weight (kg)	Average Daily Dose (mg/kg/day)
Carpets	3 <6 years	0.0132	0.13	225	5	4	0.5	14	7.1	18.6	0.38
	2 <3 years	0.0121	0.13	160	4	4	0.5	13	3.6	13.8	0.26
	1 <2 years	0.0106	0.13	150	4	4	0.5	20	3.2	11.4	0.28
	6 <12 months	0.0147	0.13	120	5	4	0.5	19	4.4	9.2	0.48
Hard surfaces	3 <6 years	0.0071	0.13	225	2	4	0.5	14	1.5	18.6	0.08
	2 <3 years	0.0081	0.13	160	2	4	0.5	13	1.2	13.8	0.09
	1 <2 years	0.0071	0.13	150	2	4	0.5	20	1.1	11.4	0.09
	6 <12 months	0.0078	0.13	120	2	4	0.5	19	0.9	9.2	0.10

Table AA-8: Indoor Object-to-Mouth Lifestage Analysis

Object Residue Calculations

Exposure Scenario	Lifestage	Application Rate (lb ai/acre)	F_o (fraction transferred to object)	Conversion Factor (ug/lb)	Conversion Factor (ft2 to cm2)	Conversion Factor (mg/ug)	Object residue loading (mg/cm^2)	
Carpet	3 <6 years	0.0001	0.06	4.50E+08	1.08E-03	0.001	0.003	
	2 <3 years						0.003	
	1 <2 years						0.003	
	6 <12 months						0.003	
Hard surface	3 <6 years		0.08				0.004	
	2 <3 years						0.004	
	1 <2 years						0.004	
	6 <12 months						0.004	

Object-to-Mouth Exposure for Indoor Activities

Exposure Scenario	Lifestage	Object residue loading (mg/cm^2)	SAM: Surface Area of Object Mouthed / Event (cm^2/event)	Exposure Time (hours/day)	N_Replen: Number of replenishment intervals per hr (intervals/hr)	SE: Extraction by Saliva	Freq_OtM: O-t-M events per hour	Exposure (mg/day)	Body Weight (kg)	Average Daily Dose (mg/kg/day)
Carpet	3 <6 years	0.003	10	5	4	0.5	10	0.48	18.6	0.03
	2 <3 years	0.003		4	4	0.5	10	0.38	13.8	0.03
	1 <2 years	0.003		4	4	0.5	14	0.43	11.4	0.04
	6 <12 months	0.003		5	4	0.5	20	0.56	9.2	0.06
Hard surface	3 <6 years	0.004		2	4	0.5	10	0.26	18.6	0.01
	2 <3 years	0.004		2	4	0.5	10	0.26	13.8	0.02
	1 <2 years	0.004		2	4	0.5	14	0.28	11.4	0.02
	6 <12 months	0.004		2	4	0.5	20	0.30	9.2	0.03

Pet SOP

Table AA-9: Pet Dermal Lifestage Analysis									
Dermal Exposure for High Contact Pet Activities									
Exposure Scenario	Lifestage	Application Rate (mg)	Surface area of pet (cm^2)	F_{AR}[a]	Transfer Coefficient (cm^2/hr)	Hours of Exposure (hr)	Exposure (mg/day)	Body Weight (kg)	Average Daily Dose (mg/kg/day)
Pet Post-application (Liquids) Medium Dog	Adult	300	7000	0.02	5,200	0.77	3.432	79.5	0.0432
	3 <6 years	300	7000	0.02	2,000	1.0	1.714	18.6	0.092
	2 <3 years	300	7000	0.02	1,600	1.0	1.372	13.8	0.0994
	1 <2 years	300	7000	0.02	1,400	1.0	1.2	11.4	0.1052
	6 <12 months	300	7000	0.02	1,200	1.0	1.028	9.2	0.1118
Pet Post-application (Solids) Medium Dogs	Adult	300	7000	0.02	140,000	0.77	92.4	79.5	1.162
	3 <6 years	300	7000	0.02	55,000	1.0	47.14	18.6	2.534
	2 <3 years	300	7000	0.02	43,000	1.0	36.86	13.8	2.67
	1 <2 years	300	7000	0.02	38,000	1.0	32.572	11.4	2.858
	6 <12 months	300	7000	0.02	32,000	1.0	27.428	9.2	2.982

b. The screening level value was selected for the F_{AR} value in this example. This value would be refined if chemical specific pet residue data are available.

Table AA-10: Pet Hand-to-Mouth Lifestage Analysis

Hand Residue Calculations

Exposure Scenario	Lifestage	Fai_{hands}	Children Dermal Exposure	SA_H (cm^2)	HRt (mg/cm^2)
Hand Residue Liquid Product Medium Dog	3 <6 years	0.04	1.714	225	0.000152
	2 <3 years	0.04	1.372	160	0.000172
	1 <2 years	0.04	1.2	150	0.00016
	6 <12 months	0.04	1.028	120	0.000171
Hand Residue Solid Product Medium Dog	3 <6 years	0.37	47.14	225	0.03876
	2 <3 years	0.37	36.86	160	0.042619
	1 <2 years	0.37	32.572	150	0.04017
	6 <12 months	0.37	27.428	120	0.04229

Hand-to-Mouth Exposure for Pet Activities

Exposure Scenario	Lifestage	HRt	F_M	SA_H (cm^2)	Exposure Time (hours/day)	N_Replen	SE	Freq_HtM	Body Weight (kg)	Average Daily Dose (mg/kg/day)
		Hand Residue (mg/cm^2)	Fraction of Hand Surface Area Mouthed / Event			Number of replenishment intervals per hr (intervals/hr)	Extraction by Saliva	H-t-M events per hour [a]		
HtM Exposure Liquid Product Medium Dog	3 <6 years	0.000152	0.13	225	1.0	4	0.48	14	18.6	0.00086
	2 <3 years	0.000172	0.13	160	1.0	4	0.48	13	13.8	0.000911
	1 <2 years	0.00016	0.13	150	1.0	4	0.48	20	11.4	0.001053
	6 <12 months	0.000171	0.13	120	1.0	4	0.48	19	9.2	0.00111
HtM Exposure Solid Product Medium Dog	3 <6 years	0.03876	0.13	225	1.0	4	0.48	14	18.6	0.219
	2 <3 years	0.042619	0.13	160	1.0	4	0.48	13	13.8	0.2263
	1 <2 years	0.04017	0.13	150	1.0	4	0.48	20	11.4	0.2644
	6 <12 months	0.04229	0.13	120	1.0	4	0.48	19	9.2	0.2740

a. HTM event frequency is not available for the pet scenario specifically; therefore, data for indoor environments was used as a surrogate.

Outdoor Fogger SOP

Table AA-11: Aerosol Can Inhalation Lifestage Analysis							
Inhalation Exposure– One 16 oz spray can							
Exposure Scenario	Lifestage	Application Rate (mL/can)	Number of cans	Volume (V) (m^3)	Airflow (Q) (m^3/hr)	IR (m^3/hr)	Average Daily Dose (mg/kg/day)
Inhalation - Aerosol Can	Adult	473	1	15	5400	0.64	0.705
	3 <6 years	473	1	15	5400	0.42	1.98
	2 <3 years	473	1	15	5400	0.37	2.35
	1 <2 years	473	1	15	5400	0.33	2.53
	6 <12 months	473	1	15	5400	0.23	2.19

Table AA-12: Candles, Coils, Torches, and Mats Inhalation Lifestage Analysis										
Inhalation Exposure- Four 0.25 ounce sticks										
Exposure Scenario	Lifestage	Application Rate (mg/product)	Number of Products	Volume (V) (m^3)	Hours of Exposure (hr)	Airflow (Q) (m^3/hr)	Useful Life (hrs)	Acs (m^2)	IR (m^3/hr)	Average Daily Dose (mg/kg/day)
Inhalation - Candles, Coils, Torches and Mats	Adult	7087	4	51	2.3	3960	4	11	0.64	0.032
	3 <6 years	7087	4	51	2.5	3960	4	11	0.42	0.099
	2 <3 years	7087	4	51	2.3	3960	4	11	0.37	0.106
	1 <2 years	7087	4	51	2.3	3960	4	11	0.33	0.115
	6 <12 months	7087	4	51	2.3	3960	4	11	0.23	0.079

Table AA-13: Residential Misting Systems Inhalation Lifestage Analysis									
Inhalation Exposure- One ounce spray nozzles									
Exposure Scenario	Lifestage	Application Rate (oz/1000ft3)	Pulse Rate (spray/hr)	Volume (V) (m^3)	Hours of Exposure (hr)	Airflow (Q) (m^3/hr)	Acs (m^2)	IR (m^3/hr)	Average Daily Dose (mg/kg/day)
Inhalation - Outdoor Residential Misting System	Adult	1	1	91	2.3	5400	15	0.64	0.32
	3 <6 years	1	1	91	2.5	5400	15	0.42	0.99
	2 <3 years	1	1	91	2.3	5400	15	0.37	1.08
	1 <2 years	1	1	91	2.3	5400	15	0.33	1.2
	6 <12 months	1	1	91	2.3	5400	15	0.23	1.01

Table AA-14: Animal Barn Misting Systems Inhalation Lifestage Analysis [a]							
Inhalation Exposure- One ounce spray nozzles							
Exposure Scenario	Lifestage	Application Rate (oz/1000ft3)	Pulse Rate (spray/hr)	ACH	Hours of Exposure (hr)	IR (m^3/hr)	Average Daily Dose (mg/kg/day)
Inhalation - Animal Barn	Adult	1	1	4	4	0.64	8.4
	11<16 group	1	1	4	2	0.63	5.8
	6 <11 years	1	1	4	2	0.50	8.2
	3 <6 years	1	1	4	2	0.42	11.8
	2 <3 years	1	1	4	2	0.37	13.9
	1 <2 years	1	1	4	2	0.33	15.1
	6 <12 months	1	1	4	2	0.23	13.1

a. The 6 < 12 month old, the 1 < 2 year old, and the 2 < 3 year old lifestages are not expected to be present in horse or animal barns for any significant length of time. For this scenario, HED believes that the 3 < 6 year old lifestage is the youngest lifestage viable for the exposure scenario and the younger lifestages will not be assessed. However, the other lifestages have been included here for illustrative purposes.

Appendix B Supporting Data Analysis and Documentation for Universal Exposure Factors for Residential Exposure Assessment

B.1 Generic Estimates of Fraction Hand Surface Area Mouthed

The generic estimates of fraction hand surface area mouthed are based on an analysis presented in Zartarian et al. (2005). Based on this analysis, it was determined that a beta distribution (3.7, 25) best fits the observed data. Table *B- 1: Fraction Hand* Surface Area Mouthed *Data* provides the raw data from this study.

Table B- 1: Fraction Hand Surface Area Mouthed Data

Mouthing Category	Frequency	Age of Child	Child ID	Fraction of Hand	Finger
partial fingers	5	1	453F01	3	1
partial fingers	1	1	453F01	5	2
partial fingers	0	1	453F01	7	3
partial fingers	1	1	453F01	9	4
partial fingers	0	1	453F01	11	5
full fingers	1	1	453F01	15	1
full fingers	0	1	453F01	29	2
full fingers	0	1	453F01	43	3
full fingers	0	1	453F01	57	4
full fingers	0	1	453F01	71	5
palm w/ fingers	0	1	453F01	49	1
palm w/ fingers	0	1	453F01	78	2
palm w/ fingers	0	1	453F01	106	3
palm w/ fingers	0	1	453F01	134	4
palm w/ fingers	0	1	453F01	163	5
palm w/out fingers	0	1	453F01	41	0
partial fingers	2	1	248M01	3	1
partial fingers	0	1	248M01	5	2
partial fingers	2	1	248M01	7	3
partial fingers	0	1	248M01	9	4
partial fingers	0	1	248M01	11	5
full fingers	26	1	248M01	15	1
full fingers	3	1	248M01	29	2
full fingers	0	1	248M01	43	3
full fingers	0	1	248M01	57	4
full fingers	0	1	248M01	71	5
palm w/ fingers	0	1	248M01	49	1
palm w/ fingers	0	1	248M01	78	2

Table B- 1: Fraction Hand Surface Area Mouthed Data					
Mouthing Category	Frequency	Age of Child	Child ID	Fraction of Hand	Finger
palm w/ fingers	0	1	248M01	106	3
palm w/ fingers	0	1	248M01	134	4
palm w/ fingers	0	1	248M01	163	5
palm w/out fingers	2	1	248M01	41	0
partial fingers	3	1	958F01	3	1
partial fingers	60	1	958F01	5	2
partial fingers	4	1	958F01	7	3
partial fingers	14	1	958F01	9	4
partial fingers	3	1	958F01	11	5
full fingers	0	1	958F01	15	1
full fingers	14	1	958F01	29	2
full fingers	0	1	958F01	43	3
full fingers	0	1	958F01	57	4
full fingers	0	1	958F01	71	5
palm w/ fingers	0	1	958F01	49	1
palm w/ fingers	0	1	958F01	78	2
palm w/ fingers	0	1	958F01	106	3
palm w/ fingers	0	1	958F01	134	4
palm w/ fingers	0	1	958F01	163	5
palm w/out fingers	1	1	958F01	41	0
partial fingers	0	1	550M01	3	1
partial fingers	3	1	550M01	5	2
partial fingers	0	1	550M01	7	3
partial fingers	0	1	550M01	9	4
partial fingers	0	1	550M01	11	5
full fingers	0	1	550M01	15	1
full fingers	0	1	550M01	29	2
full fingers	0	1	550M01	43	3
full fingers	0	1	550M01	57	4
full fingers	0	1	550M01	71	5
palm w/ fingers	0	1	550M01	49	1
palm w/ fingers	0	1	550M01	78	2
palm w/ fingers	0	1	550M01	106	3
palm w/ fingers	0	1	550M01	134	4
palm w/ fingers	0	1	550M01	163	5
palm w/out fingers	0	1	550M01	41	0
partial fingers	0	2	420M02	3	1
partial fingers	0	2	420M02	5	2
partial fingers	0	2	420M02	7	3

Table B- 1: Fraction Hand Surface Area Mouthed Data					
Mouthing Category	Frequency	Age of Child	Child ID	Fraction of Hand	Finger
partial fingers	0	2	420M02	9	4
partial fingers	0	2	420M02	11	5
full fingers	0	2	420M02	15	1
full fingers	0	2	420M02	29	2
full fingers	0	2	420M02	43	3
full fingers	0	2	420M02	57	4
full fingers	0	2	420M02	71	5
palm w/ fingers	0	2	420M02	49	1
palm w/ fingers	0	2	420M02	78	2
palm w/ fingers	0	2	420M02	106	3
palm w/ fingers	0	2	420M02	134	4
palm w/ fingers	0	2	420M02	163	5
palm w/out fingers	0	2	420M02	41	0
partial fingers	2	2	638F02	3	1
partial fingers	1	2	638F02	5	2
partial fingers	0	2	638F02	7	3
partial fingers	1	2	638F02	9	4
partial fingers	0	2	638F02	11	5
full fingers	0	2	638F02	15	1
full fingers	0	2	638F02	29	2
full fingers	0	2	638F02	43	3
full fingers	0	2	638F02	57	4
full fingers	0	2	638F02	71	5
palm w/ fingers	0	2	638F02	49	1
palm w/ fingers	0	2	638F02	78	2
palm w/ fingers	0	2	638F02	106	3
palm w/ fingers	0	2	638F02	134	4
palm w/ fingers	0	2	638F02	163	5
palm w/out fingers	0	2	638F02	41	0
partial fingers	0	2	587F02	3	1
partial fingers	0	2	587F02	5	2
partial fingers	1	2	587F02	7	3
partial fingers	0	2	587F02	9	4
partial fingers	0	2	587F02	11	5
full fingers	6	2	587F02	15	1
full fingers	0	2	587F02	29	2
full fingers	0	2	587F02	43	3
full fingers	0	2	587F02	57	4
full fingers	0	2	587F02	71	5
palm w/ fingers	0	2	587F02	49	1
palm w/ fingers	0	2	587F02	78	2
palm w/ fingers	0	2	587F02	106	3
palm w/ fingers	0	2	587F02	134	4
palm w/ fingers	0	2	587F02	163	5
palm w/out fingers	1	2	587F02	41	0

Table B- 1: Fraction Hand Surface Area Mouthed Data					
Mouthing Category	Frequency	Age of Child	Child ID	Fraction of Hand	Finger
partial fingers	5	2	806M02	3	1
partial fingers	0	2	806M02	5	2
partial fingers	0	2	806M02	7	3
partial fingers	1	2	806M02	9	4
partial fingers	0	2	806M02	11	5
full fingers	0	2	806M02	15	1
full fingers	0	2	806M02	29	2
full fingers	0	2	806M02	43	3
full fingers	0	2	806M02	57	4
full fingers	0	2	806M02	71	5
palm w/ fingers	0	2	806M02	49	1
palm w/ fingers	0	2	806M02	78	2
palm w/ fingers	0	2	806M02	106	3
palm w/ fingers	0	2	806M02	134	4
palm w/ fingers	0	2	806M02	163	5
palm w/out fingers	0	2	806M02	41	0
partial fingers	1	3	165M03	3	1
partial fingers	7	3	165M03	5	2
partial fingers	1	3	165M03	7	3
partial fingers	1	3	165M03	9	4
partial fingers	0	3	165M03	11	5
full fingers	0	3	165M03	15	1
full fingers	0	3	165M03	29	2
full fingers	0	3	165M03	43	3
full fingers	0	3	165M03	57	4
full fingers	0	3	165M03	71	5
palm w/ fingers	0	3	165M03	49	1
palm w/ fingers	0	3	165M03	78	2
palm w/ fingers	0	3	165M03	106	3
palm w/ fingers	0	3	165M03	134	4
palm w/ fingers	0	3	165M03	163	5
palm w/out fingers	0	3	165M03	41	0
partial fingers	0	3	129M03	3	1
partial fingers	0	3	129M03	5	2
partial fingers	0	3	129M03	7	3
partial fingers	1	3	129M03	9	4
partial fingers	0	3	129M03	11	5
full fingers	0	3	129M03	15	1
full fingers	2	3	129M03	29	2
full fingers	0	3	129M03	43	3
full fingers	0	3	129M03	57	4
full fingers	1	3	129M03	71	5
palm w/ fingers	0	3	129M03	49	1
palm w/ fingers	0	3	129M03	78	2
palm w/ fingers	0	3	129M03	106	3

Table B- 1: Fraction Hand Surface Area Mouthed Data					
Mouthing Category	Frequency	Age of Child	Child ID	Fraction of Hand	Finger
palm w/ fingers	0	3	129M03	134	4
palm w/ fingers	0	3	129M03	163	5
palm w/out fingers	0	3	129M03	41	0
partial fingers	0	3	317F03	3	1
partial fingers	0	3	317F03	5	2
partial fingers	0	3	317F03	7	3
partial fingers	0	3	317F03	9	4
partial fingers	0	3	317F03	11	5
full fingers	0	3	317F03	15	1
full fingers	0	3	317F03	29	2
full fingers	0	3	317F03	43	3
full fingers	0	3	317F03	57	4
full fingers	0	3	317F03	71	5
palm w/ fingers	0	3	317F03	49	1
palm w/ fingers	0	3	317F03	78	2
palm w/ fingers	0	3	317F03	106	3
palm w/ fingers	0	3	317F03	134	4
palm w/ fingers	0	3	317F03	163	5
palm w/out fingers	0	3	317F03	41	0
partial fingers	7	4	422F04	3	1
partial fingers	3	4	422F04	5	2
partial fingers	5	4	422F04	7	3
partial fingers	1	4	422F04	9	4
partial fingers	0	4	422F04	11	5
full fingers	3	4	422F04	15	1
full fingers	0	4	422F04	29	2
full fingers	0	4	422F04	43	3
full fingers	0	4	422F04	57	4
full fingers	0	4	422F04	71	5
palm w/ fingers	1	4	422F04	49	1
palm w/ fingers	0	4	422F04	78	2
palm w/ fingers	0	4	422F04	106	3
palm w/ fingers	1	4	422F04	134	4
palm w/ fingers	0	4	422F04	163	5
palm w/out fingers	0	4	422F04	41	0
partial fingers	0	4	772M04	3	1
partial fingers	0	4	772M04	5	2
partial fingers	0	4	772M04	7	3
partial fingers	0	4	772M04	9	4
partial fingers	0	4	772M04	11	5
full fingers	0	4	772M04	15	1
full fingers	0	4	772M04	29	2
full fingers	0	4	772M04	43	3
full fingers	0	4	772M04	57	4
full fingers	0	4	772M04	71	5

Table B- 1: Fraction Hand Surface Area Mouthed Data					
Mouthing Category	Frequency	Age of Child	Child ID	Fraction of Hand	Finger
palm w/ fingers	0	4	772M04	49	1
palm w/ fingers	0	4	772M04	78	2
palm w/ fingers	0	4	772M04	106	3
palm w/ fingers	0	4	772M04	134	4
palm w/ fingers	0	4	772M04	163	5
palm w/out fingers	2	4	772M04	41	0
partial fingers	0	4	575F04	3	1
partial fingers	0	4	575F04	5	2
partial fingers	0	4	575F04	7	3
partial fingers	0	4	575F04	9	4
partial fingers	0	4	575F04	11	5
full fingers	0	4	575F04	15	1
full fingers	0	4	575F04	29	2
full fingers	0	4	575F04	43	3
full fingers	0	4	575F04	57	4
full fingers	0	4	575F04	71	5
palm w/ fingers	0	4	575F04	49	1
palm w/ fingers	0	4	575F04	78	2
palm w/ fingers	0	4	575F04	106	3
palm w/ fingers	0	4	575F04	134	4
palm w/ fingers	0	4	575F04	163	5
palm w/out fingers	0	4	575F04	41	0
partial fingers	0	5	919F05	3	1
partial fingers	1	5	919F05	5	2
partial fingers	0	5	919F05	7	3
partial fingers	0	5	919F05	9	4
partial fingers	0	5	919F05	11	5
full fingers	0	5	919F05	15	1
full fingers	1	5	919F05	29	2
full fingers	0	5	919F05	43	3
full fingers	0	5	919F05	57	4
full fingers	0	5	919F05	71	5
palm w/ fingers	0	5	919F05	49	1
palm w/ fingers	0	5	919F05	78	2
palm w/ fingers	0	5	919F05	106	3
palm w/ fingers	0	5	919F05	134	4
palm w/ fingers	0	5	919F05	163	5
palm w/out fingers	0	5	919F05	41	0
partial fingers	0	5	280M05	3	1
partial fingers	1	5	280M05	5	2
partial fingers	1	5	280M05	7	3
partial fingers	0	5	280M05	9	4
partial fingers	0	5	280M05	11	5
full fingers	0	5	280M05	15	1
full fingers	0	5	280M05	29	2

Table B- 1: Fraction Hand Surface Area Mouthed Data					
Mouthing Category	Frequency	Age of Child	Child ID	Fraction of Hand	Finger
full fingers	0	5	280M05	43	3
full fingers	0	5	280M05	57	4
full fingers	0	5	280M05	71	5
palm w/ fingers	0	5	280M05	49	1
palm w/ fingers	0	5	280M05	78	2
palm w/ fingers	0	5	280M05	106	3
palm w/ fingers	0	5	280M05	134	4
palm w/ fingers	0	5	280M05	163	5
palm w/out fingers	0	5	280M05	41	0
partial fingers	0	5	557F05	3	1
partial fingers	0	5	557F05	5	2
partial fingers	0	5	557F05	7	3
partial fingers	0	5	557F05	9	4
partial fingers	0	5	557F05	11	5
full fingers	0	5	557F05	15	1
full fingers	0	5	557F05	29	2
full fingers	0	5	557F05	43	3
full fingers	0	5	557F05	57	4
full fingers	0	5	557F05	71	5
palm w/ fingers	0	5	557F05	49	1
palm w/ fingers	0	5	557F05	78	2
palm w/ fingers	0	5	557F05	106	3
palm w/ fingers	0	5	557F05	134	4
palm w/ fingers	0	5	557F05	163	5
palm w/out fingers	0	5	557F05	41	0
partial fingers	1	6	257F06	3	1
partial fingers	0	6	257F06	5	2
partial fingers	0	6	257F06	7	3
partial fingers	0	6	257F06	9	4
partial fingers	0	6	257F06	11	5
full fingers	0	6	257F06	15	1
full fingers	0	6	257F06	29	2
full fingers	0	6	257F06	43	3
full fingers	0	6	257F06	57	4
full fingers	0	6	257F06	71	5
palm w/ fingers	0	6	257F06	49	1
palm w/ fingers	0	6	257F06	78	2
palm w/ fingers	0	6	257F06	106	3
palm w/ fingers	0	6	257F06	134	4
palm w/ fingers	0	6	257F06	163	5
palm w/out fingers	0	6	257F06	41	0
partial fingers	2	6	338F06	3	1
partial fingers	2	6	338F06	5	2
partial fingers	1	6	338F06	7	3
partial fingers	0	6	338F06	9	4

Table B- 1: Fraction Hand Surface Area Mouthed Data					
Mouthing Category	Frequency	Age of Child	Child ID	Fraction of Hand	Finger
partial fingers	0	6	338F06	11	5
full fingers	0	6	338F06	15	1
full fingers	0	6	338F06	29	2
full fingers	0	6	338F06	43	3
full fingers	0	6	338F06	57	4
full fingers	0	6	338F06	71	5
palm w/ fingers	0	6	338F06	49	1
palm w/ fingers	0	6	338F06	78	2
palm w/ fingers	0	6	338F06	106	3
palm w/ fingers	0	6	338F06	134	4
palm w/ fingers	0	6	338F06	163	5
palm w/out fingers	0	6	338F06	41	0
partial fingers	1	6	331F06	3	1
partial fingers	5	6	331F06	5	2
partial fingers	2	6	331F06	7	3
partial fingers	4	6	331F06	9	4
partial fingers	0	6	331F06	11	5
full fingers	2	6	331F06	15	1
full fingers	0	6	331F06	29	2
full fingers	0	6	331F06	43	3
full fingers	0	6	331F06	57	4
full fingers	0	6	331F06	71	5
palm w/ fingers	0	6	331F06	49	1
palm w/ fingers	0	6	331F06	78	2
palm w/ fingers	0	6	331F06	106	3
palm w/ fingers	0	6	331F06	134	4
palm w/ fingers	0	6	331F06	163	5
palm w/out fingers	0	6	331F06	41	0

Statistics such as standard deviations and select percentiles are presented in *Table B- 2* below.

Table B- 2: Fraction Hand Surface Area Mouthed	
Statistic	**Fraction Hand Surface Area Mouthed**
50^{th} percentile	0.118
75^{th} percentile	0.164
95^{th} percentile	0.243
AM (SD)	0.127 (0.0614)
GM (GSD)	0.114 (1.58)
Range	0.05 – 0.4
N	220
AM (SD) = arithmetic mean (standard deviation) GM (GSD) = geometric mean (geometric standard deviation)	

B.2 Generic Estimates of Object Surface Area Mouthed

A factor used in object-to-mouth post-application assessments is the surface area of the object that a child puts in its mouth. This value (expressed in cm^2) is utilized in a number of the SOPs in this document. Based on the area of hand mouthed by 2-5 years old as reported by Leckie et al. (2000), and the assumption that children mouth a smaller area of an object than their hand, an exponential distribution with a minimum of 1 cm^2, a mean of 10 cm^2, and a maximum of 50 cm^2 was chosen. The maximum is comparable to the surface area of a ping-pong ball. *Figure B-1* presents the Monte Carlo simulation based on the distribution derived from Leckie et al. (2000).

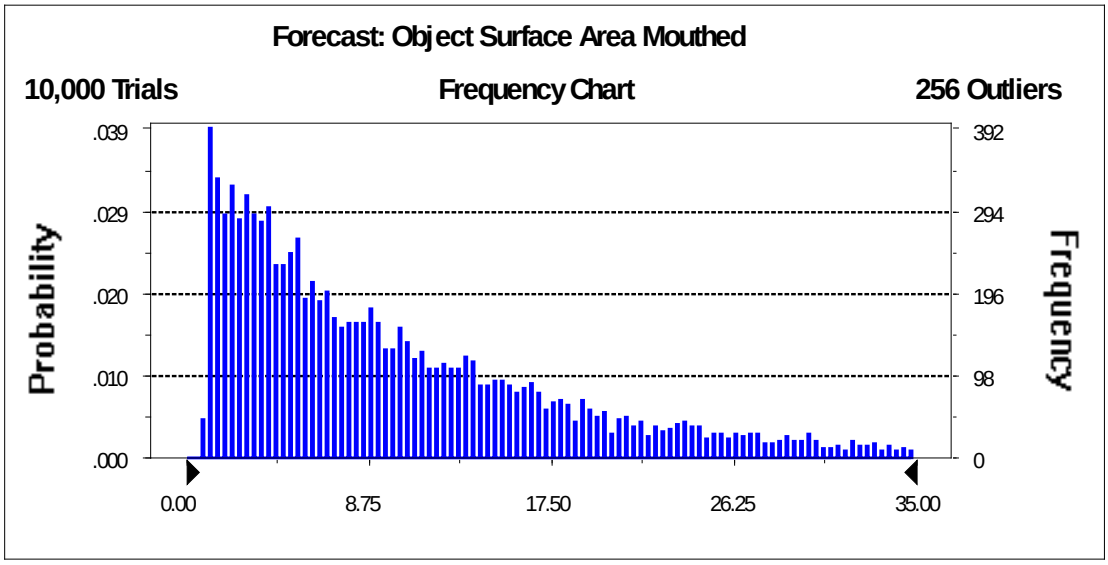


Figure B-1: Monte Carlo Simulation for Object Surface Area Mouthed (cm2) Assuming an Exponential Distribution (Minimum= 1 cm2, Mean= 10 cm2, Maximim= 50 cm2)

B.3 Generic Estimates of Fraction of Pesticide Extracted by Saliva

The fraction of pesticide extracted by saliva is an important variable for hand-to-mouth and object-to-mouth post-application exposure assessments. The fraction of pesticide extracted by saliva has historically been referred to as the saliva extraction factor or mouthing removal efficiency. It is used in hand-to-mouth and object-to-mouth assessments to account for removal of pesticides from hands or objects via saliva. Data to adequately characterize the fraction of pesticide extracted by saliva are limited and difficult to collect. However, one study, Camann et al. (1996), is available to determine generic values for the fraction of pesticide extracted by saliva.

The Camann et al. study examined the removal efficiencies from hands with gauze moistened with artificial and human saliva. This activity was meant to simulate removal of pesticides resulting from placement of a hand into the mouth. Only the data collected with human saliva are presented here. Triplicate samples were collected three times for three different pesticides (chlorpyrifos, pyrethrin, and PBO). This resulted in a total of twenty-seven samples (nine for each pesticide). All data were compiled and it was determined that the distribution of saliva extraction values was best approximated by a beta distribution ($\alpha = 7.0$, $\beta = 7.6$). *Table B- 3* provides the raw data for the study. Following this table, *Figure B-2* provides a comparison of

the recommended beta distribution and actual observed values and *Figure B-3* provides the results of a Monte Carlo simulation using this distribution. Based on the recommended distribution, the summary statistics presented in *Table B- 4* were derived for fraction of pesticide extracted by saliva. Note: This study focused specifically on fraction of pesticide extracted by saliva from hands; not objects. However, there are currently no data available to address the removal of residues from objects by saliva during mouthing events so this study is being used for both hands and objects.

Table B- 3: Fraction of Pesticide Extracted by Saliva Data

	Subject	Day	Hand	Amount Transferred to Hand (ug)	Amount Removed by Salivary Wipe (ug)	Salivary Wipe Efficiency
Chlorpyrifos	Subject A	1	RIGHT	5.58	2.01	0.360
	Subject A	3	LEFT	6.63	2.13	0.321
	Subject A	4	RIGHT	7.29	3.21	0.440
	Subject B	2	LEFT	5.36	3.59	0.670
	Subject B	3	RIGHT	6.47	3.16	0.488
	Subject B	5	LEFT	4.7	2.74	0.583
	Subject C	1	LEFT	7.46	3.75	0.503
	Subject C	2	RIGHT	7.17	5.11	0.713
	Subject C	4	LEFT	7.78	4.7	0.604
Pyrethrin	Subject A	1	RIGHT	24.8	10.6	0.427
	Subject A	3	LEFT	26.8	10	0.373
	Subject A	4	RIGHT	31.3	13.6	0.435
	Subject B	2	LEFT	20.8	12.4	0.596
	Subject B	3	RIGHT	26	15.5	0.596
	Subject B	5	LEFT	19.4	9.6	0.495
	Subject C:	1	LEFT	32.2	19	0.590
	Subject C:	2	RIGHT	29.1	18.6	0.639
	Subject C:	4	LEFT	33.3	18.2	0.547
PBO	Subject A	1	RIGHT	28.1	11.9	0.423
	Subject A	3	LEFT	43.1	11.1	0.258
	Subject A	4	RIGHT	53.3	15.1	0.283
	Subject B	2	LEFT	20.5	10.7	0.522
	Subject B	3	RIGHT	40.4	8.9	0.220
	Subject B	5	LEFT	19.6	10.8	0.551
	Subject C	1	LEFT	51.2	22.6	0.441
	Subject C	2	RIGHT	51.9	31.1	0.599
	Subject C	4	LEFT	58.7	21.1	0.359

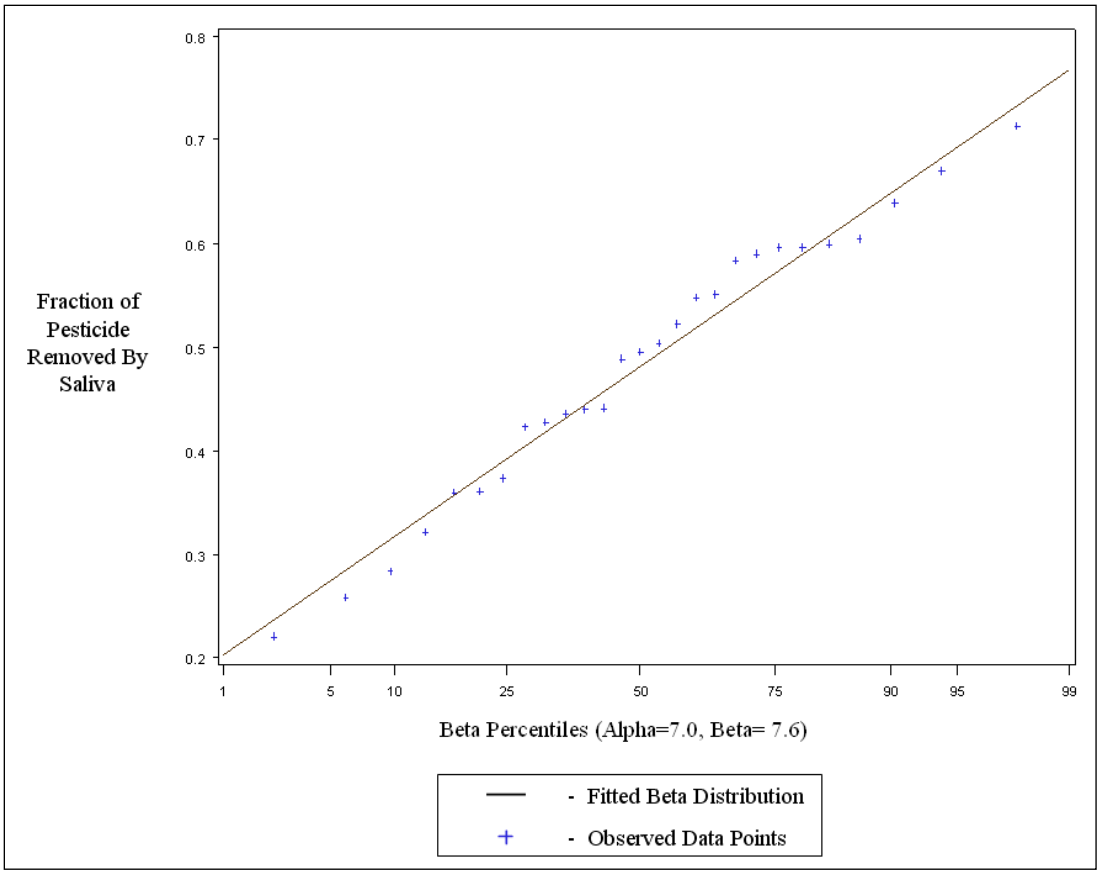


Figure B-2: Comparison of the Recommended Beta Distribution (α = 7.0, β = 7.6) and the observed data points from Camann et al. (1995).

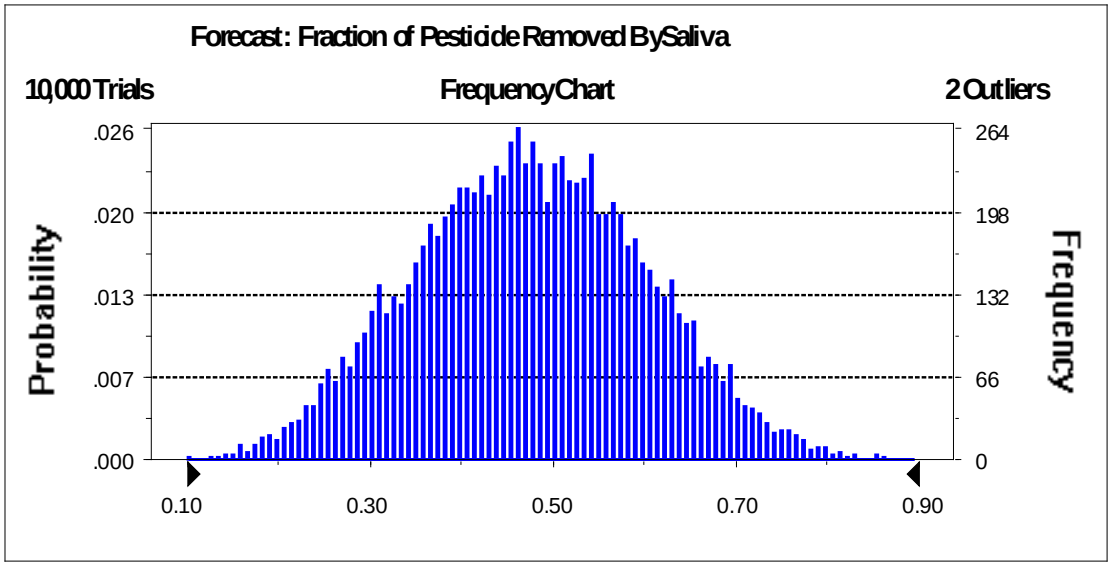


Figure B-3: Monte Carlo Simulation for Fraction of Pesticide Extracted by Saliva Using a Beta Distribution (α = 7.0, β = 7.6)

Table B- 4: Fraction of Pesticide Extracted by Saliva	
Statistic	Fraction of Pesticide Extracted by Saliva
50th percentile	0.50
75th percentile	0.57
90th percentile	0.64
95th percentile	0.68
99th percentile	0.80
Arithmetic Mean	0.48
Arithmetic Standard Deviation	0.13
Geometric Mean	0.46
Geometric Mean Standard Deviation	1.35

Appendix C Supporting Data Analysis and Documentation for Residential Handler Exposure Assessment

C.1 Summary of Exposure Data Used to Generate Residential Unit Exposures

Throughout the Residential SOPs, references are made to formulation- and application method-specific unit exposures for use in various handler exposure assessment scenarios. The following appendix provides summary information on the exposure studies that serve as the basis for those unit exposures. It includes:

- Scenario summaries organized by formulation, equipment/application methods, and application site(s);
- References for all available studies that could potentially be used for residential exposure assessment (note: for confidentiality reasons, PHED studies are referenced by their PHED code);
- Brief study descriptions;
- Tables outlining relevant characteristics for each study with respect to its potential use in residential handler exposure assessments; and,
- Study-specific data summaries, including limitations and uncertainties.

Analytical commonalities for all studies include:

- Statistics for all exposure studies are based on fitting lognormal distributions. Given that environmental data routinely follow a lognormal distribution and many of the exposure studies display this trend, this is not an unreasonable assumption – including for scenarios based on small datasets or those that may not exhibit an exact match with a lognormal distribution with the data available;
- Lognormal probability plots are presented, providing a visual demonstration of the lognormal fit (or lack thereof) for the dataset. Additionally, plots that incorporate multiple datasets included study-specific coding (different shapes) to provide visual reference of the distribution of data points within studies and the studies within the overall distribution.
- Means and standard deviations are calculated using the minimum variance unbiased estimator for lognormal distributions:
    - AM = GM *exp{0.5*((lnGSD)^2)};
    - SD = AM * SQRT(exp((lnGSD)^2)-1); and
    - Where: AM = arithmetic mean; GM = geometric mean; GSD = geometric standard deviation.
- Unit exposures are representative of individuals wearing short-sleeve shirts; shorts, shoes/socks, and no other protective equipment including chemical resistant gloves or respirators;
- Using ½ the limit of detection or limit of quantification for non-detect samples as is standard practice;

- 90% protection is assumed when back-calculating gloved hand exposure to bare hand exposure;
- 50% protection is assumed when back-calculating covered forearm and shin exposure to bare forearm and shin exposure;
- Corrections for field fortification recoveries as appropriate; and,
- Using a breathing rate of 16.7 liters per minute, representing light activities (NAFTA-CDPR, 1998), to extrapolate air samples to residential handler inhalation exposure.

Note that the exposure studies recommended for use in residential handler exposure assessment inform only the default unit exposure data for each scenario and does not mean that a study not recommended for use cannot ever be used. Should a non-recommended study in this appendix be deemed useful given a unique situation, the assessment should provide justification for its use and deviation from the default data.

Table C-1: List of Handler Scenarios

Formulation	Equipment/Application Method	Application Site(s)	Page Number
Granules	Push-type Spreader	outdoors (lawn, gardens)	*C-4*
	Belly grinder	outdoors (lawn, gardens, trees/bushes, perimeter, mounds/nests, aquatic areas)	*C-11*
	Spoon	outdoors (lawn, gardens, trees/bushes, perimeter, mounds/nests, aquatic areas)	*C-20*
	Cup	outdoors (lawn, gardens, trees/bushes, perimeter, mounds/nests, aquatic areas)	*C-24*
	Hand dispersal	outdoors (lawn, gardens, trees/bushes, perimeter, mounds/nests, aquatic areas)	*C-28*
Dusts/Powders	Plunger duster	outdoors (lawns, gardens, trees/bushes, perimeter, mounds/nests), indoors (general broadcast treatments)	*C-32*
	Shaker can	outdoors (lawns, gardens, trees/bushes, perimeter, mounds/nests), indoors (general broadcast treatments), pets/animals	*C-36*
Paints and Stains	Airless sprayer	outdoors and indoors (general paint and stain applications)	*C-42*
	Brush	outdoors and indoors (general paint and stain applications)	*C-48*
Mothballs	Hand placement	cabinets, sheds, closets	*C-52*
Liquids (emulsifiable concentrates, soluble concentrates, etc.)	Manually-pressurized handwand	outdoors (lawns, gardens, trees/bushes, perimeter, mounds/nests, aquatic areas), indoors (general broadcast treatments, baseboards, cracks and crevices)	*C-56*
	Handheld Fogger	outdoors (lawns, gardens, trees/bushes, perimeter, mounds/nests)	*C-68*
	Dipping	pets/animals	*C-71*
	Sponge	pets/animals	*C-75*
	Hose-end sprayer	outdoors (lawns, gardens, trees/bushes, perimeter, mounds/nests, aquatic areas)	*C-79*
	Backpack sprayer	outdoors (lawns, gardens, trees/bushes, perimeter, mounds/nests, aquatic areas)	*C-91*
Ready-to-use (RTU)	Hose-end sprayer	outdoors (lawns, gardens, trees/bushes, perimeter, mounds/nests, aquatic areas)	*C-107*
	Trigger-pump sprayer	outdoors (lawns, gardens, trees/bushes, perimeter,	*C-113*

		mounds/nests, aquatic areas), indoors (plants, cracks and crevices), pets/animals	
	Shampoo	pets/animals, children	*C-124*
	Spot-on	pets/animals	*C-130*
	Aerosol can	outdoors (gardens, trees/bushes, perimeter, mounds/nests, aquatic areas), indoors (general broadcast treatments, baseboards, cracks and crevices), pets/animals	*C-134*
Wettable Powder (WP)	Manually-pressurized handwand	outdoors (lawns, gardens, trees/bushes, perimeter, mounds/nests, aquatic areas), indoors (general broadcast treatments, baseboards, cracks and crevices)	*C-141*
	Backpack sprayer	outdoors (lawns, gardens, trees/bushes, perimeter, mounds/nests, aquatic areas), indoors (general broadcast treatments, baseboards, cracks and crevices)	*C-148*

Scenario Summary

Table C-2: Scenario Description and Available Exposure Studies	
Formulation	Granules
Equipment/Application Method	Push-type Spreader (also: rotary spreader, cyclone spreader, "Scotts" spreader)
Application Site(s)	Outdoors (lawn, gardens)
Available Exposure Studies	Klonne, D. (1999); MRID 44972201
	PHED 1027
	Solomon, K. R., Harris, S. A, Stephenson, G. R. (1993)

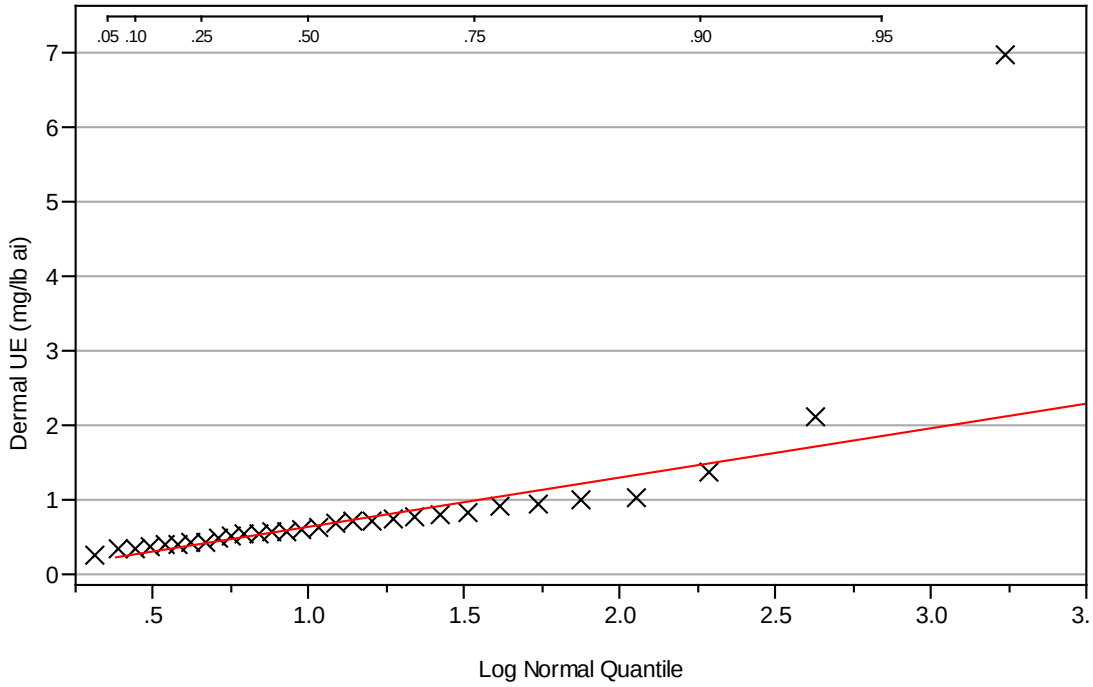
Table C-3: Unit Exposures (mg/lb ai) – Granule Push-type Spreader Applications		
Statistic	**Dermal**	**Inhalation**
50^{th} percentile	0.66	0.0014
75^{th} percentile	1.0	0.0029
95^{th} percentile	1.9	0.0089
99^{th} percentile	2.9	0.019
99.9^{th} percentile	4.7	0.047
AM (SD)	0.81 (0.57)	0.0026 (0.0043)
GM (GSD)	0.66 (1.9)	0.0014 (3.1)
Range	0.25 – 7.0	0.00013 – 0.019
N	30	45

Dermal Unit Exposure Data Summary: The recommended dermal unit exposures for push-type spreader applications of granule pesticide formulations is based on a lognormal distribution fit with exposure monitoring data from Klonne, D. (1999) [EPA MRID 44972201]. This study monitored 30 applications of a granule formulation for approximately 20 minutes to approximately 10,000 square feet of turf in North Carolina using a rotary spreader. While other studies were available to potentially represent homeowner exposure potential, this study was the most reliable to represent the type of clothing a homeowner or amateur applicator would wear (i.e., shorts, short-sleeve shirt, no chemical-resistant gloves).

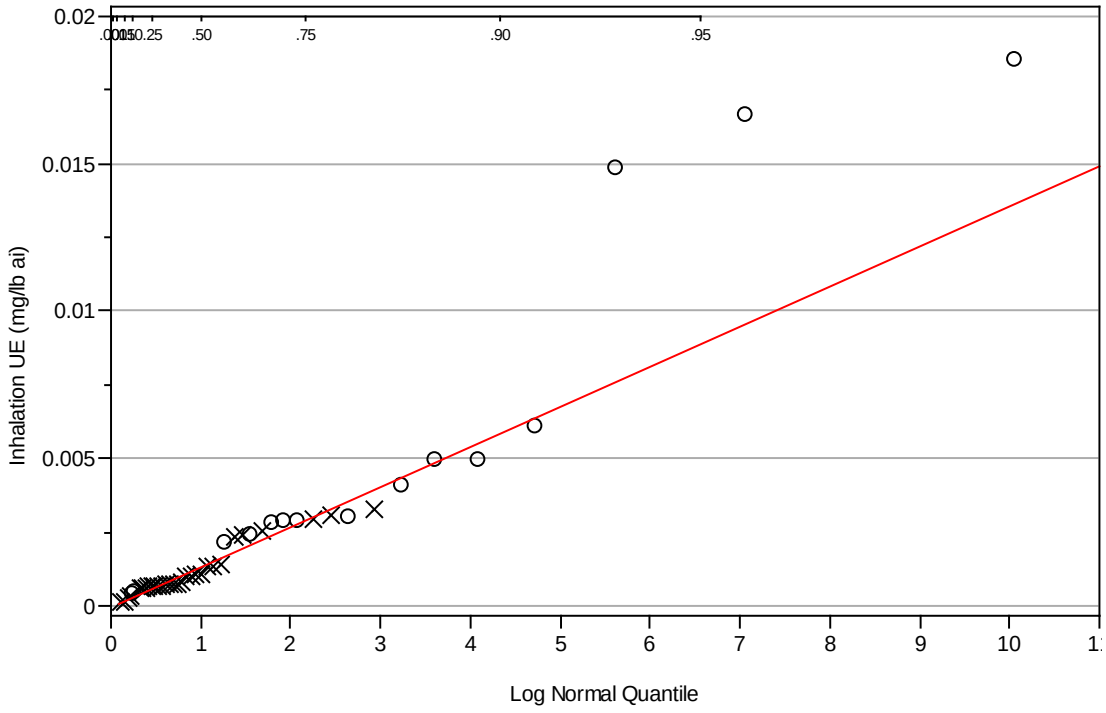
Inhalation Unit Exposure Data Summary: The recommended inhalation unit exposures for push-type spreader applications of granule pesticide formulations is based on a lognormal distribution fit with exposure monitoring data from Klonne, D. (1999) [EPA MRID 44972201] and PHED 1027. Klonne, D. (1999) monitored 30 individuals while applying a granule formulation for approximately 20 minutes to approximately 10,000 square feet of turf in North Carolina using a rotary spreader. PHED 1027 monitored 15 applications of a granule formulation for approximately 30-40 minutes to turf in North Carolina using a push cyclone spreader. Since both available studies were accurate representations of homeowner or amatueur applicator inhalation exposure, and were generally of the same magnitude, they were combined and recommended for use as one dataset.

Lognormal Probability Plots

Legend: X = Klonne, D. (1999)



Legend: X = Klonne, D. (1999); O = PHED 1027



Available Handler Exposure Studies

Table C-4: Study Identification Information	
Citation	Klonne, D. (1999). Integrated Report on Evaluation of Potential Exposure to Homeowners and Professional Lawn Care Operators Mixing, Loading, and Applying Granular and Liquid Pesticides to Residential Lawns. Sponsor/Submitter: Outdoor Residential Exposure Task Force.
EPA MRID	449722201
ORETF Code	OMA003
EPA Review	D261948
	EPA Memo from G. Bangs to D. Fuller (3/5/03)
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: A total of 30 individuals were monitored using passive dosimetry (inner and outer whole body dosimeters, hand washes, face/neck wipes, and personal inhalation monitors). Each test subject carried, loaded, and applied two 25-lb bags of a granule pesticide (a 0.89% dacthal, weed-and-feed fertilizer) with a rotary-type spreader to a lawn (a turf farm in North Carolina) covering 10,000 ft^2 (one bag to each of the two 5000 ft^2 test plots). The target application rate was approximately 2 lb ai/acre, with each individual handling approximately 0.45 lb of active ingredient. The average application time was 22 minutes, including loading the rotary push-spreader and disposing of empty bags.

Dermal exposure was measured using inner and outer whole body dosimeters, hand washes, and face/neck washes, such that exposure could be constructed for various clothing scenarios (including a short-sleeve shirt and shorts). Inhalation exposure was measured using standard personal air monitoring devices set at 1.5 liters per minute. All fortified samples and field samples collected on the same study day were stored frozen and analyzed together, eliminating the need for storage stability determination. Seventy-seven percent (77%) of the face and neck washes were below the level of quantification (LOQ) for dacthal, and 10% of the air samples were also at or below the LOQ. Where results were less than the reported LOQ, ½ LOQ value was used for calculations, and no recovery corrections were applied. Lab spike recoveries for all matrices were in the range of 83-99%. Mean field fortification recoveries over the four study days for each fortification level ranged from 83 to 97%.

Table C-5: MRID 44972201 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Both dermal and inhalation exposure are included since both are recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-6: MRID 44972201 – Data Summary

Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
1	0.45	0.24	0.000058	0.53	0.00013
2	0.45	0.18	0.000311	0.39	0.00071
3	0.45	0.30	0.000449	0.67	0.00102
4	0.45	0.31	0.001113	0.69	0.00253
5	0.45	0.15	0.000056	0.33	0.00013
6	0.45	0.17	0.000278	0.37	0.00063
7	0.45	0.16	0.000286	0.36	0.00065
8	0.45	0.27	0.000585	0.60	0.00133
9	0.45	0.15	0.000298	0.34	0.00068
10	0.45	0.25	0.000564	0.56	0.00128
11	0.45	0.32	0.001048	0.71	0.00238
12	0.45	0.11	0.000242	0.25	0.00055
13	0.45	0.35	0.001436	0.79	0.00326
14	0.45	0.23	0.001324	0.51	0.00301
15	0.45	0.45	0.000601	1.00	0.00137
16	0.45	0.19	0.000311	0.41	0.00071
17	0.45	0.19	0.000289	0.43	0.00066
18	0.45	0.41	0.000438	0.92	0.00099
19	0.45	0.34	0.000423	0.76	0.00096
20	0.45	0.37	0.000334	0.83	0.00076
21	0.45	0.28	0.000253	0.62	0.00058
22	0.45	0.33	0.000115	0.73	0.00026
23	0.45	0.25	0.000251	0.55	0.00057
24	0.45	0.95	0.000461	2.10	0.00105
25	0.45	0.61	0.001290	1.36	0.00293
26	0.45	0.41	0.001025	0.91	0.00233
27	0.45	0.23	0.000265	0.52	0.00060
28	0.45	3.14	0.000322	6.98	0.00073
29	0.45	0.21	0.000276	0.46	0.00063
30	0.45	0.46	0.000138	1.02	0.00031

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of residential applications of granule pesticide formulations using a push-type spreader, the following limitations are noted:

- Each individual handled the same amount of active ingredient, making analysis of the relationship between exposure and the amount of active ingredient handled (the underlying basis of unit exposures) difficult.

Table C-7: Study Identification Information	
Citation	PHED 1027
EPA MRID	NA
ORETF Code	NA
EPA Review	None
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: A total of 15 application events were monitored using 8 volunteers loading and applying granules to turf sites in North Carolina using a "push cyclone spreader". Each individual handled approximately 110 lbs of granule formulation (1.02% active ingredient; 1.1 lbs active ingredient) and spent approximately 30-40 minutes per application. Dermal exposure was measured using whole body dosimetry underneath work clothing – a long-sleeve shirt, pants, socks and shoes – and hand washes were used to collect exposure to bare hands (no chemical-resistant gloves were worn). Inhalation exposure was measured using standard pumps (set at 1.5 liters per minute), cassettes, and tubing. Percent recovery (mean ± SD) for laboratory fortifications is as follows: 97.2 ± 19.2% for glass fiber filter, 96.3 ± 29.4% for handwash, 107 ± 12.1% for facial swipe, and 105 ± 32.3% for whole-body dosimeter. With the exception of one low average recovery, 42.4% for handwashes at site 1, average field fortification recoveries ranged from 61.5% to 98.2%. The majority of the individual fortification recoveries fell within the 50% to 120% range with the noted exception of the high-level fortification of the handwash solutions, facial swabs, and whole-body dosimeters at Site 1, which averaged from 61.6% to 68.2%.

Table C-8: PHED 1027 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**No**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Note that only inhalation exposure data are included since the dermal exposure data are not recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-9: PHED 1027 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
A	1.1100	--	0.0006	--	0.0005

Table C-9: PHED 1027 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
A	1.1100	--	0.0024	--	0.0022
A	1.1100	--	0.0032	--	0.0029
A	1.1100	--	0.0056	--	0.0050
A	1.1100	--	0.0046	--	0.0041
A	1.1100	--	0.0055	--	0.0050
B	1.1100	--	0.0206	--	0.0186
B	1.1100	--	0.0032	--	0.0029
B	1.1100	--	0.0032	--	0.0028
B	1.1100	--	0.0027	--	0.0024
C	1.1100	--	0.0068	--	0.0061
C	1.1100	--	0.0165	--	0.0149
C	1.3900	--	0.0042	--	0.0030
C	1.3900	--	0.0006	--	0.0004
C	1.0500	--	0.0175	--	0.0167

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of residential applications of granule pesticide formulations using a push-type spreader, the following limitations are noted:

- Each individual handled practically the same amount of active ingredient, making analysis of the relationship between exposure and the amount of active ingredient handled (the underlying basis of unit exposures) difficult.

Table C-10: Study Identification Information	
Citation	Solomon, K. R., Harris, S. A, Stephenson, G. R. (1993). Applicator And Bystander Exposure To Home Garden And Landscape Pesticides. American Chemical Society, 1993, pp. 262-273
EPA MRID	none
ORETF Code	NA
EPA Review	none
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: A total of 20 application events were monitored using volunteers loading and applying granules using a "drop spreader". Eleven of the applications were conducted while wearing "protective" clothing, while 9 applications were conducted while wearing "normal" clothing. The exact nature of the clothing worn was not provided. Each individual handled approximately 0.3 – 2.6 lbs of 2, 4-D per application. Exposure was measured using biomonitoring with passive monitoring only conducted for inhalation exposure using standard pumps (set at 1 liter per minute), cassettes, and tubing. All except one inhalation exposure sample was a non-detect (limit of detection = 0.0001 μg/L). Recoveries from field fortifications of exposure sampling matrices were generally above 85% with little variation (standard deviation approximately 3%).

Table C-11: Solomon, et al. (1993) – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**No**	**No**

Data Summary: A summary of the data from this study is not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Limitations: Any data limitations associated with the exposure data in this study are not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Scenario Summary

Table C-12: Scenario Description and Available Exposure Studies	
Formulation	Granules
Equipment/Application Method	Belly grinder (also: hand cyclone spreader, whirly-bird spreader)
Application Site(s)	outdoors (lawn, gardens, trees/bushes, perimeter, mounds/nests, aquatic areas)
Available Exposure Studies	PHED 1027
	PHED 419
	PHED 459
	PHED 504
	Spencer, et al. (1997)

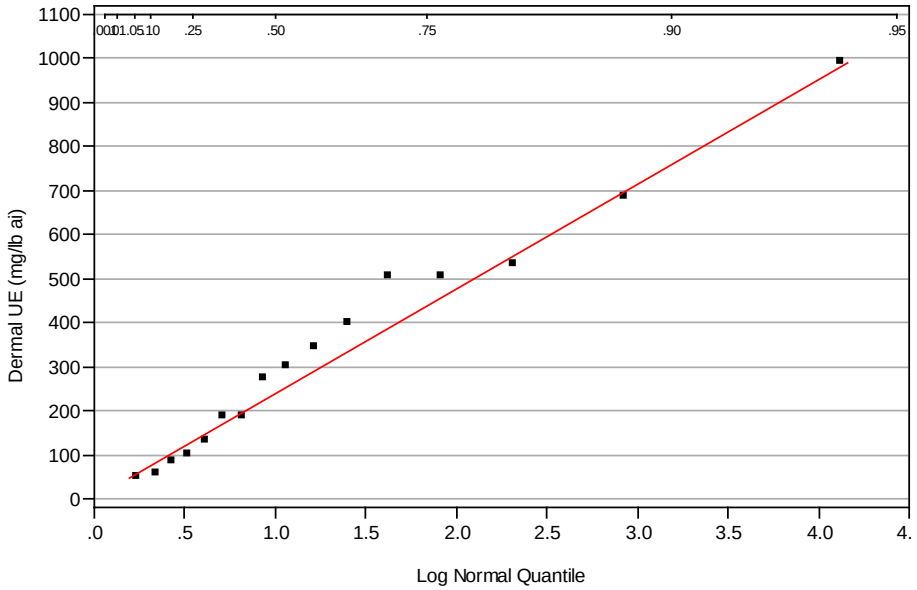
Table C-13: Unit Exposures (mg/lb ai) – Granule Belly Grinder Applications		
Statistic	Dermal	Inhalation
50th percentile	240	0.016
75th percentile	440	0.039
95th percentile	1100	0.142
99th percentile	2000	0.351
99.9th percentile	3900	0.966
AM (SD)	360 (405)	0.039 (0.085)
GM (GSD)	240 (2.5)	0.016 (3.76)
Range	49 – 992	0.0017 – 0.29
N	16	28

Dermal Unit Exposure Data Summary: The recommended dermal unit exposures for belly grinder applications of granule pesticide formulations is based on a lognormal distribution fit with exposure monitoring data from PHED 459. PHED 459 monitored 16 applications of a granule formulation foundations, patios, driveways, and sidewalks of houses using a "whirly-bird spreader". While other available studies were reasonable representations of residential exposure, this study best represented a residential homeowner application while also providing a reliable representation of the type of clothing a homeowner or amateur applicator would wear (i.e., shorts, short-sleeve shirt, no chemical-resistant gloves).

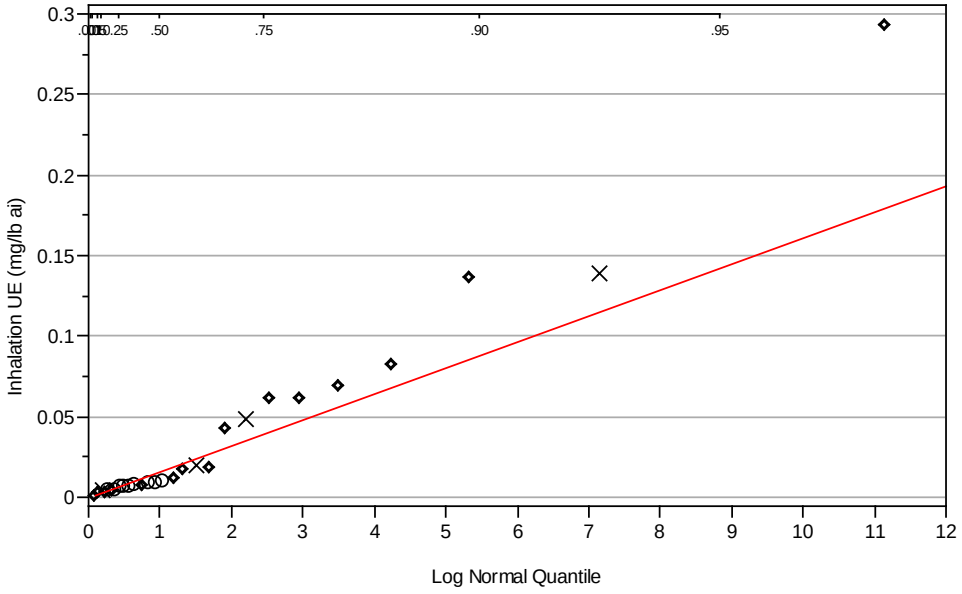
Inhalation Unit Exposure Data Summary: The recommended inhalation unit exposures for belly grinder applications of granule pesticide formulations is based on a lognormal distribution fit with exposure monitoring data from PHED 1027, PHED 419, and PHED 504. PHED 1027 monitored 15 applications of a granule formulation for approximately 30-40 minutes to turf in North Carolina using a hand cyclone spreader. PHED 419 monitored 5 applications of a granule formulation to approximately 2 acres of container ornamentals in California using chest-mounted application equipment. PHED 504 monitored 9 applications of a granule formulation for approximately 4 hours to approximately 1 acre of turf in Michigan using a "hand cyclone spreader". These studies all provided a reasonable representation of residential exposure, including representing individuals without respiratory protection. As they were generally of similar magnitudes, the studies are utilized as a composite dataset.

Log-normal Probability Plots

Legend: ■ = PHED 459



Legend: X = PHED 419; ◊ = PHED 1027; O = PHED 504



Available Handler Exposure Studies

Table C-14: Exposure Study Identification Information	
Citation	PHED 1027
EPA MRID	NA
ORETF Code	NA
EPA Review	none
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: A total 15 application events were monitored using 8 volunteers loading and applying granules to turf sites in North Carolina using a "hand cyclone spreader" (i.e., a belly grinder). Each individual handled approximately 170 lbs granule formulation (1.02% active ingredient; 1.7 lbs active ingredient) and spent approximately 30-40 minutes per application. Dermal exposure monitoring represented an individual wearing a long-sleeve shirt, pants, shoes, socks, and no chemical-resistant gloves. Inhalation exposure was measured using standard pumps (set at 1.5 liters per minute), cassettes, and tubing. Percent recovery (mean ± SD) for laboratory fortifications is as follows: 97.2 ± 19.2% for glass fiber filter, 96.3 ± 29.4% for handwash, 107 ± 12.1% for facial swipe, and 105 ± 32.3% for whole-body dosimeter. With the exception of one low average recovery, 42.4% for handwashes at site 1, average field fortification recoveries ranged from 61.5% to 98.2%. The majority of the individual fortification recoveries fell within the 50% to 120% range with the noted exception of the high-level fortification of the handwash solutions, facial swabs, and whole-body dosimeters at Site 1, which averaged from 61.6% to 68.2%.

Table C-15: PHED 1027 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**No**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Note that only inhalation exposure data are included since the dermal exposure data are not recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-16: PHED 1027 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
D	1.84	--	0.008	--	0.0043

D	1.49	--	0.013	--	0.0087
D	1.67	--	0.021	--	0.0126
D	1.67	--	0.009	--	0.0054
D	1.67	--	0.031	--	0.0186
E	1.67	--	0.072	--	0.0431
E	1.67	--	0.032	--	0.0192
E	1.67	--	0.116	--	0.0695
E	1.67	--	0.104	--	0.0623
E	1.67	--	0.103	--	0.0617
E	1.67	--	0.140	--	0.0838
F	1.65	--	0.486	--	0.2945
F	1.65	--	0.227	--	0.1376
F	1.67	--	0.003	--	0.0018
F	1.67	--	0.006	--	0.0036

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of residential applications of granule pesticide formulations using a belly grinder, the following limitations are noted:

- Each individual handled practically the same amount of active ingredient, making analysis of the relationship between exposure and the amount of active ingredient handled (the underlying basis of unit exposures) difficult.

Table C-17: Exposure Study Identification Information	
Citation	PHED 419
EPA MRID	NA
ORETF Code	NA
EPA Review	none

MRID = Master Record Identification
ORETF = Outdoor Residential Exposure Task Force

Study Description: Three workers were monitored over the course of three days (totaling 5 monitored application events) while applying a granule formulation using "chest-mounted application equipment" to container ornamentals in California. Each application consisted of applying approximately 174 lbs product/acre (3.5 lbs ai/acre) to approximately 2 acres of container ornamentals. Dermal exposure was measured using gauze patches placed strategically across the workers' bodies (inside and outside the work clothing) as well as hand washes underneath chemical-resistant gloves. Inhalation exposure was measured using standard pumps (4-7 liters of air collected per application; flow rate unknown), cassettes, and tubing. Recoveries from field fortifications of exposure sampling matrices were generally above 90%, though inhalation sampling varied widely from 68 to 97% recovery.

Table C-18: PHED 419 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation

Table C-18: PHED 419 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	No	No
Should this study be recommended for use in residential handler exposure assessments?	**No**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Note that only inhalation exposure data are included since the dermal exposure data are not recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-19: PHED 419 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
A	6.0000	--	0.833	--	0.139
A	8.1200	--	--	--	--
B	6.0000	--	0.116	--	0.019
B	7.5200	--	0.358	--	0.048
C	7.2000	--	0.028	--	0.004

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of residential applications of granule pesticide formulations using a belly grinder, the following limitations are noted:

- The study monitored workers in a California nursery; therefore, using this study for residential assessments introduces uncertainty.
- The second application for Worker A was not used as the collection pump reportedly malfunctioned.

Table C-20: Exposure Study Identification Information	
Citation	PHED 459
EPA MRID	NA
ORETF Code	NA
EPA Review	none
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: A total of 16 applications were monitored using 3 volunteers loading and applying 2% active ingredient granules around foundations, patios, driveways, and sidewalks of houses using a "whirly-bird spreader" (i.e., belly grinder). Each worker applied approximately 5.7 oz of the bait formulation per 1000 ft^2 resulting in a range of 0.0069 to 0.0425 lbs of active ingredient per application. The sampling time ranged from 4 to 11 minutes. Dermal exposure was monitored using gauze patches strategically placed on each body part both inside and outside the individuals clothing. This methodology allows for representation of individuals wearing shorts, a short-sleeve shirt, shoes and socks. Chemical-resistant gloves were worn so exposure values to bare hands had to be back-calculated assuming 90% protection from chemical-resistant gloves. Inhalation exposure was measured using standard pumps (set at 1 liter per minute), cassettes, and tubing. All air samples were below the limit of quantification. Average laboratory recovery values are as follows, 103% with a standard deviation of 1.9% for air filters, 117% with a standard deviation of 7.7% for gauze pads, 116% with a standard deviation of 1.5% for low-level hand rinse and 122% with a standard deviation of 3.8% for high-level hand rinse. Average field recovery values are as follows, 95% with a standard deviation of 4.4% for air filters, 105% with a standard deviation of 2.9% for gauze pads (outside clothing), 90% with a standard deviation of 4.5% for gauze pads (outside clothing), 103% with a standard deviation of 3.5% for gauze pads (inside clothing), and 102% with a standard deviation of 1.4% for hand rinses.

Table C-21: PHED 459 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**No**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Note that only dermal exposure is included, as inhalation exposure data was not recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-22: PHED 459 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
A	0.0288	1.40	--	49	--
A	0.0425	4.31	--	101	--
A	0.0106	3.17	--	299	--
A	0.01	5.33	--	533	--
B	0.0125	1.65	--	132	--
B	0.0088	0.74	--	84	--
B	0.0125	4.31	--	345	--
B	0.0169	8.51	--	503	--
B	0.0119	4.74	--	398	--
B	0.015	14.89	--	992	--
C	0.0075	1.40	--	186	--
C	0.0088	6.03	--	685	--
C	0.0081	2.22	--	274	--
C	0.0069	3.48	--	504	--
C	0.0138	0.78	--	56	--
C	0.0081	1.50	--	186	--

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of residential applications of granule pesticide formulations using a belly grinder, the following limitations are noted:

- The individuals monitored in the study wore chemical-resistant gloves. Because residential handler exposure assessments representative of individuals wearing chemical-resistant gloves are not typically conducted, a back-calculation (i.e., increasing hand exposures by 90%) to represent "bare hand" exposure was necessary, adding uncertainty to the unit exposures.
- All inhalation samples were non-detects. One-half the limit of detection (0.2 μg) was used in exposure calculations.

Table C-23: Exposure Study Identification Information	
Citation	PHED 504
EPA MRID	NA
ORETF Code	NA
EPA Review	none

MRID = Master Record Identification
ORETF = Outdoor Residential Exposure Task Force

Study Description: A total of 9 application events were monitored while loading and applying granules using a "hand cyclone spreader" to approximately 0.9 acres (six 0.15 acre plots) of turf in Michigan over the course of a 4 hour period. Each individual handled a total of approximately 400 lbs of formulation (1.4 lbs active ingredient), equivalent to approximately 1.5 lb ai per acre. Dermal exposure was monitored using gauze patches, though the placement only allows for

representation of individuals wearing a long-sleeve shirt, long pants, shoes and socks. Chemical-resistant gloves were not worn. Inhalation exposure was measured using standard pumps (set at 1 liter per minute), cassettes, and tubing. Average laboratory recoveries were as follows: 99.0 ± 10.2% for air filters and 98.0 ± 9.9% for tubes; 118.4 ± 6.5% for hand washes; and 100.3 ± 6.9% for the gauze patches. Travel spike average recoveries for the tube, filter, hand rinse, and gauze patch travel spikes were 104%, 112%, 101%, and 112%, respectively. Since the results were all equal to or greater than 100%, no corrections to the data were applied based on these spikes. Field fortification recoveries for the filter, hand rinse, and gauze patch field spikes were 104%, 98%, and 90%, respectively.

Table C-24: PHED 504 – Checklist and Use Recommendation

Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**No**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Note that only inhalation exposure data are included since the dermal exposure data are not recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-25: PHED 504 – Data Summary

Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
DS	1.33	--	0.009	--	0.007
DV	0.82	--	0.006	--	0.008
IC	1.29	--	0.006	--	0.005
JC	1.00	--	0.011	--	0.011
JJ	1.26	--	0.012	--	0.009
JM	1.24	--	0.009	--	0.007
MD	1.36	--	0.007	--	0.005
MS	1.28	--	0.012	--	0.010
NB	1.37	--	0.010	--	0.007

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of residential applications of granule pesticide formulations using a belly grinder, the following limitations are noted:

- Based on the amount of product applied and the application duration, the study was meant to simulate a professional lawn care operator, so using this study for residential assessments introduces uncertainty.

Table C-26: Exposure Study Identification Information	
Citation	Spencer, et al. (1997). Exposure of Hand Applicators to Granular Hexazinone in Forest Settings, 1993-1995.
EPA MRID	none
ORETF Code	NA
EPA Review	none
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Twenty-nine workers were monitored on 11 days at 4 different sites over the course of 3 years, totaling 129 monitored worker-days, while applying 10% hexazinone granules to forestry areas using a belly grinder. Applying approximately 3-4 lbs/acre, each worker handled from 15 – 35 lbs of hexazinone per workday (150 – 350 lbs formulation). Dermal exposure was monitored using whole body dosimetry underneath normal work clothing and hand wipes used at various intervals throughout the workday. Workers wore various types of clothing and personal protective equipment. Inhalation exposure was measured using standard pumps (set at 2 liters per minute), cassettes, and tubing. Recoveries from field fortifications of exposure sampling matrices were generally above 90%.

Table C-27: Spencer, et al. (1997) – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**No**	**No**

Data Summary: A summary of the data from this study is not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Limitations: Any data limitations associated with the exposure data in this study are not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Scenario Summary

Table C-28: Scenario Description and Available Exposure Studies	
Formulation	Granules
Equipment/Application Method	Spoon
Application Site(s)	outdoors (lawn, gardens, trees/bushes, perimeter, mounds/nests, aquatic areas)
Available Exposure Studies	Pontal, P.G. (1996); MRID 45250702

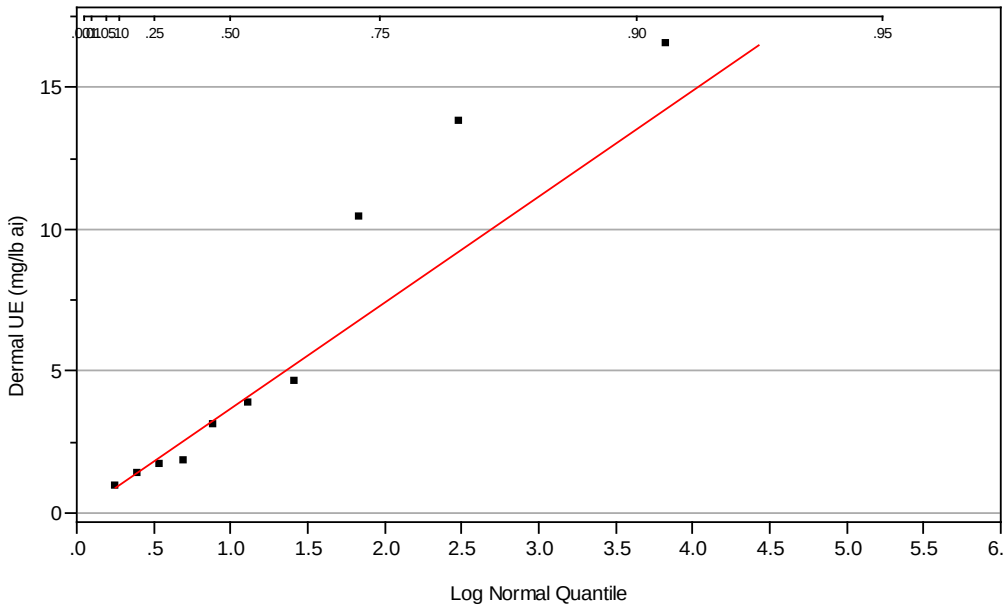
Table C-29: Unit Exposures (mg/lb ai) – Granule Spoon Applications		
Statistic	Dermal	Inhalation
50th percentile	3.7	0.024
75th percentile	7.3	0.071
95th percentile	20	0.34
99th percentile	39	1.0
99.9th percentile	83	3.4
AM (SD)	6.2 (8.2)	0.087 (0.30)
GM (GSD)	3.7 (2.7)	0.024 (5.0)
Range	1 – 16	0.0024 – 0.33
N	10	10

Dermal Unit Exposure Data Summary: The recommended dermal unit exposures for applications of granule pesticide formulations using a spoon is based on a lognormal distribution fit with exposure monitoring data from Pontal, P.G. (1996) [EPA MRID 45250702]. Pontal, P.G. (1996) monitored 10 applications of a granule formulation to a 1 acre banana plantation in Cameroon using a spoon. Despite being an occupational exposure monitoring study, and thus potentially an inaccurate representation of residential exposure, this is the only available study for this application pattern.

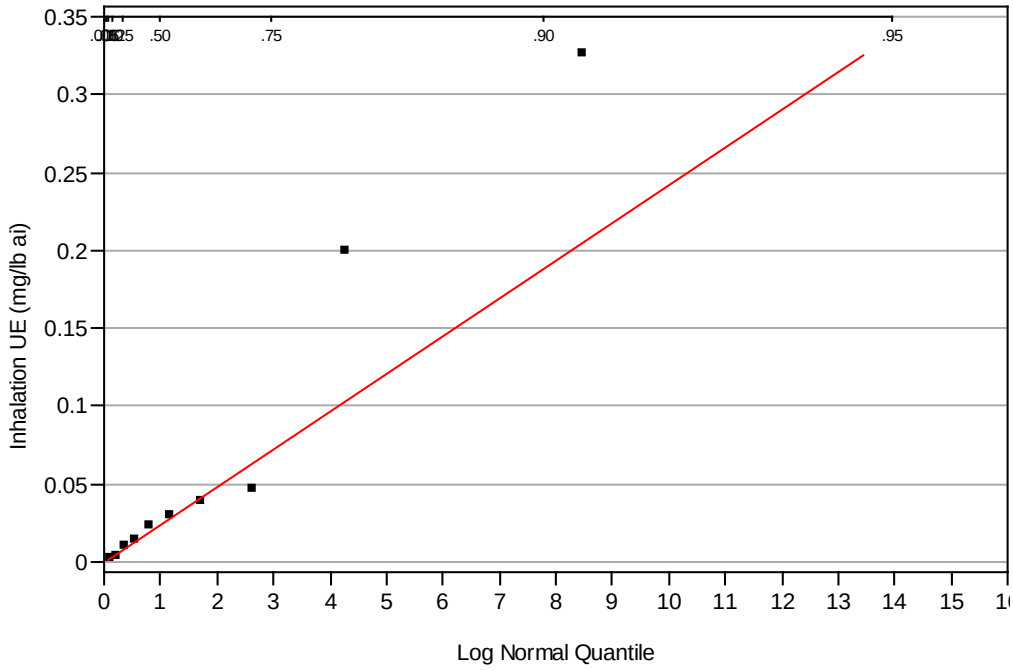
Inhalation Unit Exposure Data Summary: The recommended inhalation unit exposures for applications of granule pesticide formulations using a spoon is based on a lognormal distribution fit with exposure monitoring data from Pontal, P.G. (1996) [EPA MRID 45250702]. Pontal, P.G. (1996) monitored 10 applications of a granule formulation to a 1 acre banana plantation in Cameroon using a spoon. Despite being an occupational exposure monitoring study, and thus potentially an inaccurate representation of residential exposure, this is the only available study for this application pattern.

Log-normal Probability Plots

Legend: ■ = Pontal, P.G. (1996)



Legend: ■ = Pontal, P.G. (1996)



Available Handler Exposure Studies:

Table C-30: Exposure Study Identification Information	
Citation	Pontal, P.G. (1996). Worker Exposure Study During Application Of Regent 20GR In Banana Plantation, (RP Study 94/136 - Amended)
EPA MRID	45250702
ORETF Code	NA
EPA Review	D270065
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: A total of 10 applications were monitored on two days for workers applying a granule formulation of fipronil with a spoon in banana plantations in Cameroon. The workers covered approximately 1 acre per application-event, applying granules to approximately 800 plants at a rate of 0.15 gms active ingredient per plant (13 lbs product; 0.26 lbs fipronil). Dermal exposure was monitored using whole body dosimetry – which served as the workers normal clothing (i.e., measurements would be representative of workers without clothing). Clothing protection factors were required to estimate exposure for workers while wearing clothing. Workers wore chemical-resistant gloves with cotton gloves underneath serving as the hand exposure measurement method. Inhalation exposure was measured using standard pumps (set at 1 liter per minute), cassettes, and tubing. Overall recovery levels from field spiked samples were between 64% and 99% (average 87%) with only one recovery below 80%. Overall recovery levels from samples spiked in the laboratory were between 92 and 117.5%.

Table C-31: MRID 45250702 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Both dermal and inhalation exposure are included since both are recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-32: MRID 45250702 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
1	0.368	1.13	0.0010	3.06	0.0027
2	0.368	3.84	0.0009	10.42	0.0024
3	0.368	5.06	0.1198	13.76	0.3255

4	0.368	1.71	0.0731	4.64	0.1986
5	0.368	0.62	0.0037	1.70	0.0101
6	0.368	6.07	0.0109	16.50	0.0296
7	--	--	--	--	--
8	0.247	0.94	0.0114	3.82	0.0462
9	0.247	0.45	0.0057	1.83	0.0231
10	0.247	0.23	0.0034	0.94	0.0138
11	0.247	0.33	0.0094	1.36	0.0381

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of residential applications of granule pesticide formulations using a spoon, the following limitations are noted:

- Dermal exposure was measured using clothing the individuals wore, thus representing applicators not wearing any clothing. To estimate exposure representative of applicators wearing shorts, short-sleeve shirt, shoes, and socks, a penetration factor of 50% was used for exposure measurements to the torso, upper arms, and upper legs.
- For hand exposure, since chemical-resistant gloves were worn, a protection factor of 90% was used to back-calculate "bare" hand exposure.

Scenario Summary

Table C-33: Scenario Description and Available Exposure Studies	
Formulation	Granules
Equipment/Application Method	Cup
Application Site(s)	outdoors (lawn, gardens, trees/bushes, perimeter, mounds/nests, aquatic areas)
Available Exposure Studies	Merricks, L. (2001); MRID 45333401

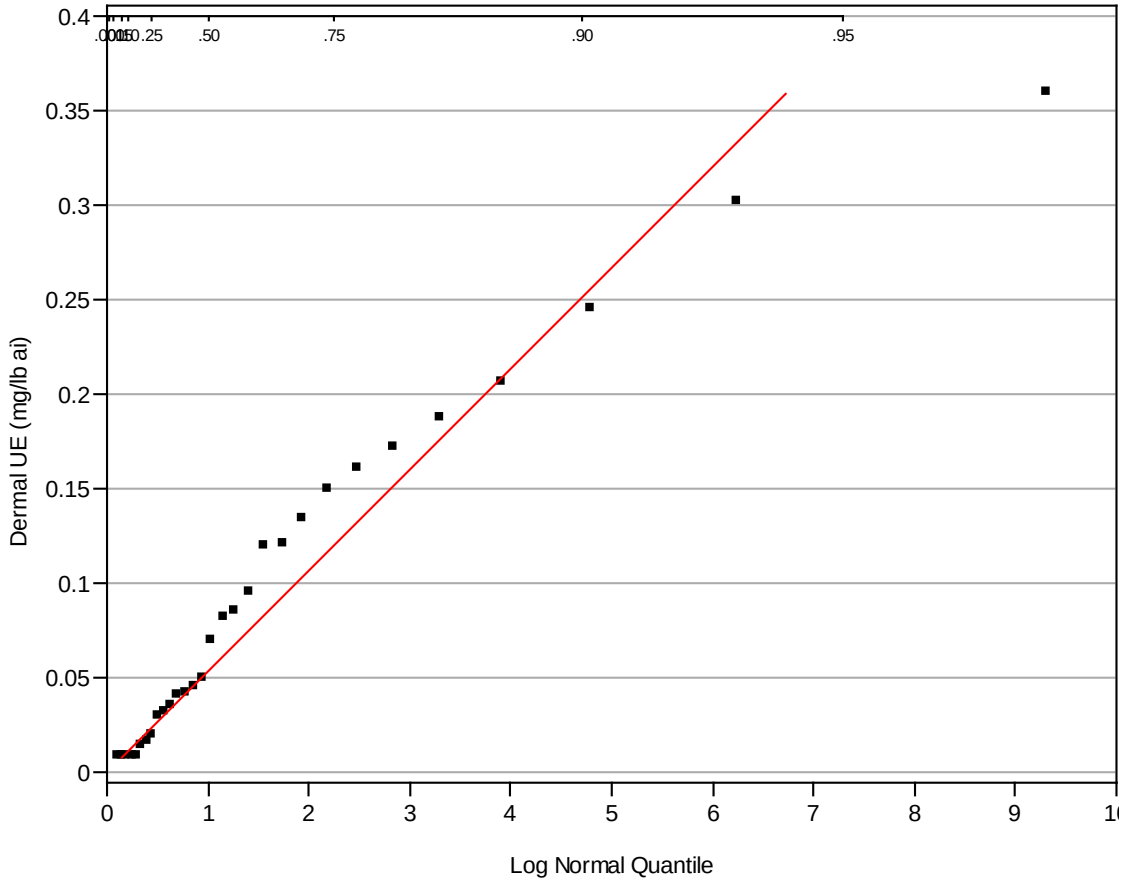
Table C-34: Unit Exposures (mg/lb ai) – Granule Cup Applications		
Statistic	Dermal	Inhalation
50th percentile	0.05	0.013
75th percentile	0.12	0.013
95th percentile	0.40	0.013
99th percentile	0.91	0.013
99.9th percentile	2.3	0.013
AM (SD)	0.11 (0.21)	0.013 (0)
GM (GSD)	0.05 (3.4)	0.013 (1)
Range	0.0075 – 0.36	0.013 – 0.013
N	30	30

Dermal Unit Exposure Data Summary: The recommended dermal unit exposures for applications of granule pesticide formulations using a cup is based on a lognormal distribution fit with exposure monitoring data from Merricks, L. (2001) [EPA MRID 45333401]. Merricks, L. (2001) monitored 60 applications of a granule formulation for approximately 20-40 minutes to shrubs and flower beds using a cup. Despite certain limitations (e.g., the lower body was not measured), this study is a fair representation of residential exposure and is the only available study for this application pattern.

Inhalation Unit Exposure Data Summary: The recommended inhalation unit exposures for applications of granule pesticide formulations using a cup is based on a lognormal distribution fit with exposure monitoring data from Merricks, L. (2001) [EPA MRID 45333401]. Merricks, L. (2001) monitored 60 applications of a granule formulation for approximately 20-40 minutes to shrubs and flower beds using a cup. Despite certain limitations (e.g., all inhalation samples were non-detects), this study is a fair representation of residential exposure and is the only available study for this application pattern.

Log-normal Probability Plots

Legend: ■ = Merricks, L. (2001)



Note: Inhalation unit exposure lognormal probability plot not shown as all unit exposures were identical – all inhalation samples were non-detects and all individuals handled the same amount of active ingredient.

Available Handler Exposure Studies

Table C-35: Exposure Study Identification Information	
Citation	Merricks, L. (2001) Determination of Dermal (Hand and Forearm) and Inhalation Exposure to Disulfoton Resulting from Residential Application of Bayer Advanced Garden 2-in-1 Systematic Rose and Flower Care to Shrubs and Flower Beds: Lab Project Number: 4201. Unpublished study prepared by Agrisearch Inc. 178 p.
EPA MRID	45333401
ORETF Code	NA
EPA Review	D273144
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Fifteen individuals were monitored during 4 applications (for a total of 60 application-events) of 1.04% disulfoton granules to shrubs and flower beds using a cup. An application consisted of pouring the product into the measuring cup/lid attached to the product package, then distributing the granules onto the soil around the base of the shrub or flower bed. Each application lasted between 20 and 40 minutes to apply approximately 10 pounds of formulation (0.1 lbs of disulfoton). Dermal exposure was measured for the hands and forearms only using detergent washes. Half of the applications were with chemical-resistant gloves and half were without (i.e., 30 applications with and 30 applications without chemical-resistant gloves). Inhalation exposure was measured using standard pumps (set at 1 liter per minute), cassettes, and tubing. All inhalation samples were non-detects. The overall mean percent recovery of concurrent laboratory fortifications from air sampling tubes was 99.9 ± 6.42%. The overall mean percent recovery from hand/forearm wash solution was 99.5 ± 9.15%. For air samples, the overall average fortified field recovery was 98.2 ± 6.32% with no apparent differences in mean recoveries between days or fortification levels. Overall field fortified recovery for hand/forearm wash samples collected from volunteers who did not wear gloves was 99.4 ± 7.95% with no apparent differences in recovery values between days.

Table C-36: MRID 45333401 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Both dermal and inhalation exposure are included since both are recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-37: MRID 45333401 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
1	0.1	0.013	0.0013	0.13	0.013
2	0.1	0.030	0.0013	0.30	0.013
3	0.1	0.019	0.0013	0.19	0.013
4	0.1	0.015	0.0013	0.15	0.013
5	0.1	0.004	0.0013	0.04	0.013
6	0.1	0.017	0.0013	0.17	0.013
7	0.1	0.005	0.0013	0.05	0.013
8	0.1	0.002	0.0013	0.02	0.013
9	0.1	0.009	0.0013	0.09	0.013
10	0.1	0.036	0.0013	0.36	0.013
11	0.1	0.004	0.0013	0.04	0.013
12	0.1	0.025	0.0013	0.25	0.013
13	0.1	0.001	0.0013	0.01	0.013
14	0.1	0.007	0.0013	0.07	0.013
15	0.1	0.016	0.0013	0.16	0.013
1	0.1	0.001	0.0013	0.01	0.013
2	0.1	0.003	0.0013	0.03	0.013
3	0.1	0.002	0.0013	0.02	0.013
4	0.1	0.021	0.0013	0.21	0.013
5	0.1	0.008	0.0013	0.08	0.013
6	0.1	0.001	0.0013	0.01	0.013
7	0.1	0.001	0.0013	0.01	0.013
8	0.1	0.001	0.0013	0.01	0.013
9	0.1	0.004	0.0013	0.04	0.013
10	0.1	0.005	0.0013	0.05	0.013
11	0.1	0.012	0.0013	0.12	0.013
12	0.1	0.003	0.0013	0.03	0.013
13	0.1	0.012	0.0013	0.12	0.013
14	0.1	0.001	0.0013	0.01	0.013
15	0.1	0.008	0.0013	0.08	0.013

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of residential applications of granule pesticide formulations using a cup, the following limitations are noted:

- Dermal exposure was measured only on the hands and forearms. To the extent that this type of application would result in significant exposure to the lower body, the use of this data may underestimate exposure.
- Each individual handled the same amount of active ingredient making analysis of the relationship between exposure and the amount of active ingredient handled (the underlying basis of unit exposures) difficult.
- All inhalation samples were non-detects. One-half the limit of quantification (0.30) was used.

Scenario Summary

Table C-38: Scenario Description and Available Exposure Studies	
Formulation	Granules
Equipment/Application Method	Hand dispersal
Application Site(s)	outdoors (lawn, gardens, trees/bushes, perimeter, mounds/nests, aquatic areas)
Available Exposure Studies	PHED 520

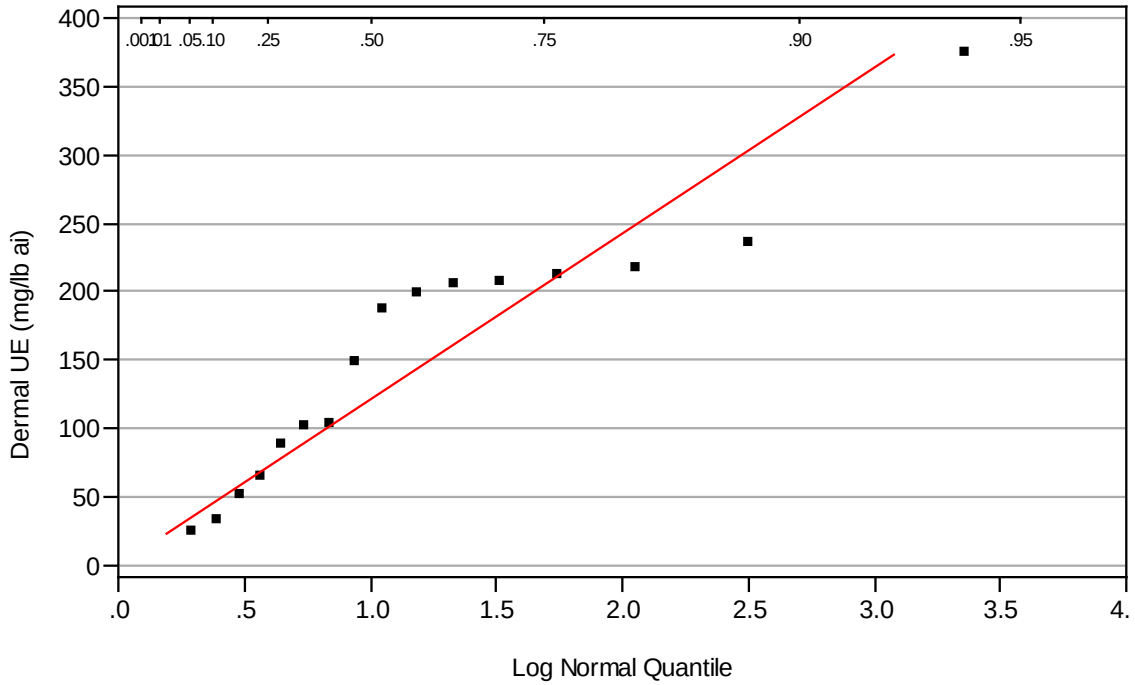
Table C-39: Unit Exposures (mg/lb ai) – Granule Applications by Hand		
Statistic	Dermal	Inhalation
50th percentile	120	0.28
75th percentile	205	0.47
95th percentile	430	1.0
99th percentile	740	1.7
99.9th percentile	1300	3.1
AM (SD)	160 (150)	0.38 (0.35)
GM (GSD)	120 (2.2)	0.28 (2.2)
Range	24 – 370	0.064 – 0.95
N	16	16

Dermal Unit Exposure Data Summary: The recommended dermal unit exposures for applications of granule pesticide formulations by hand is based on a lognormal distribution fit with exposure monitoring data from PHED 520. PHED 520 monitored 16 applications of a granule formulation to driveways, sidewalks, patios, foundations, and flower beds around private residences in Florida. Despite certain limitations (e.g., back-calculations were necessary to represent individuals wearing shorts, short-sleeve shirt and no chemical-resistant gloves), this study is a good respresentation of residential exposure and is the only available study for this application pattern.

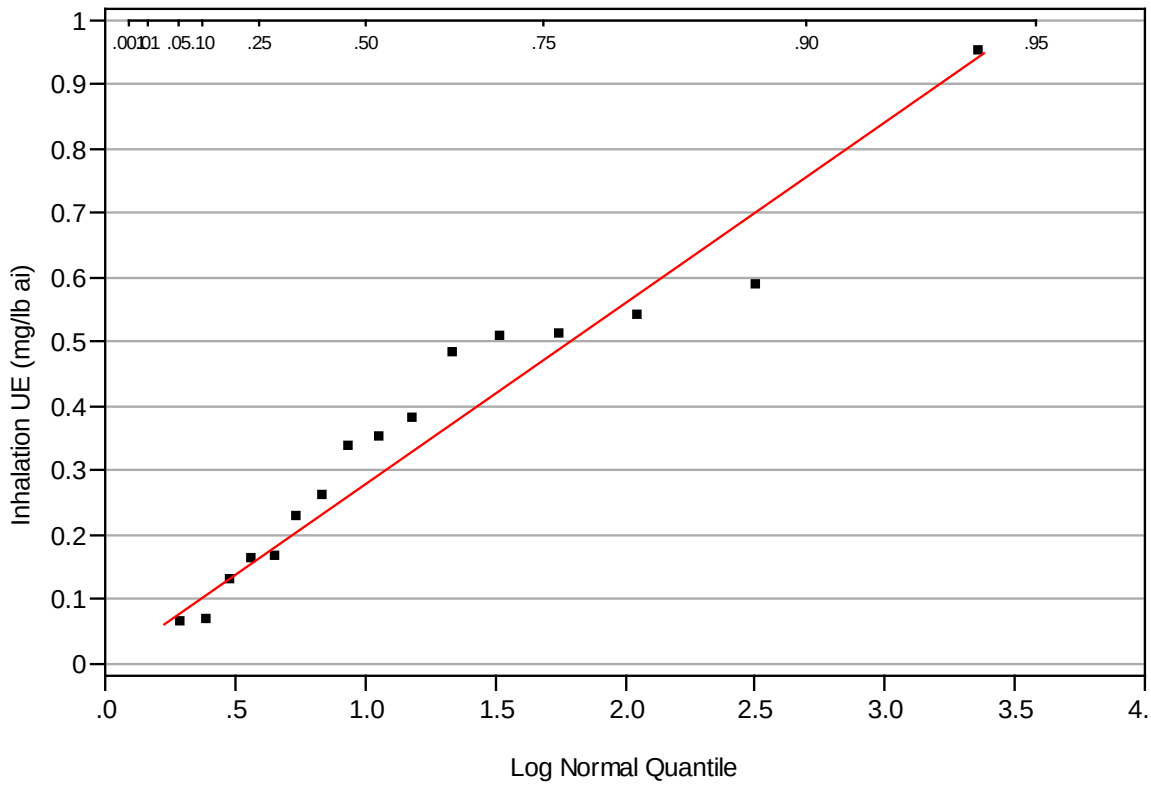
Inhalation Unit Exposure Data Summary: The recommended inhalation unit exposures for applications of granule pesticide formulations by hand is based on a lognormal distribution fit with exposure monitoring data from PHED 520. PHED 520 monitored 16 applications of a granule formulation to driveways, sidewalks, patios, foundations, and flower beds around private residences in Florida. Despite certain limitations (e.g., all inhalation samples were non-detects), this study is a good respresentation of residential exposure and is the only available study for this application pattern.

Log-normal Probability Plots

Legend: ■ = PHED 520



Legend: ■ = PHED 520



Available Handler Exposure Studies

Table C-40: Exposure Study Identification Information	
Citation	PHED 520
EPA MRID	NA
ORETF Code	NA
EPA Review	none
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Three commercial applicators were each monitored 5 times (for a total of 16 application-events) while applying 2% active ingredient granules by hand to driveways, sidewalks, patios, foundations, and flower beds around private residences in Florida. Each application consisted of treating one residences using less than 1 lb of product with gloved hands at a rate of approximately 4 ounces per 1000 ft^2 (0.005 lb ai/1000 ft^2). Dermal exposure was measured using gauze patches both inside and outside the normal work clothing (long-sleeve shirt, long pants, shoes, socks) as well as hand washes to measure exposure to hands underneath chemical-resistant gloves. Inhalation exposure was measured using standard pumps (set at 1 liter per minute), cassettes, and tubing. Recoveries from field fortifications of exposure sampling matrices were generally above 90%.

Table C-41: PHED 520 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Both dermal and inhalation exposure are included since both are recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-42: PHED 520 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
A	0.026	0.635	0.0017	24	0.0654
A	0.003	0.635	0.0016	205	0.5333
A	0.003	0.635	0.0016	235	0.5333
A	0.005	0.970	0.0016	206	0.3200
A	0.005	0.970	0.0016	216	0.3200
B	0.013	0.635	0.0016	51	0.1231

B	0.003	0.635	0.0016	212	0.5333
B	0.002	0.635	0.0016	374	0.8000
B	0.003	0.635	0.0016	199	0.5333
B	0.006	0.635	0.0016	102	0.2667
C	0.010	0.635	0.0016	64	0.1600
C	0.007	0.635	0.0016	88	0.2286
C	0.003	0.635	0.0016	187	0.5333
C	0.004	0.635	0.0016	148	0.4000
C	0.010	1.034	0.0016	103	0.1600
C	0.024	0.780	0.0016	33	0.0667

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of residential applications of granule pesticide formulations by hand, the following limitations are noted:

- The individuals monitored in the study wore chemical-resistant gloves and nearly all dermal measurements (hands and body) were non-detects. Exposure was therefore calculated using ½ of the limit of quantification (0.41 ug for body exposure; 41 ug for hand exposure) and hand measurements required a back-calculation using a 90% protection factor to represent "bare" hand exposure.
- All inhalation samples were non-detects. One-half the limit of detection (0.2 μg) was used.

Scenario Summary

Table C-43: Scenario Description and Available Exposure Studies	
Formulation	Dusts/Powders
Equipment/Application Method	Plunger duster
Application Site(s)	outdoors (lawns, gardens, trees/bushes, perimeter, mounds/nests), indoors (general broadcast treatments)
Available Exposure Studies	Merricks, D.L. (1997); MRID 44459801

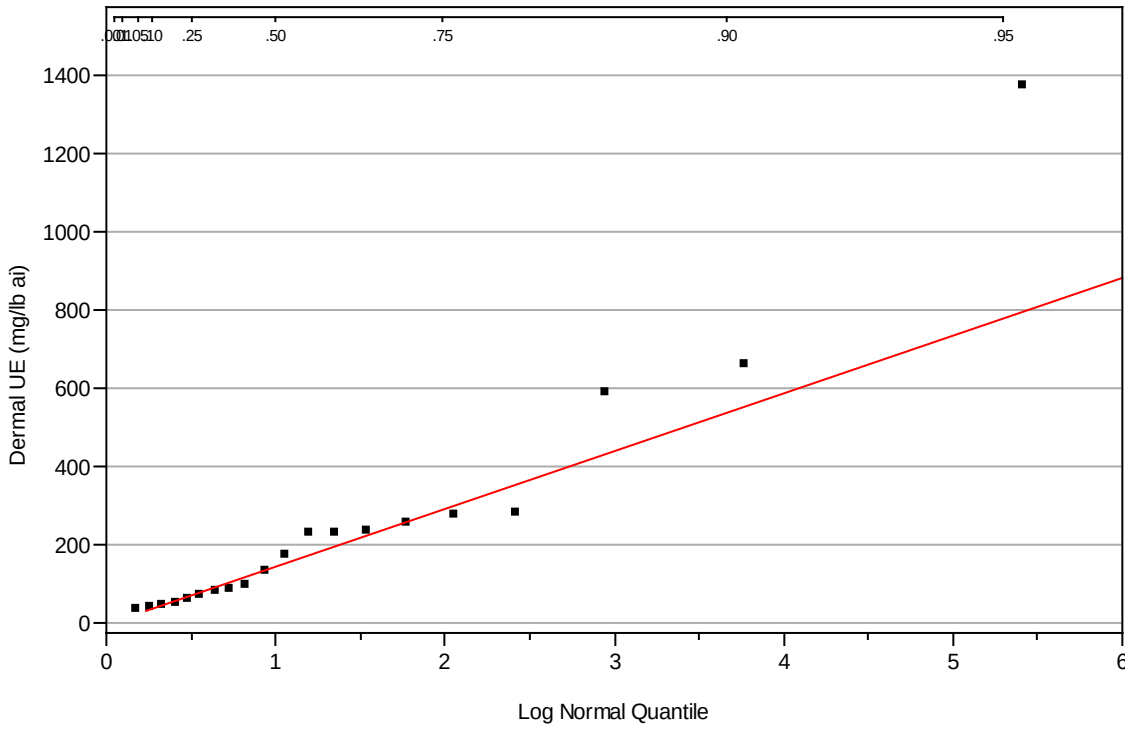
Table C-44: Unit Exposures (mg/lb ai) – Dust/Powder Plunger Duster Applications		
Statistic	Dermal	Inhalation
50^{th} percentile	150	0.50
75^{th} percentile	290	1.4
95^{th} percentile	790	6.5
99^{th} percentile	1600	19
99.9^{th} percentile	3400	62
AM (SD)	250 (330)	1.7 (5.4)
GM (GSD)	150 (2.8)	0.50 (4.8)
Range	36 – 1400	0.0045 – 8.2
N	20	20

Dermal Unit Exposure Data Summary: The recommended dermal unit exposures for applications of dust or powder pesticide formulations using a plunger duster is based on a lognormal distribution fit with exposure monitoring data from Merricks, D.L. (1997) [EPA MRID 44459801]. Merricks, D.L. (1997) monitored 20 applications of a dust formulation for approximately 20 minutes to garden plants using a hand-operated plunger duster. As well as being the only available data for this scenario, this study well represents the type of clothing a homeowner or amateur applicator would wear (i.e., shorts, short-sleeve shirt, no chemical-resistant gloves).

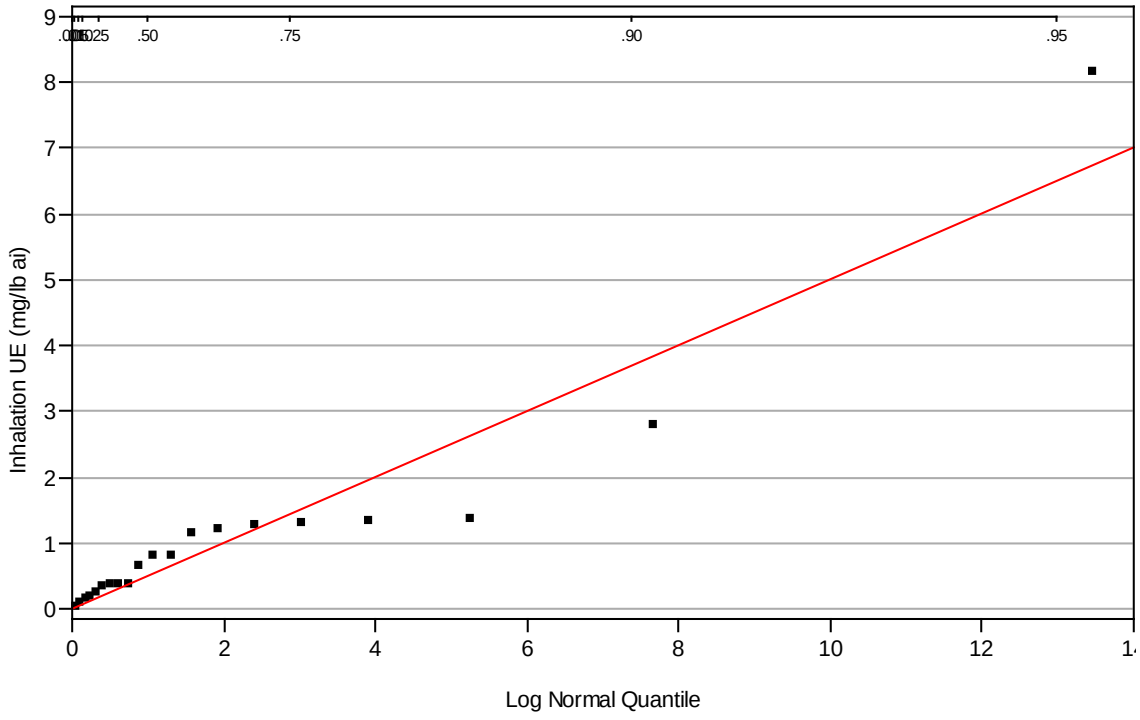
Inhalation Unit Exposure Data Summary: The recommended inhalation unit exposures for applications of dust or powder pesticide formulations using a plunger duster is based on a lognormal distribution fit with exposure monitoring data from Merricks, D.L. (1997) [EPA MRID 44459801]. Merricks, D.L. (1997) monitored 20 applications of a dust formulation for approximately 20 minutes to garden plants using a hand-operated plunger duster. As well as being the only available data for this scenario, this study well represents residential applications in terms of the clothing representation and activities.

Lognormal Probability Plots

Legend: ■ = Merricks, D.L. (1997)



Legend: ■ = Merricks, D.L. (1997)



Available Handler Exposure Studies

Table C-45: Exposure Study Identification Information	
Citation	Merricks, D.L. (1997). Carbaryl Mixer/Loader/Applicator Exposure Study during Application of RP-2 Liquid (21%), Sevin® Ready to Use Insect Spray or Sevin® 10 Dust to Home Garden Vegetables
EPA MRID	44459801
ORETF Code	OMA006
EPA Review	EPA Memo from G. Bangs to D. Fuller (3/5/03)
	D287251
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Twenty individuals were monitored while applying a dust formulation (10% carbaryl) to gardens using a hand-operated plunger duster (The Spritzer™). Each application was approximately 20 minutes and consisted of loading the duster and applying approximately 0.16 lbs formulation (0.017 lbs carbaryl) to garden plants. Dermal exposure was measured using inner and outer whole body dosimetry and hand washes (without chemical-resistant gloves worn). Inhalation exposure was measured using standard pumps (set at 2 liters per minute), cassettes, and tubing. Field fortification recoveries for passive dosimeters averaged 84.3% for inner dosimeters and 77.7% for outer dosimeters. Face and neck wipe field fortifications averaged 84.8%. Both handwash and inhalation tube field fortification averaged >90%. Laboratory method validation for each matrix fell within the acceptable range of 70 to 120%. The limit of quantitation (LOQ) was 1.0 µg/sample for all media except the inhalation monitors where the LOQ was 0.01 µg/sample. The limit of detection (LOD) was 0.5 µg/sample for all media except the inhalation monitors where the LOQ was 0.005 µg/sample.

Table C-46: MRID 44459801 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Both dermal and inhalation exposure are included since both are recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-47: MRID 44459801 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation

E	0.003	2.22	0.0043	661	1.43
F	0.025	14.70	0.0087	590	0.35
I	0.007	1.99	0.0058	275	0.83
H	0.012	1.55	0.0154	132	1.28
K	0.012	2.11	0.0021	172	0.18
L	0.013	1.22	0.0046	97	0.35
O	0.005	1.06	0.0126	234	2.52
P	0.009	2.13	0.0000	228	0.00
S	0.013	1.09	0.0158	82	1.22
T	0.015	1.03	0.0033	70	0.22
W	0.019	1.55	0.0235	84	1.24
X	0.012	3.10	0.0045	252	0.38
A2	0.029	1.48	0.0332	51	1.14
B2	0.003	3.61	0.0214	1375	7.13
E2	0.020	0.80	0.0014	40	0.07
F2	0.009	2.41	0.0053	280	0.59
I2	0.030	1.28	0.0242	42	0.81
J2	0.044	1.58	0.0144	36	0.33
M2	0.013	2.85	0.0171	227	1.32
O2	0.026	1.54	0.0039	60	0.15

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of residential applications of dust/powder formulations using a plunger duster, the following limitations are noted:

- Though the study was strictly conducted outdoors, it is recommended for indoor use as well since no indoor plunger duster study is available. Such use introduces uncertainty.

Scenario Summary

Table C-48: Scenario Description and Available Exposure Studies	
Formulation	Dusts/Powders
Equipment/Application Method	Shaker can
Application Site(s)	outdoors (lawns, gardens, trees/bushes, perimeter, mounds/nests), indoors (general broadcast treatments), pets/animals
Available Exposure Studies	Merricks, D. (1997); MRID 44439901
	McKeown, K. (2001); MRID 45519601

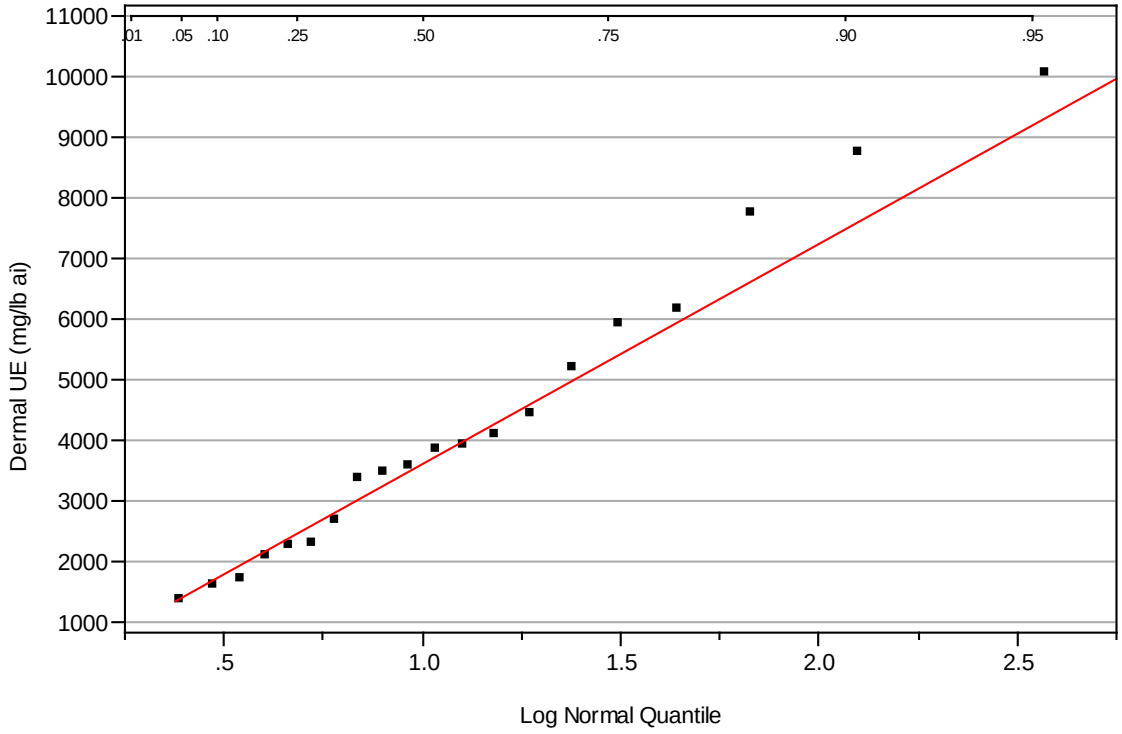
Table C-49: Unit Exposures (mg/lb ai) – Dust/Powder Shaker can Applications		
Statistic	Dermal	Inhalation
50th percentile	3600	9.4
75th percentile	5300	20
95th percentile	9200	59
99th percentile	14000	130
99.9th percentile	21000	290
AM (SD)	4300 (2600)	18 (28)
GM (GSD)	3600 (1.8)	9.4 (3.1)
Range	1400 – 10000	0.36 – 74
N	20	55

Dermal Unit Exposure Data Summary: The recommended dermal unit exposures for applications of dust or powder pesticide formulations using a shaker can is based on a lognormal distribution fit with exposure monitoring data from Merricks, D. (1997) [EPA MRID 44439901]. Merricks, D. (1997) monitored 40 applications of a dust formulation to dogs for approximately 7 minutes using a 1 lb shaker can. While another study was also available and reasonably representative of residential applications, Merricks, D., (1997) employed monitoring methods that best represented the type of clothing a homeowner or amateur applicator would wear (i.e., shorts, short-sleeve shirt, no chemical-resistant gloves).

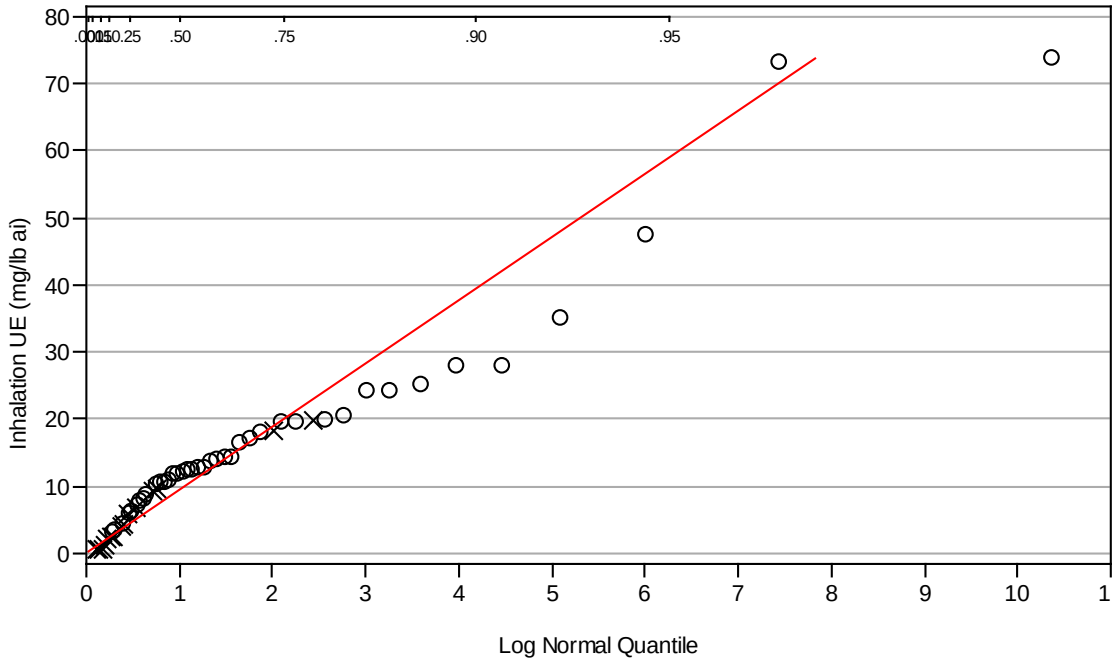
Inhalation Unit Exposure Data Summary: The recommended inhalation unit exposures for applications of dust or powder pesticide formulations using a shaker can is based on a lognormal distribution fit with exposure monitoring data from Merricks, D. (1997) [EPA MRID 44439901] and McKeown, K. (2001) [MRID 45519601]. Merricks, D. (1997) monitored 40 applications of a dust formulation to dogs for approximately 7 minutes using a 1 lb shaker can. McKeown, K. (2001) monitored 15 applications of approximately 1 ounce of a dust formulation for approximately 2-3 minutes to dogs using a shaker can. Both studies were reasonably representative of residential applications with inhalation exposures of the same general magnitude, thus a composite dataset was utilized.

Lognormal Probability Plots

Legend: ■ = Merricks, D.L. (1997)



Legend: X= McKeown, K. (2001); O = Merricks, D.L. (1997)



Available Handler Exposure Studies

Table C-50: Exposure Study Identification Information	
Citation	Merricks, D. (1997) Carbaryl Applicator Exposure Study During Application of Sevin 5 Dust to Dogs by the Non Professional: Lab Project Number: 1517: 10565: ML96 0662 RHP. Unpublished study prepared by Agrisearch Inc., Rhone Poulenc Ag Co. and Morse Laboratories, Inc. 212 p.
EPA MRID	44439901
ORETF Code	NA
EPA Review	D287251
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: A total of 40 individuals – 20 with and 20 without chemical-resistant gloves – were monitored while applying a dust formulation (5% carbaryl) to dogs. Each application, lasting approximately 7 minutes, consisted of an individual using a 1 lb shaker can to apply an average of 0.15 lbs of dust (0.008 lbs carbaryl) to 3 dogs, then rubbing the dust into the dog's coat. Dermal exposure was measured using inner and outer whole body dosimetry and hand washes. Inhalation exposure was measured using standard pumps (set at 2 liters per minute), cassettes, and tubing. Field fortification recoveries for passive dosimeters averaged >90% for inner and outer dosimeters. Face and neck wipe field fortifications average 87.6%. Inhalation tube field fortification averaged 100. Laboratory method validation for each matrix fell within the acceptable range of 70 to 120%.

Table C-51: MRID 44439901 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Both dermal (individuals without chemical-resistant gloves only) and inhalation exposure are included since both are recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-52: MRID 44439901 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
1	0.005	--	0.036	--	7.20
2	0.015	--	0.307	--	20.47

Table C-52: MRID 44439901 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
3	0.0034	34.15	0.220	10044	64.71
4	0.016	82.94	0.134	5184	8.38
5	0.005	--	0.016	--	3.20
6	0.008	--	0.100	--	12.50
7	0.0079	10.84	0.145	1372	18.35
8	0.0042	25.84	0.140	6152	33.33
9	0.01	--	0.120	--	12.00
10	0.0083	64.13	0.086	7726	10.36
11	0.002	--	0.029	--	14.50
12	0.007	--	0.137	--	19.57
13	0.0025	10.19	0.022	4076	8.80
14	0.003	10.76	0.038	3586	12.67
15	0.008	--	0.062	--	7.75
16	0.0068	18.19	0.098	2676	14.41
17	0.009	--	0.094	--	10.44
18	0.011	--	0.221	--	20.09
19	0.0068	15.49	0.091	2278	13.38
20	0.012	104.75	0.302	8729	25.17
21	0.008	--	0.225	--	28.13
22	0.017	--	0.280	--	16.47
23	0.0047	20.82	0.140	4431	29.79
24	0.022	84.35	0.280	3834	12.73
25	0.004	--	0.048	--	12.00
26	0.009	15.91	0.099	1711	11.00
27	0.002	--	0.024	--	12.00
28	0.008	--	0.591	--	73.88
29	0.0014	8.28	0.048	5914	34.29
30	0.0093	13.59	0.124	1599	13.33
31	0.005	--	0.072	--	14.40
32	0.005	--	0.044	--	8.80
33	0.014	29.36	0.293	2097	20.93
34	0.0069	23.17	0.120	3359	17.39
35	0.007	--	0.043	--	6.14
36	0.0064	24.96	0.039	3900	6.09
37	0.006	--	0.027	--	4.50
38	0.011	--	0.269	--	24.45
39	0.006	13.65	0.021	2275	3.50
40	0.004	13.86	0.098	3465	24.50

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of residential applications of dust/powder formulations using a shaker can, the following limitations are noted:

- Though the study was strictly conducted on dogs, it is recommended for all other uses as well since studies measuring exposure during shaker can applications of dust/powders to other sites are available. Such use introduces uncertainty.

Table C-53: Exposure Study Identification Information	
Citation	McKeown, K. (2001). Determination of Dermal and Inhalation Exposures to Tetrachlorvinphos (TCVP) During the Application of an Insecticide Powder to a Dog: Lab Project Number: 1556. Unpublished study prepared by The Hartz Mountain Corp. 215 p.
EPA MRID	45519601
ORETF Code	NA
EPA Review	D278626
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Five different applicators applied insecticidal powder (3.29% TCVP) using a shaker can to 3 different dogs for a total of 15 application events. Each application of approximately 1 ounce of product (approximately 0.0017 lbs TCVP) ranged between 2 and 3 minutes. Dermal exposure was measured using inner dosimetry underneath shorts and a short-sleeve shirt and hand washes (face/neck exposure was not measured). Inhalation exposure was measured using standard pumps (set at 15 liters per minute), cassettes, and tubing. Recoveries from field fortifications of exposure sampling matrices were variable. Field fortification recoveries averaged 96.9% ± 12.1 for handwipes, 82.12% ± 2.3 for inhalation samples, and 64.1% ± 12.4 for whole body dosimeters. For the whole body dosimeters, recoveries were low (48% ± 2 at the low fortification level of 10 µg and 72.2% ± 3.2 at the higher fortification levels of 500 and 3000 µg). Laboratory recoveries averaged 104.8% ± 7.1 for handwipes, 100.2% ± 9.3 for inhalation samples for the air filter/PUF plug, and 97.9% ± 9.2 whole body dosimeters.

Table C-54: MRID 45519601 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	No	Yes
Should this study be recommended for use in residential handler exposure assessments?	**No**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Note that only inhalation exposure data are presented as the dermal exposure data are not recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-55: MRID 45519601 Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
A	0.0017	--	0.0040	--	2.35

Table C-55: MRID 45519601 Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
A	0.0015	--	0.0105	--	7.00
A	0.0016	--	0.0008	--	0.50
B	0.0019	--	0.0105	--	5.53
B	0.0019	--	0.0076	--	4.00
B	0.0017	--	0.0340	--	20.00
C	0.0019	--	0.0177	--	9.32
C	0.0018	--	0.0036	--	2.00
C	0.0019	--	0.0082	--	4.32
D	0.0019	--	0.0168	--	8.84
D	0.0017	--	0.0037	--	2.18
D	0.0019	--	0.0354	--	18.63
E	0.0017	--	0.0018	--	1.06
E	0.0019	--	0.0007	--	0.37
E	0.0018	--	0.0011	--	0.61

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations:

- Each individual handled the same amount of active ingredient making analysis of the relationship between exposure and the amount of active ingredient handled (the underlying basis of unit exposures) difficult.
- The use of 15 liters per minute is much higher than the standard setting of 1- 2 liters per minute and could complicate air sampling.

Scenario Summary

Table C-56: Scenario Description and Available Exposure Studies	
Formulation	Paints and Stains
Equipment/Application Method	Airless sprayer
Application Site(s)	outdoors and indoors (general paint and stain applications)
Available Exposure Studies	Formella, T. (1995); MRID 43600102
	PHED 467

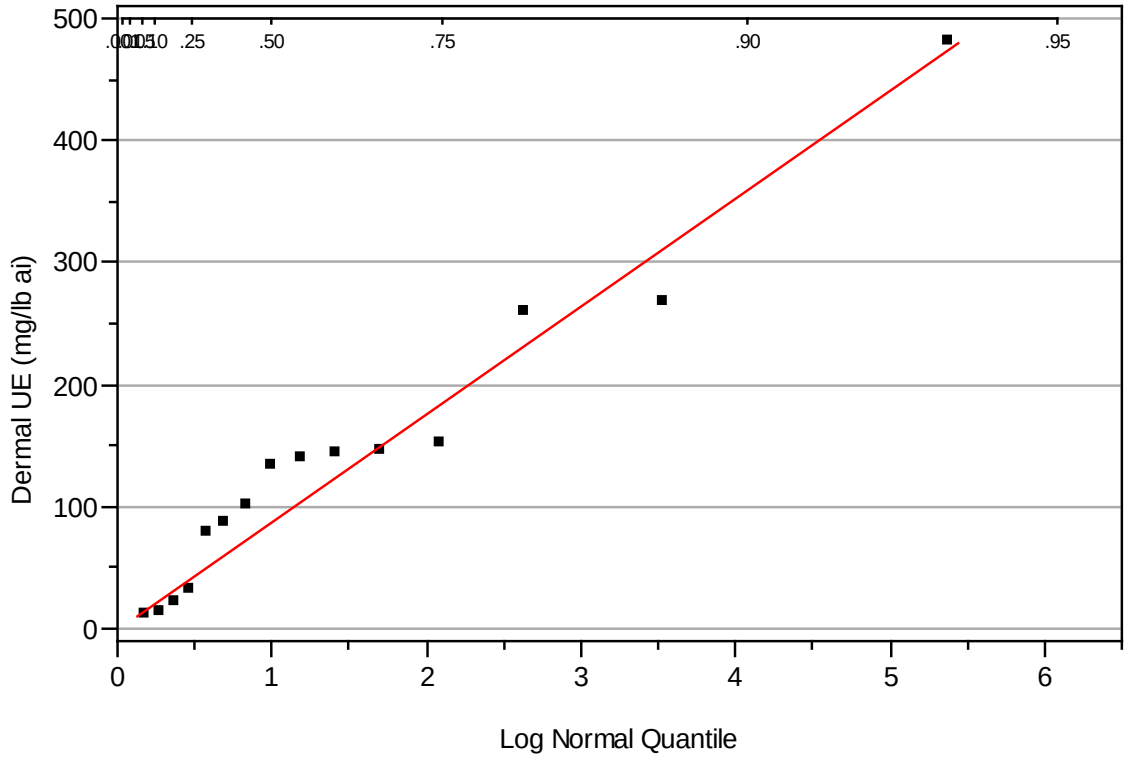
Table C-57: Unit Exposures (mg/lb ai) – Paint/Stain Airless Sprayer Applications		
Statistic	Dermal	Inhalation
50th percentile	88	0.38
75th percentile	190	0.69
95th percentile	540	1.6
99th percentile	1100	2.9
99.9th percentile	2700	5.7
AM (SD)	160 (250)	0.56 (0.60)
GM (GSD)	88 (3.01)	0.38 (2.4)
Range	12 – 480	0.078 – 1.6
N	15	51

Dermal Unit Exposure Data Summary: The recommended dermal unit exposures for applications of pesticide-containing paints or stains using an airless sprayer is based on a lognormal distribution fit with exposure monitoring data from PHED 467. PHED 467 monitored 15 applications of approximately 5 gallons of pesticide-containing stain with an airless sprayer. While another study was available that was also reasonably representative of residential applications, PHED 467 employed exposure monitoring methods that best represented the type of clothing a homeowner or amateur applicator would wear (i.e., shorts, short-sleeve shirt, no chemical-resistant gloves).

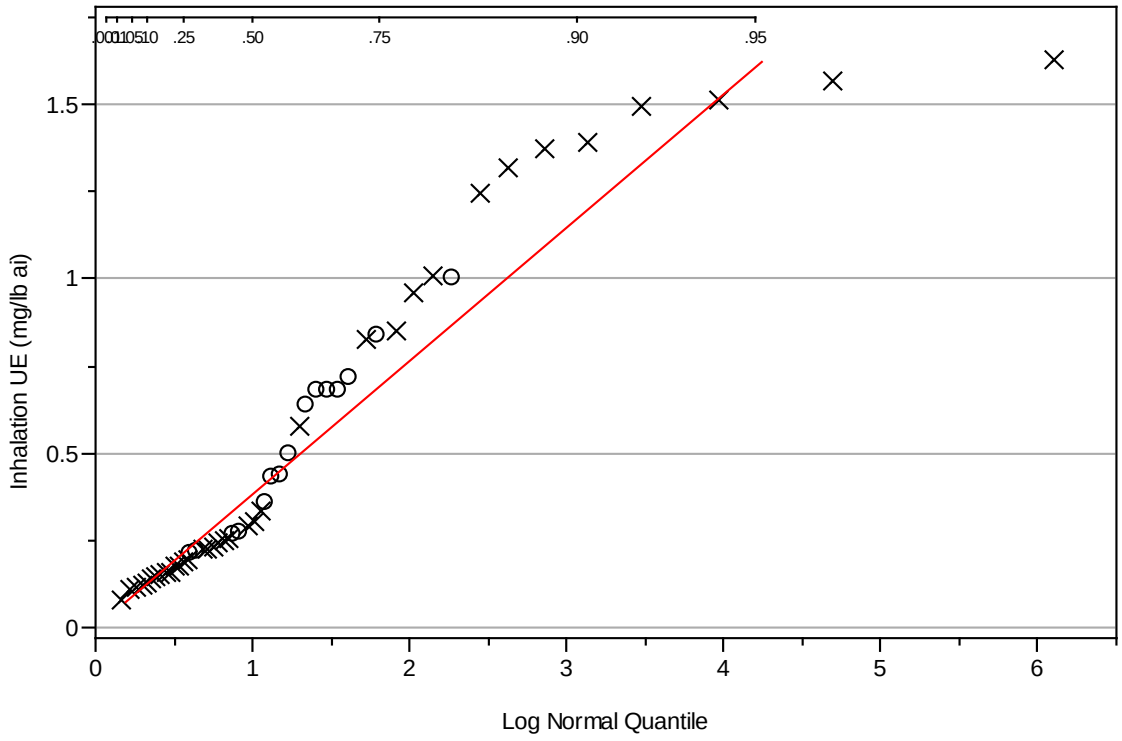
Inhalation Unit Exposure Data Summary: The recommended inhalation unit exposures for applications of pesticide-containing paints or stains using an airless sprayer is based on a lognormal distribution fit with exposure monitoring data from Formella, T. (1995) [EPA MRID 43600102] and PHED 467. Formella, T. (1995) monitored 36 applications of approximately 5 gallons of pesticide-containing paint inside and outside houses for approximately 22-81 minutes using an airless sprayer. PHED 467 monitored 15 applications of approximately 5 gallons of pesticide-containing stain with an airless sprayer. Both studies were reasonably representative of residential applications with inhalation exposures of the same general magnitude, thus a composite dataset was utilized.

Lognormal Probability Plots

Legend: ■ = PHED 467



Legend: X= Formella, T. (1995); O = PHED 467



Available Handler Exposure Studies

Table C-58: Exposure Study Identification Information	
Citation	Formella, T. (1995) Potential Exposure of Workers to Chlorothalonil when Handling and Applying Paint Containing Chlorothalonil: Lab Project Number: 94 0204: ISKB 1894 002 02: 5227 94 0204 CR 001. Unpublished study prepared by Ricerca, Inc. 272 p.
EPA MRID	43600102
ORETF Code	NA
EPA Review	none
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Four individuals were monitored while applying chlorothalonil-containing paint with an airless sprayer. Each individual was monitored 3 times for each of 3 paint-types (interior latex-based, exterior latex-based, and exterior alkyd-based) – for a total of 36 application-events – while spraying 5 gallons of paint (< 1 lb chlorothalonil). Each application-event ranged from 22 to 81 minutes. Dermal exposure was measured using whole body dosimetry underneath a long-sleeve shirt, long pants, socks, and shoes. Hand exposure was measured using inner and outer gloves. Inhalation exposure was measured using standard pumps (set at 1.5 liters per minute), cassettes, and tubing. Field fortification samples fortified with exterior latex paint containing had a mean recovery of 96% with a standard deviation of 10.1%. Those samples fortified with interior latex paint had a mean recovery of 96% with a standard deviation of 6.5% and those fortified with exterior alkyd paint had a mean recovery of 97% with a standard deviation of 10.4%. Overall laboratory concurrent recovery samples had a mean recovery of 101% with a standard deviation of 11%.

Table C-59: MRID 43600102 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**No**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Note that only inhalation exposure data are presented as the dermal exposure data are not recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-60: MRID 43600102 Data Summary			
Person ID	AaiH[1]	Exposure (mg)	Unit Exposure (mg/lb ai)[4]

	(lbs)	Dermal[2]	Inhalation[3]	Dermal	Inhalation
1	0.54	--	0.178	--	0.33
2	0.49	--	0.142	--	0.29
3	0.52	--	0.101	--	0.19
4	0.52	--	0.079	--	0.15
5	0.51	--	0.089	--	0.17
6	0.51	--	0.129	--	0.25
7	0.53	--	0.062	--	0.12
8	0.50	--	0.111	--	0.22
9	0.42	--	0.240	--	0.57
10	0.49	--	0.062	--	0.13
11	0.50	--	0.087	--	0.17
12	0.53	--	0.161	--	0.30
1	0.19	--	0.154	--	0.81
2	0.19	--	0.238	--	1.25
3	0.18	--	0.178	--	0.99
4	0.17	--	0.240	--	1.41
5	0.16	--	0.139	--	0.87
6	0.18	--	0.243	--	1.35
7	0.17	--	0.252	--	1.48
8	0.18	--	0.175	--	0.97
9	0.19	--	0.246	--	1.29
10	0.17	--	0.279	--	1.64
11	0.19	--	0.293	--	1.54
12	0.15	--	0.230	--	1.53
1	0.29	--	0.073	--	0.25
2	0.30	--	0.023	--	0.08
3	0.30	--	0.043	--	0.14
4	0.27	--	0.030	--	0.11
5	0.28	--	0.062	--	0.22
6	0.27	--	0.050	--	0.19
7	0.32	--	0.073	--	0.23
8	0.29	--	0.043	--	0.15
9	0.28	--	0.030	--	0.11
10	0.29	--	0.039	--	0.13
11	0.29	--	0.071	--	0.24
12	0.28	--	0.044	--	0.16

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: No limitations are identified for this study.

Table C-61: Available Exposure Study Identification Information	
Citation	PHED 467
EPA MRID	NA
ORETF Code	NA
EPA Review	none
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Eight different individuals were monitored at 3 different sites (for a total of 15 application-events) while apply stain with an airless sprayer. Each application consisted of an individual applying a 5 gallon container of stain to approximately 1000 ft^2. Dermal exposure was measured using gauze patches outside and inside standard cotton clothing. Hand exposure was measured using cotton gloves on the outside of protective latex gloves. Inhalation exposure was measured using standard pumps (set at 2 liters per minute), cassettes, and tubing. Field fortification recoveries averaged 80.3% for the patches, 90.7% for the filters, and 82.4% for the cotton gloves. The average recovery from laboratory fortified control samples that were analyzed with each set of test samples was 90.0% for white cotton gloves and 108.2% for polyurethane foam filters.

Table C-62: PHED 467 – Checklist and Use Recommendation

Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Both dermal and inhalation exposure are included since both are recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-63: PHED 467 Data Summary

Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
A	0.1667	80.16	0.073	481	0.441
A	0.1667	22.17	0.168	133	1.007
B	0.1667	5.15	0.036	31	0.215
C	0.1667	23.31	0.140	140	0.842
B	0.1667	25.11	0.114	151	0.681
D	0.1667	1.95	0.045	12	0.270
C	0.1667	16.88	0.084	101	0.501
D	0.1667	2.27	0.046	14	0.275
E	0.1667	43.29	0.120	260	0.721
E	0.1667	14.45	0.107	87	0.641
F	0.1667	24.01	0.114	144	0.686
G	0.1667	24.23	0.060	145	0.361
F	0.1667	44.72	0.037	268	0.220
G	0.1667	3.72	0.073	22	0.436
H	0.1667	12.94	0.114	78	0.686

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant

gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of paint/stain applications using an airless sprayer, the following limitations are noted:

- Cotton gloves were used to measure hand exposure which, though used in the past as a frequent collection method for hand exposure may result in an overestimate.

Scenario Summary

Table C-64: Scenario Description and Available Exposure Studies	
Formulation	Paints and Stains
Equipment/Application Method	Brush
Application Site(s)	outdoors and indoors (general paint and stain applications)
Available Exposure Studies	PHED 467

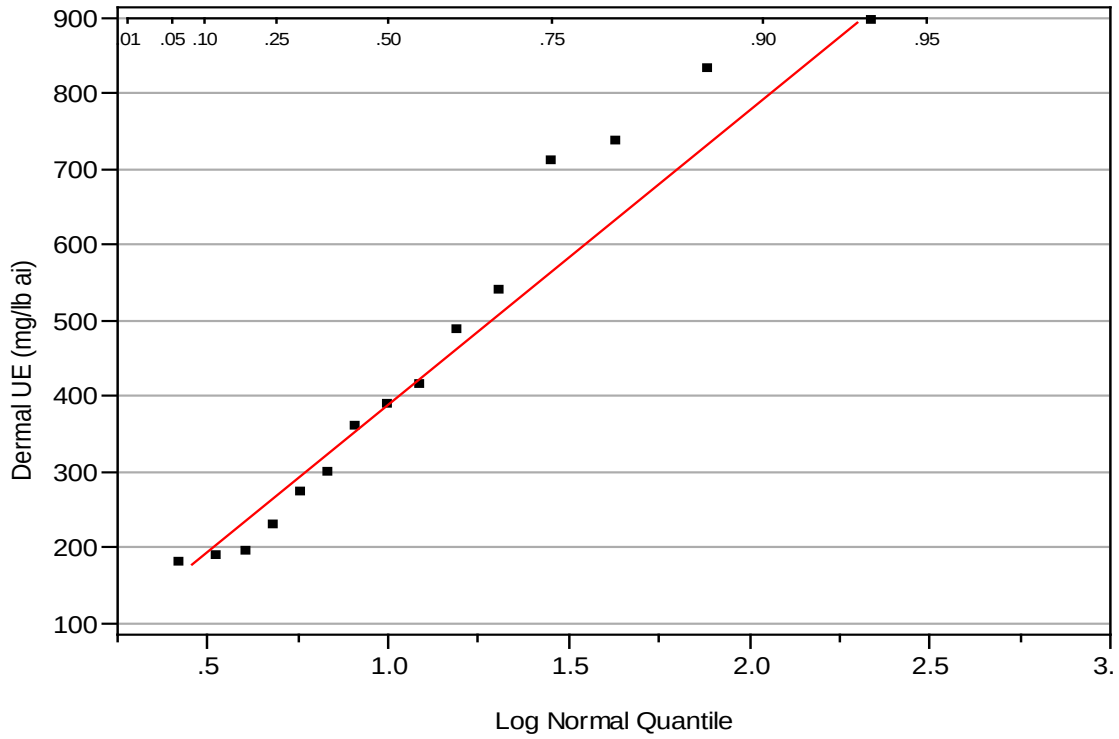
Table C-65: Unit Exposures (mg/lb ai) – Paint/Stain Brush Applications		
Statistic	Dermal	Inhalation
50th percentile	390	0.19
75th percentile	570	0.23
95th percentile	970	0.30
99th percentile	1400	0.37
99.9th percentile	2200	0.46
AM (SD)	450 (270)	0.20 (0.058)
GM (GSD)	390 (1.7)	0.19 (1.3)
Range	180 – 900	0.16 – 0.33
N	15	15

Dermal Unit Exposure Data Summary: The recommended dermal unit exposures for applications of pesticide-containing paints or stains using a brush is based on a lognormal distribution fit with exposure monitoring data from PHED 467. PHED 467 monitored 15 applications of approximately 1 gallon of pesticide-containing paint to an interior bathroom for approximately 34-94 minutes with 2- or 4-inch brushes. This was the only available study for this exposure scenario.

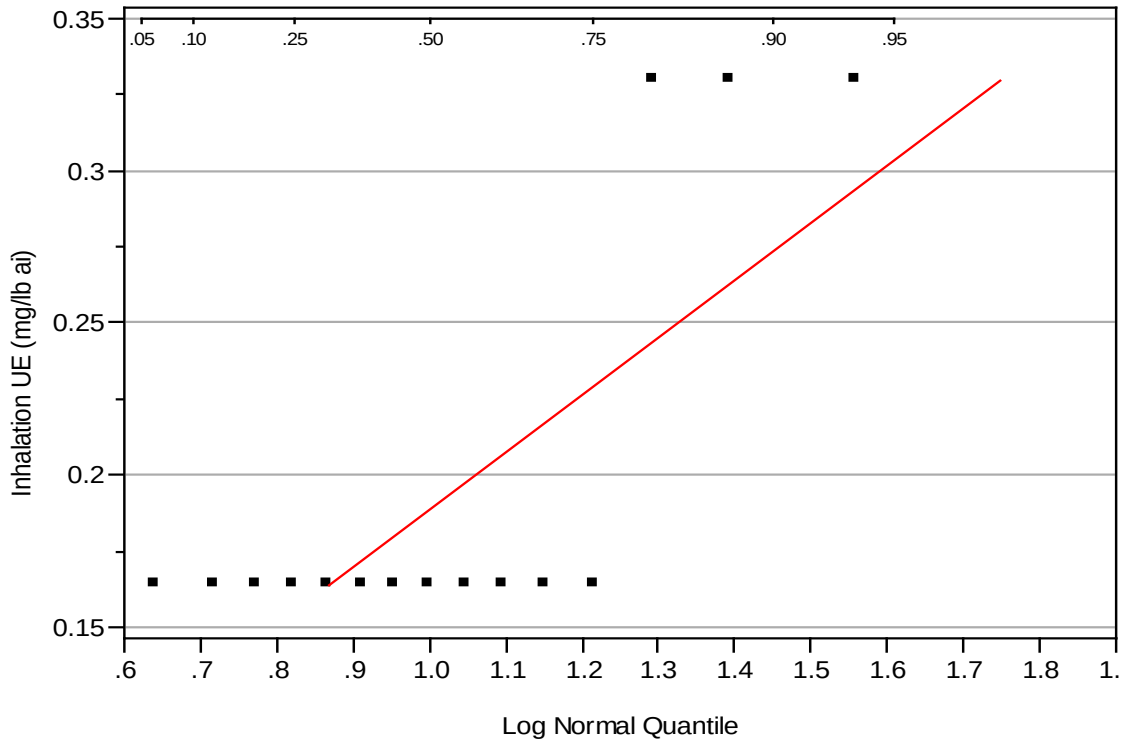
Inhalation Unit Exposure Data Summary: The recommended inhalation unit exposures for applications of pesticide-containing paints or stains using a brush is based on a lognormal distribution fit with exposure monitoring data from PHED 467. PHED 467 monitored 15 applications of approximately 1 gallon of pesticide-containing paint to an interior bathroom for approximately 34-94 minutes with 2- or 4-inch brushes. This was the only available study for this exposure scenario.

Lognormal Probability Plots

Legend: ■ = PHED 467



Legend: ■ = PHED 467



Available Exposure Studies

Table C-66: Exposure Study Identification Information	
Citation	PHED 467
EPA MRID	NA
ORETF Code	NA
EPA Review	none
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Ten different individuals were monitored at 3 different sites (for a total of 15 application-events) while applying approximately 1 gallon of paint with 2- or 4-inch brushes to an interior bathroom. Each application ranged from 34-94 minutes. Dermal exposure was measured using gauze patches outside and inside standard cotton clothing. Hand exposure was measured using cotton gloves on the outside of protective latex gloves. Inhalation exposure was measured using standard pumps (set at 2 liters per minute), cassettes, and tubing. Field fortification recoveries average 82.5% for patches, 87.5% for filters, and 74.7% for gloves. A laboratory storage stability study was initiated with each type of matrix. Patch samples had a recovery of 75.6%, gloves had 81.5%, and filters had a recovery of 94.6% after 89 days storage. The average recovery from laboratory fortified control samples averaged 87.5% for white cotton gloves and 99.0% for polyurethane foam air filters.

Table C-67: PHED 467 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Both dermal and inhalation exposure are included since both are recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-68: PHED 467 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
AA	0.0253	5.82	0.00835	230	0.330
BB	0.0253	4.87	0.00835	193	0.330
CC	0.051	18.32	0.00835	359	0.164
DD	0.051	12.35	0.00835	488	0.164
EE	0.051	4.75	0.00835	188	0.164

Table C-68: PHED 467 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
FF	0.051	10.50	0.00835	415	0.164
GG	0.051	21.05	0.00835	832	0.164
HH	0.051	7.59	0.00835	300	0.164
II	0.0253	13.67	0.00835	540	0.330
JJ	0.051	6.90	0.00835	273	0.164
KK	0.051	4.52	0.00835	179	0.164
LL	0.051	18.62	0.00835	736	0.164
MM	0.051	22.70	0.00835	897	0.164
NN	0.051	17.95	0.00835	710	0.164
OO	0.051	19.74	0.00835	387	0.164

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of paint/stain applications using a brush, the following limitations are noted:

- All inhalation samples were non-detects. One-half the limit of detection (2 μg) was used.

Scenario Summary

Table C-69: Scenario Description and Available Exposure Studies	
Formulation	Mothballs
Equipment/Application Method	Hand placement
Application Site(s)	Cabinets, sheds, closets
Available Exposure Studies	Waggoner, T. (1994); MRID 43716501

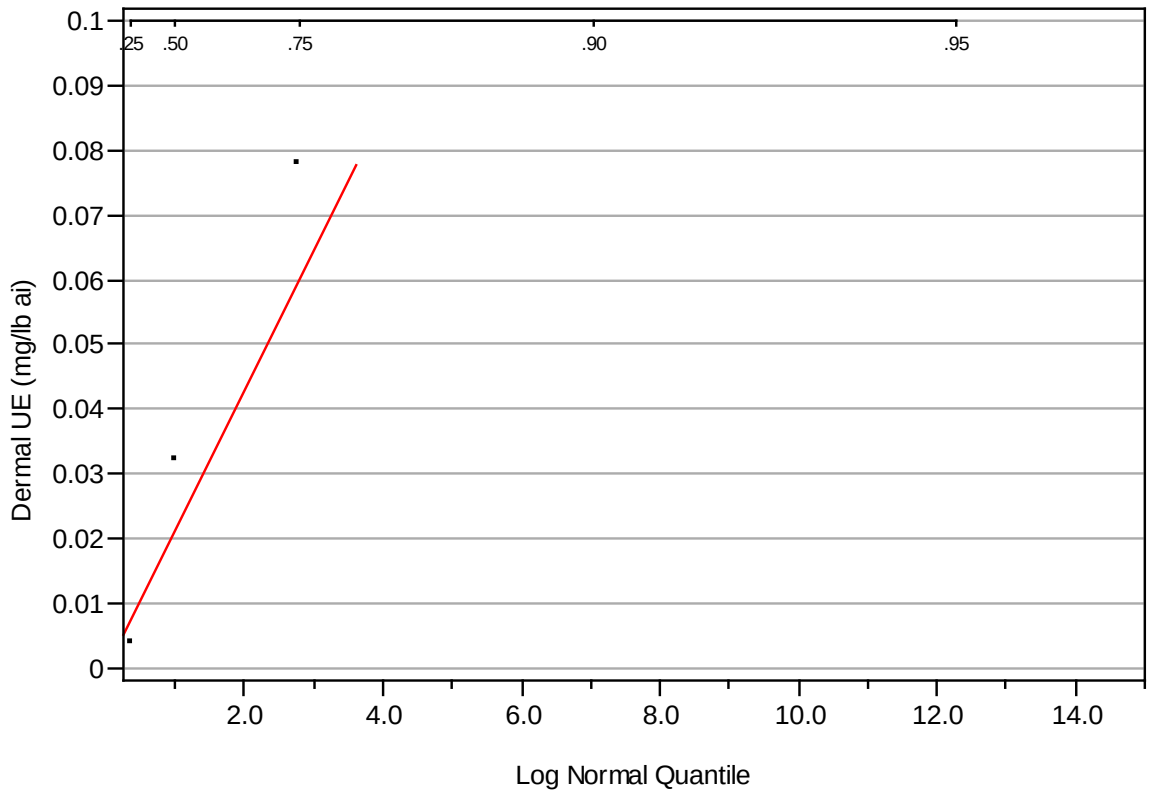
Table C-70: Unit Exposures (mg/lb ai) – Mothball Applications by Hand		
Statistic	Dermal	Inhalation
50th percentile	0.021	Inhalation exposure while placing mothballs in cabinets, closets, etc. is assumed negligible. The post-application inhalation exposure assessment is considered protective of handler inhalation exposure.
75th percentile	0.060	
95th percentile	0.28	
99th percentile	0.81	
99.9th percentile	2.7	
AM (SD)	0.072 (0.24)	
GM (GSD)	0.021 (4.8)	
Range	0.032 – 0.078	
N	3	

Dermal Unit Exposure Data Summary: The recommended dermal unit exposures for applications of pesticide-containing mothballs by hand is based on a lognormal distribution fit with exposure monitoring data from Waggoner, T. (1990) [EPA MRID 43716501]. Waggoner, T. (1990) monitored 3 applications of mothballs in closets and dresser drawers in 3 residences in Georgia by hand. This was the only study available for this exposure scenario.

Inhalation Unit Exposure Data Summary: Inhalation exposure while placing mothballs in cabinets, closets, etc. is assumed negligible.

Lognormal Probability Plots

Legend: ■ = Waggoner, T. (1994)



Available Exposure Studies

Table C-71: Exposure Study Identification Information	
Citation	Waggoner, T. (1994) Estimation of Homeowner Exposure to LX1298-01 (Napthalene) Resulting from Simulated Residential Use as an Insect Repellent: Final Report: Lab Project Number: 93-9083: 92-298-01-21H-02: 92-298-01-21H-03. Unpublished study prepared by Landis International, Inc. and Pharmaco LSR, Inc. 100 p.
EPA MRID	43716501
ORETF Code	NA
EPA Review	D340008
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Three individuals were monitored while placing mothballs in closets and dresser drawers in 3 residences in Georgia (1 person monitored in each residence for a total of 3 application-events). Each application consisted of weighing the mothballs (so as to place approximately 1.0 lb naphthalene per 50 ft^3 of space), placing mothballs in closets and/or dresser drawers and closing the closet or dresser drawer. The amount of naphthalene used ranged from 1.34 lbs to 2.2 lbs. Dermal exposure was monitored for hands only using cotton gloves. Inhalation exposure was monitored during the placement of the mothballs using standard pumps (set at 0.5 liter per minute), cassettes, and tubing – but the results were not reported. Recoveries from field fortifications of exposure sampling matrices were not reported.

Table C-72: MRID 43716501 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	No	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	No	No
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**No**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Both dermal and inhalation exposure are included since both are recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-73: MRID 43716501 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
A	2.2	0.0081	--	0.004	--
B	1.3	0.1040	--	0.078	--

C	1.5	0.0465	--	0.032	--

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm). Since "applicator" inhalation samples were not reported, the highest reported post-application inhalation exposures are shown.
[4] Unit Exposure = Exposure/AaiH.

Limitations:

- The adequacy of the results is compromised due to the limited sample size.
- Inhalation exposure during application of mothballs was not reported.

Scenario Summary

Table C-74: Scenario Description and Available Exposure Studies	
Formulation	Liquids (emulsifiable concentrates, soluble concentrates, etc.)
Equipment/Application Method	Manually-pressurized handwand (also: handheld pump sprayer)
Application Site(s)	outdoors (lawns, gardens, trees/bushes, perimeter, mounds/nests, aquatic areas), indoors (general broadcast treatments, baseboards, cracks and crevices)
Available Exposure Studies	Merricks, D.L. (1997); MRID 44459801
	Merricks, D.L. (1998); MRID 44518501
	PHED 471
	PHED 1024
	Stewart, P., et al. (1999)
	PHED 468
	Rosenheck, L. (2000); MRID 45184305

Table C-75: Unit Exposures (mg/lb ai) – Liquid Manually-pressurized Handwand Applications				
Statistic	Indoor Uses		Outdoor Uses	
	Dermal	Inhalation	Dermal	Inhalation
50th percentile	Studies measuring exposure while mixing/loading/applying liquid formulations indoors using a manually-pressurized handwand are unavailable. The dataset for mixing/loading/applying wettable powder formulations indoors should be used as a surrogate.		36	0.0069
75th percentile			73	0.018
95th percentile			204	0.069
99th percentile			422	0.178
99.9th percentile			949	0.517
AM (SD)			63 (91)	0.018 (0.045)
GM (GSD)			36 (2.89)	0.0069 (4.0)
Range			1.75 – 354	0.0021 – 0.742
N			50	69

Dermal Unit Exposure Data Summary

Outdoor Environments: The recommended dermal unit exposures for applications of liquid pesticide formulations using a manually-pressurized handwand in outdoor environments is based on a lognormal distribution fit with exposure monitoring data from Merricks, D.L. (1997) [EPA MRID 44459801], Merricks, D.L. (1998) [EPA MRID 44518501], and Rosenheck, L. (2000) [EPA MRID 45184305]. Merricks, D.L. (1997) monitored 40 applications of a liquid pesticide formulation for approximately 20 minutes to tomato and cucumber gardens using a manually-pressurized handwand. Merricks, D.L. (1998) monitored 20 applications of a liquid pesticide formulation for approximately 20 minutes to citrus trees and shrubs using a manually-pressurized handwand. Rosenheck, L. (2000) monitored 10 applications of a liquid pesticide formulation ranging from 25 to 44 minutes to lawns, gardens, ornamentals, shrubs, and house foundations. These studies best represent outdoor residential use of this type of equipment – while other studies are more occupational in nature – and the exposure monitoring enables representation of the type of clothing a homeowner or amateur applicator would wear (i.e., shorts, short-sleeve shirt, no chemical-resistant gloves). As the results were generally of the same magnitude, they were combined into one dataset.

Indoor Environments: Dermal exposure monitoring data for applications of liquid pesticide formulations using a manually-pressurized handwand in indoor environments is unavailable; dermal unit exposures for applications of wettable powder pesticide formulations using a manually-pressurized handwand in indoor environments are recommended as surrogate data.

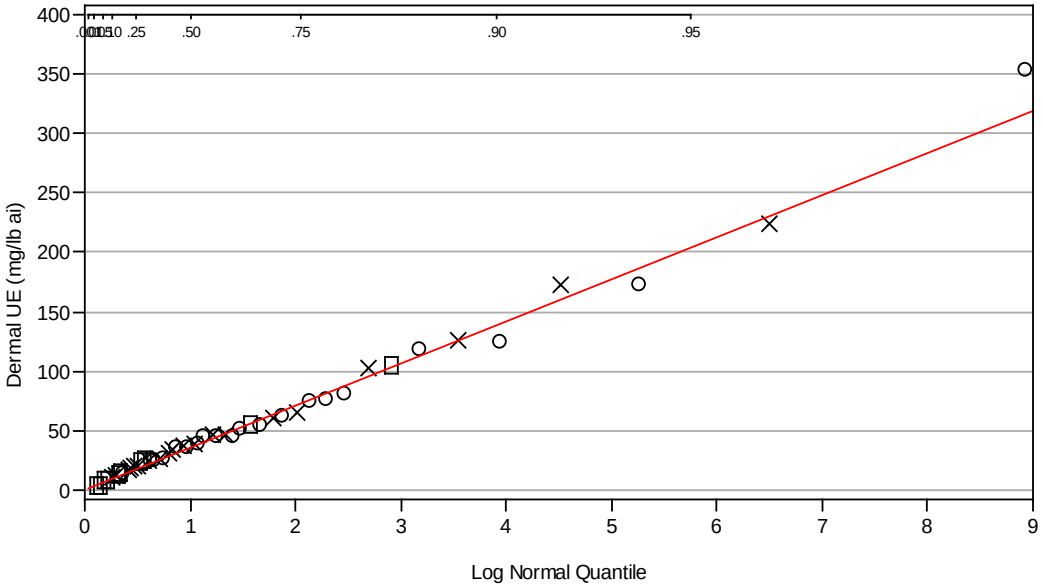
Inhalation Unit Exposure Data Summary

Outdoor Environments: The recommended inhalation unit exposures for applications of liquid pesticide formulations using a manually-pressurized handwand in outdoor environments is based on a lognormal distribution fit with exposure monitoring data from Merricks, D.L. (1997) [EPA MRID 44459801], Merricks, D.L. (1998) [EPA MRID 44518501], and Rosenheck, L. (2000). Merricks, D.L. (1997) monitored 40 applications of a liquid pesticide formulation for approximately 20 minutes to tomato and cucumber gardens using a manually-pressurized handwand. Merricks, D.L. (1998) monitored 20 applications of a liquid pesticide formulation for approximately 20 minutes to citrus trees and shrubs using a manually-pressurized handwand. Rosenheck, L. (2000) monitored 10 applications of a liquid pesticide formulation ranging from 25 to 44 minutes to lawns, gardens, ornamentals, shrubs, and house foundations. These studies best represent outdoor residential use of this type of equipment – other available studies are more occupational in nature. Additionally, despite Rosenheck, L. (2000) resulting in considerably higher inhalation exposures, the datasets were combined.

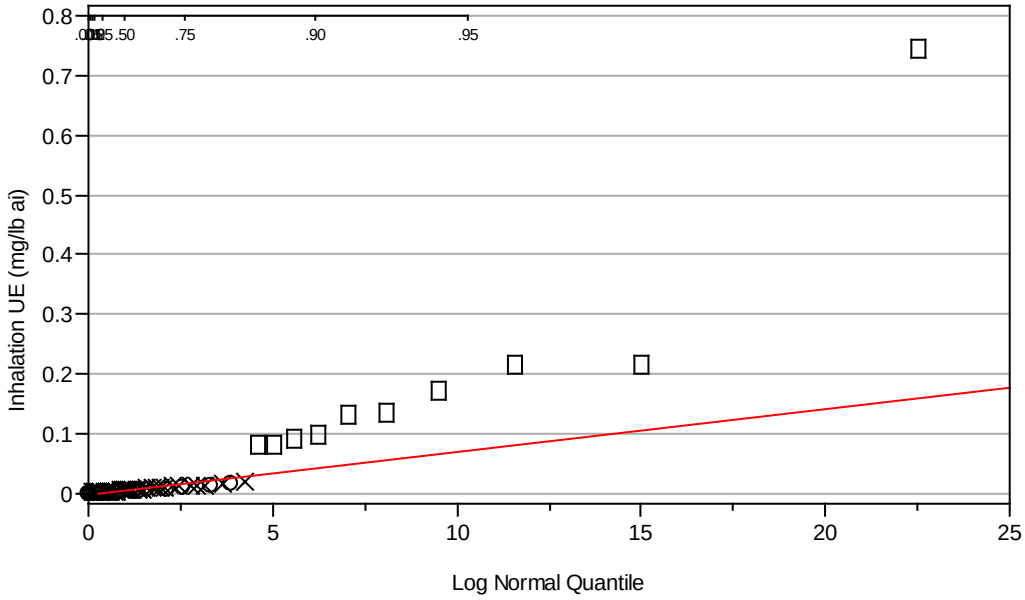
Indoor Environments: Inhalation exposure monitoring data for applications of liquid pesticide formulations using a manually-pressurized handwand in indoor environments is unavailable; inhalation unit exposures for applications of wettable powder pesticide formulations using a manually-pressurized handwand in indoor environments are recommended as surrogate data.

Lognormal Probability Plots

Legend: X = Merricks, D.L. (1997); O = Merricks, D.L. (1998); □ = Rosenheck, L. (2000)



Legend: X = Merricks, D.L. (1997); O = Merricks, D.L. (1998); □ = Rosenheck, L. (2000)



Available Exposure Studies

Table C-76: Exposure Study Identification Information	
Citation	Merricks, D.L. (1997). Carbaryl Mixer/Loader/Applicator Exposure Study during Application of RP-2 Liquid (21%), Sevin® Ready to Use Insect Spray or Sevin® 10 Dust to Home Garden Vegetables
EPA MRID	44459801
ORETF Code	OMA006
EPA Review	Memo from G. Bangs to D. Fuller (3/5/03)
	D287251
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Forty individuals were monitored while mixing, loading, and applying a liquid formulation (21% carbaryl) to tomato and cucumber gardens using a manually-pressurized handwand. Each application was approximately 20 minutes and consisted of loading the manually-pressurized handwand and applying approximately 0.07 lbs formulation (approximately 0.01 gallons; 0.02 lbs carbaryl) in 2 gallons of water to garden plants. Dermal exposure was measured using inner and outer whole body dosimetry and hand washes (20 individuals were monitored without gloves). Inhalation exposure was measured using standard pumps (set at 2 liters per minute), cassettes, and tubing. Field fortification recoveries for passive dosimeters averaged 84.3% for inner dosimeters and 77.7% for outer dosimeters. Face and neck wipe field fortifications averaged 84.8%. Both handwash and inhalation tube field fortification averaged >90%. Laboratory method validation for each matrix fell within the acceptable range of 70 to 120%. The limit of quantitation (LOQ) was 1.0 µg/sample for all media except the inhalation monitors where the LOQ was 0.01 µg/sample. The limit of detection (LOD) was 0.5 µg/sample for all media except the inhalation monitors where the LOQ was 0.005 µg/sample.

Table C-77: MRID 44459801 – Checklist and Use Recommendation for		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	Yes	Yes

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Both dermal and inhalation exposure are included since both are recommended for use in residential handler exposure assessment. Note that only dermal exposure data representative of individuals wearing short-sleeve shirt, shorts, shoes, socks, and no chemical-resistant gloves are presented. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-78: MRID 44459801 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
P2	0.018	--	0.00017	--	0.0094
Q2	0.019	--	0.00004	--	0.0023
R2	0.015	--	0.00009	--	0.0067
S2	0.017	--	0.00008	--	0.0041
V2	0.013	--	0.00004	--	0.0041
W2	0.017	--	0.00004	--	0.0041
X2	0.019	--	0.00004	--	0.0033
Y2	0.019	--	0.00004	--	0.0022
B3	0.017	--	0.00004	--	0.0032
C3	0.019	--	0.00008	--	0.0044
D3	0.019	--	0.00004	--	0.0021
E3	0.013	--	0.00004	--	0.0027
H3	0.018	--	0.00017	--	0.0131
I3	0.019	--	0.00025	--	0.0129
J3	0.019	--	0.00004	--	0.0023
K3	0.019	--	0.00004	--	0.0027
N3	0.015	--	0.00004	--	0.0027
O3	0.019	--	0.00004	--	0.0027
P3	0.015	--	0.00016	--	0.0107
Q3	0.019	--	0.00017	--	0.0101
A	0.018	1.16	0.00008	65	0.0047
B	0.018	0.88	0.00004	46	0.0022
G	0.013	0.30	0.00008	20	0.0053
C	0.020	2.84	0.00026	171	0.0155
J	0.010	0.21	0.00004	17	0.0033
D	0.010	3.71	0.00008	224	0.0050
M	0.013	0.33	0.00008	17	0.0044
N	0.019	1.14	0.00025	60	0.0131
Q	0.013	0.32	0.00004	19	0.0025
R	0.019	0.65	0.00017	34	0.0087
U	0.020	0.21	0.00004	11	0.0022
V	0.015	0.59	0.00025	46	0.0197
Y	0.013	1.81	0.00004	102	0.0023
Z	0.019	0.47	0.00004	25	0.0022
C2	0.018	2.39	0.00017	125	0.0087
D2	0.015	0.69	0.00008	36	0.0044
G2	0.015	0.45	0.00004	30	0.0027
H2	0.015	0.49	0.00017	26	0.0087
K2	0.015	0.16	0.00004	10	0.0027
L2	0.017	0.72	0.00008	38	0.0044

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of residential applications of liquid concentrate formulations using a manually-pressurized handwand, the following limitations are noted:

- Each individual handled the same amount of active ingredient, making analysis of the relationship between exposure and the amount of active ingredient handled (the underlying basis of unit exposures) difficult.

Table C-79: Exposure Study Identification Information	
Citation	Merricks, D.L. (1998). Carbaryl Mixer/Loader/Applicator Exposure Study During Application of RP-2 Liquid (21%) to Fruit Trees and Ornamental Plants
EPA MRID	44518501
ORETF Code	OMA005
EPA Review	Memo from G. Bangs to D. Fuller (3/5/03)
	D287251
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Twenty individuals were monitored while loading and applying a liquid formulation (21% carbaryl) to citrus trees and shrubs using a manually-pressurized handwand. Each application consisted of pouring the formulation into the tank and spraying the trees – all lasting less than 20 minutes. The amount of carbaryl handled ranged from 0.02 to 0.09 lbs. Dermal exposure was measured using inner and outer whole body dosimetry and hand washes (individuals were monitored without gloves). Inhalation exposure was measured using standard pumps (set at 2 liters per minute), cassettes, and tubing. Field fortification recoveries for passive dosimeters averaged 88.3% for inner and 76.2% for outer dosimeters. Face and neck wipe fortifications averaged 82.5%. Handwash fortifications averaged 93.6% and air sampler tube fortification was 91.8%. Laboratory method validation for each matrix fell within the acceptable range of 70 to 120%. The limit of quantitation (LOQ) was 1.0 µg/sample for all media except the inhalation monitors where the LOQ was 0.01 µg/sample. The limit of detection (LOD) was 0.5 µg/sample for all media except the inhalation monitors where the LOQ was 0.005 µg/sample.

Table C-80: MRID 44518501 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Both dermal and inhalation exposure are included since both are recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-81: MRID 44518501 – Data Summary			
Person ID	AaiH[1]	Exposure (mg)	Unit Exposure (mg/lb ai)[4]

	(lbs)	Dermal[2]	Inhalation[3]	Dermal	Inhalation
2	0.018	0.45	0.000042	25	0.0023
4	0.015	0.79	0.000042	52	0.0027
6	0.020	2.57	0.000042	126	0.0021
8	0.019	0.51	0.000042	27	0.0022
10	0.013	4.52	0.000042	354	0.0033
12	0.014	0.78	0.000043	56	0.0031
14	0.018	2.12	0.000042	119	0.0023
16	0.020	3.52	0.000167	174	0.0083
18	0.017	0.75	0.000084	45	0.0050
20	0.015	0.61	0.000167	40	0.0109
22	0.019	0.88	0.000042	46	0.0022
24	0.018	0.27	0.000042	15	0.0023
26	0.018	0.64	0.000043	36	0.0024
28	0.020	1.66	0.000042	82	0.0021
30	0.015	1.17	0.000257	77	0.0168
32	0.018	1.34	0.000086	75	0.0048
34	0.020	0.92	0.000042	46	0.0021
36	0.017	0.61	0.000251	37	0.0151
38	0.020	0.50	0.000042	25	0.0021
40	0.018	1.13	0.000167	63	0.0094

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of residential applications of liquid concentrate formulations using a manually-pressurized handwand, the following limitations are noted:

- Each individual handled the same amount of active ingredient, making analysis of the relationship between exposure and the amount of active ingredient handled (the underlying basis of unit exposures) difficult.

Table C-82: Exposure Study Identification Information	
Citation	PHED 471
EPA MRID	NA
ORETF Code	NA
EPA Review	None
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Four workers at 4 different sites (for a total of 16 application events) were monitored while mixing, loading, and applying a liquid formulation to poultry litter using a manually-pressurized handwand. Each applicator mixed and applied 3, 2-gallon solutions (equal to approximately 0.052 lbs active ingredient), a task that lasted on average 53 minutes. Dermal exposure was measured using gauze patches (both inside and outside normal work clothing) and cotton gloves (underneath chemical-resistant gloves) for hand exposure. Inhalation exposure was measured using standard pumps (set at 2 liters per minute), cassettes, and tubing. All inhalation samples were non-detects. An average of 84.9 ± 5.2 (n=18) was recovered from field

fortified patches, 79.3 ± 7.3% from gloves and 84.0 ± 16.8% from foam air filters. The overall average recovery from laboratory fortified control samples was 87 ± 12.0% for alpha-cellulose gauze patches, 75 ± 11.6% for cotton gloves, and 89 ± 10.5% for foam air filters.

Table C-83: PHED 471 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**No**	**No**

Data Summary: A summary of the data from this study is not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Limitations: Any data limitations associated with the exposure data in this study are not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Table C-84: Exposure Study Identification Information	
Citation	PHED 1024
EPA MRID	NA
ORETF Code	NA
EPA Review	None
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Sixteen individuals were monitored while applying a liquid formulation to greenhouse plants hanging overhead or on the floor or on benches using a manually-pressurized handwand. A wide range of solution was applied ranging from 5 gallons to 120 gallons per applicator, which corresponded to a range of 0.06 to 0.91 lbs of active ingredient handled. Each application event generally lasted 1.5 hours. Dermal exposure was measured using gauze patches (both inside and outside normal work clothing) and hand rinses (underneath chemical-resistant gloves) for hand exposure. Inhalation exposure was measured using standard pumps (set at 1.5 liters per minute), cassettes, and tubing. Recoveries from field fortifications of exposure sampling matrices were generally above 90%.

Table C-85: PHED 1024 – Checklist and Use Recommendation for		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	

Table C-85: PHED 1024 – Checklist and Use Recommendation for		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**No**	**No**

Data Summary: A summary of the data from this study is not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Limitations: Any data limitations associated with the exposure data in this study are not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Table C-86: Exposure Study Identification Information	
Citation	Stewart, P., T. Fears, H.F. Nicholson, B.C. Kross, L. K. Ogilvie, S.H. Zahm, M.H. Ward and A. Blair (1999) Exposure Received From Application Of Animal Insecticides. American Industrial Hygiene Association Journal. 60:208-212
EPA MRID	NA
ORETF Code	NA
EPA Review	none
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Three farmers were monitored while applying insecticides to animals using a manually-pressurized handwand. Each application ranged from approximately 1 to 200 liters of solution and varied among 6 active ingredients. Clothing worn varied between farmers. Dermal exposure was measured using a fluorescent dye video-imaging technique. Inhalation exposure was not measured.

Table C-87: Stewart, et al. (1999) – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	No	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	NA
Should this study be recommended for use in residential handler exposure assessments?	**No**	**NA**

Data Summary: A summary of the data from this study is not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Limitations: Any data limitations associated with the exposure data in this study are not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Table C-88: Exposure Study Identification Information	
Citation	PHED 468
EPA MRID	NA
ORETF Code	NA
EPA Review	none
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Nine individuals were monitored on two days (4 on the 1st day, 5 on the 2nd day) while applying a plant growth regulator to ornamentals in a 2000 ft^2 greenhouse. Each worker was suited with sampling media separately for the mixing/loading portion of the task and the application portion. Each application consisted of spraying 2 gallons of spray solution for approximately 30 minutes at a rate of 1 gallon per 200 ft^2. The solution was 100 ppm (active ingredient unknown) so each applicator handled approximately 0.0017 lbs of active ingredient. Dermal exposure was measured using gauze patches (both inside and outside normal work clothing) and cotton gloves worn over chemical-resistant gloves for hand exposure. Inhalation exposure was measured using standard pumps (set at 1.5 liters per minute), cassettes, and tubing. All inhalation samples were non-detects. The overall recovery from samples fortified in the laboratory and analyzed with each set of field samples averaged 102% for alpha-cellulose, 106% for gloves, and 101% for foam filters.

Table C-89: PHED 468 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**No**	**No**

Data Summary: A summary of the data from this study is not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Limitations: Any data limitations associated with the exposure data in this study are not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Table C-90: Exposure Study Identification Information	
Citation	Rosenheck, L. (2000) Determination of Exposure During the Mixing, Loading and Application of Liquid Diazinon to Residential Turf Through the Use of Passive Dosimetry and Biological Monitoring: Lab Project Number 767-98: I024480NAU950T. Unpublished study prepared by Development Resources/Chemical Support Department, Novartis Crop Protection, Inc. 574 p.
EPA MRID	45184305
ORETF Code	NA
EPA Review	D268247
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Ten non-professional volunteers were monitored while making applications of a liquid pesticide formulation (22.4% diazinon) with a manually-pressurized 2 gallon hand-pump sprayer. Each application consisted of filling and spraying the tank twice, handling a total of 8 teaspoons, or 0.021 lb active ingredient. Spot treatments were made to lawns, gardens, ornamentals, shrubs, and house foundations. Dermal exposure was measured using whole body dosimetry (100% cotton union suit) worn under shorts and a T-shirt, hand washes, and face/neck wipes. No chemical-resistant gloves were worn. Inhalation exposure was measured using standard pumps (set at 1.5 liters per minute), cassettes, and tubing. Field fortification recoveries for the cotton union suit dosimeters averaged 99%, face and neck wipe fortifications averaged 89.1%, handwash fortifications averaged 75% and air sampler tube fortification was 109%. Laboratory method validation for each matrix fell within the acceptable range of 70 to 120%. The limit of quantitation (LOQ) was 1.0 µg/sample for the cotton dosimeters, 0.5 µg/sample for the face/neck wipes, 1.0 µg/sample for the hand washes and 0.01 µg/sample for the inhalation monitors.

Table C-91: MRID 45184305 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Both dermal and inhalation exposure are included since both are recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-92: MRID 45184305 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
33	0.021	0.261	0.00167	12.43	0.0795
37	0.021	0.0368	0.00189	1.75	0.0901
38	0.021	0.507	0.00356	24.14	0.1697
39	0.021	0.137	0.00278	6.52	0.1325
40	0.021	1.12	0.00445	53.33	0.2121
41	0.021	0.156	0.00267	7.43	0.1272
42	0.021	0.278	0.00445	13.24	0.2121
43	0.021	0.473	0.01559	22.52	0.7422
31	0.021	2.176	0.00200	103.62	0.0954
32	0.021	0.0423	--	2.01	--

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of residential applications of liquid concentrate formulations using a manually-pressurized handwand, the following limitations are noted:

- Each individual handled the same amount of active ingredient, making analysis of the relationship between exposure and the amount of active ingredient handled (the underlying basis of unit exposures) difficult.

Scenario Summary

Table C-93: Scenario Description and Available Exposure Studies	
Formulation	Liquids (emulsifiable concentrates, soluble concentrates, etc.)
Equipment/Application Method	Handheld Fogger
Application Site(s)	outdoors (lawns, gardens, trees/bushes, perimeter, mounds/nests, aquatic areas)
Available Exposure Studies	Nigg, et al (1987); MRID 40350501
	Bergman, J. (2003); MRID 45869301

Table C-94: Unit Exposures (mg/lb ai) – Liquid Handheld Fogger Applications		
Statistic	Dermal	Inhalation
50th percentile	Studies measuring exposure while mixing/loading/applying liquid formulations using a handheld fogger are available, but not recommended for residential handler exposure assessment. Therefore, the exposure studies recommended for applying an aerosol should be used as a surrogate.	
75th percentile		
95th percentile		
99th percentile		
99.9th percentile		
AM (SD)		
GM (GSD)		
Range		
N		

Available Handler Exposure Studies

Table C-95: Exposure Study Identification Information	
Citation	Nigg, et al (1987) Pesticide Exposure to Florida Greenhouse Applicators, Nigg, H.N., Stamper, J.H. and Mahon, W.D., University of Florida, 1987
EPA MRID	40350501
ORETF Code	NA
EPA Review	None
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Four different workers were monitored while using a pulse-fogging device in a Florida greenhouse. Four active ingredients were used at rates ranging from 0.03 lbs/hr to 0.2 lbs/hr. Dermal exposure was measured using gauze patches (both inside and outside normal work clothing) and hand rinses were used for hand exposure (hand exposure was measured only when gloves were not worn). Inhalation exposure was measured using standard pumps (set at 3 liters per minute), cassettes, and tubing. Recoveries from field fortifications of exposure sampling matrices were poor, ranging from 13% to 94% depending on the chemical and matrix. Mean recoveries (%) from 10 µg fortifications of fluvalinate on gauze pads was 75% ± 6%, for handwashes was 62 ± 6%, and for air sampler plugs was 51 ± 4%. Mean recoveries from 10 µg fortifications of the compound chlorpyrifos on gauze pads was 82 ± 3%, for handwashes was 79 ± 4%, and for air sampler plugs was 73 ± 4%. Mean recoveries from 10 µg fortifications of the compound ethazol on gauze pads was 51 ± 7%, for handwashes was 45 ± 10%, and for air sampler plugs was 68 ± 8%. Mean recoveries (%) from 10 µg fortifications of the compound dicofol on gauze pads was 89 ± 5%, for handwashes was 76 ± 4%, and for air sampler plugs was 90 ± 9%. Mean recoveries (%) from 10 µg fortifications of the compound captan on gauze pads was 61 ± 8%, for handwashes was 13 ± 2%, and for air sampler plugs was 63 ± 14%. Mean recoveries (%) from 10 µg fortifications of the compound chlorothalonil on gauze pads was 94 ± 3%, for handwashes was 25 ± 14%, and for air sampler plugs was 67 ± 8%.

Table C-96: MRID 40350501 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**No**	**No**

Data Summary: A summary of the data from this study is not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Limitations: This study has been identified to have ethical concerns.

Table C-97: Exposure Study Identification Information	
Citation	Bergman, J. (2003) Applicator Exposure and Air Sampling Following Application of ETOC Fogging Concentrate 2764 by ULV Fogging: Lab Project Number: GLP-1648. Unpublished study prepared by McLaughlin Gormley King Company. 107 p. {OPPTS 875.1400 and 875.2500}
EPA MRID	45869301
ORETF Code	NA
EPA Review	D289337
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: One individual was monitored during 25 applications of a liquid concentrate (active ingredient prallethrin) to a 5500 ft^3 test chamber using a handheld ultra low-volume (ULV) fogger at the maximum application rate of 1 fl. oz. per 1000 ft^3 (equivalent to approximately 0.001 lb ai/1000 ft^3). Dermal exposure was not monitored in this study. Inhalation exposure was measured using standard pumps (set at 0.03 liter per minute), cassettes, and tubing. One set of recovery results were provided, however, the study author did not specify whether the recovery samples represented laboratory fortified samples or field fortified samples. The results for these fortification recoveries are discussed in the Field Recovery section of this study review. Three fortification samples were prepared at three concentrations (LOQ, 10 X LOQ, and 100 X LOQ) for each application. Sample preparation and storage were not discussed. Recoveries ranged from 76.8% to 147.3%. The average percent recovery for samples fortified at the LOQ, at 10X LOQ and at 100X LOQ were 119.6%, 113.1%, and 92.3%, respectively. The overall average percent recovery was 108.3 ± 14.3%.

Table C-98: MRID 45869301 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	No	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**No**	**No**

Data Summary: A summary of the data from this study is not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Limitations: This study has been identified to have ethical concerns.

Scenario Summary

Table C-99: Scenario Description and Available Exposure Studies	
Formulation	Liquids (emulsifiable concentrates, soluble concentrates, etc.)
Equipment/Application Method	Dipping
Application Site(s)	Pets/animals
Available Exposure Studies	McKeown, K. (2001); MRID 45528801

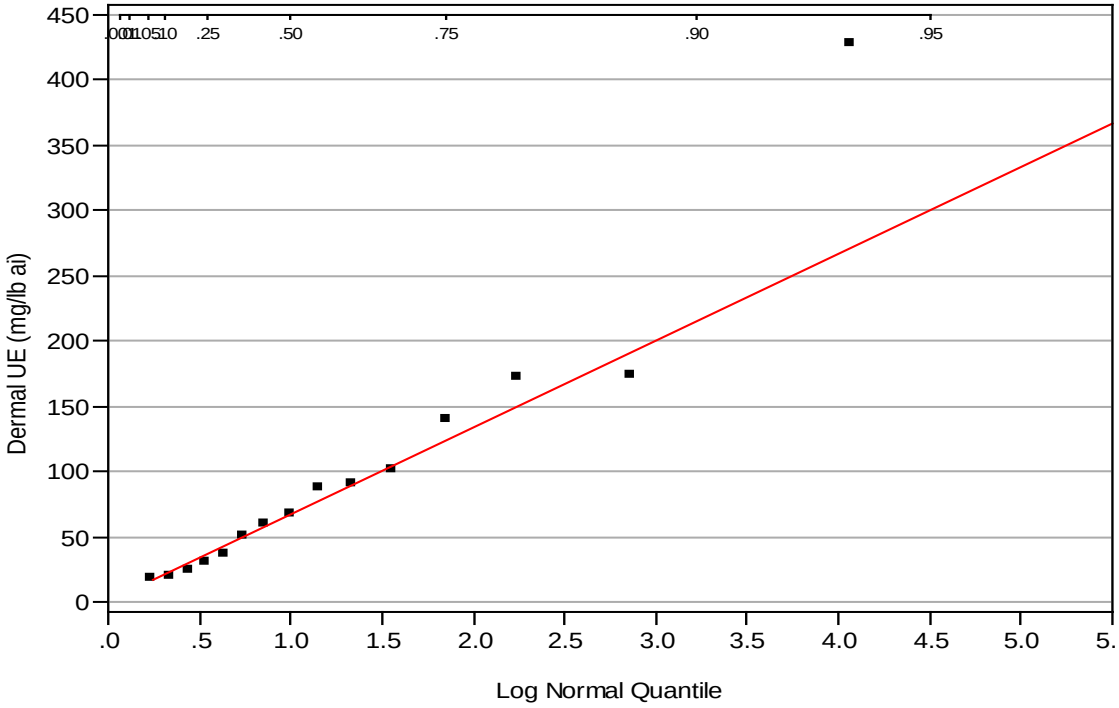
Table C-100: Unit Exposures (mg/lb ai) – Liquid Dipping Applications		
Statistic	Dermal	Inhalation
50th percentile	67	0.026
75th percentile	120	0.028
95th percentile	300	0.031
99th percentile	560	0.034
99.9th percentile	1100	0.037
AM (SD)	100 (120)	0.027 (0.0028)
GM (GSD)	67 (2.5)	0.026 (1.1)
Range	17 – 430	0.022 – 0.032
N	15	15

Dermal Unit Exposure Data Summary: The recommended dermal unit exposures for dipping pets or animals in liquid pesticide formulations is based on a lognormal distribution fit with exposure monitoring data from McKeown, K. (2001) [EPA MRID 45528801]. McKeown, K. (2001) monitored 15 applications of dipping dogs in a tub containing a liquid pesticide solution for approximately 4 to 5 minutes. This was the only available study for this exposure scenario.

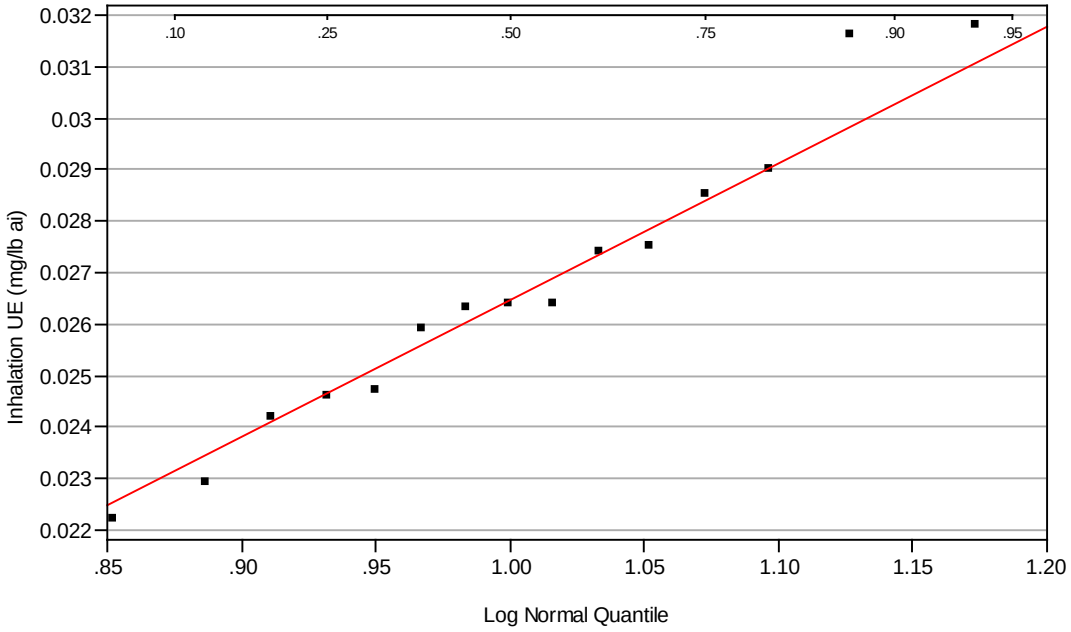
Inhalation Unit Exposure Data Summary: The recommended inhalation unit exposures for dipping pets or animals in liquid pesticide formulations is based on a lognormal distribution fit with exposure monitoring data from McKeown, K. (2001) [EPA MRID 45528801]. McKeown, K. (2001) monitored 15 applications of dipping dogs in a tub containing a liquid pesticide solution for approximately 4 to 5 minutes. This was the only available study for this exposure scenario.

Lognormal Probability Plots

Legend: ■ = McKeown, K. (2001)



Legend: ■ = McKeown, K. (2001)



Available Handler Exposure Studies

Table C-101: Exposure Study Identification Information	
Citation	McKeown, K. (2001) Determination of Dermal and Inhalation Exposures to Tetrachlorvinphos (TCVP) During the Application of a Dipping Solution to a Dog: Lab Project Number: TX 76384: 1557: ML01-0925-HMT. Unpublished study prepared by The Hartz Mountain Corporation, Morse Laboratories, Inc. and Sharp Veterinary Research. 258 p.
EPA MRID	45528801
ORETF Code	NA
EPA Review	D279176
	Contractor (Versar, Inc.) review 1/7/02
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Five individuals were monitored while dipping 3 dogs (for a total of 15 application events) in a solution with the active ingredient TCVP. Each application event, lasting only 4 to 5 minutes, consisted of mixing the solution (8 oz of product per 4 gallons water; 3.29% TCVP) in a tub, dipping the dog in the solution and pouring the solution over those parts not submerged, then removing the dog from the tub. Dermal exposure was measured using a whole body dosimeter (underneath a short-sleeve shirt and shorts) and hand washes. Inhalation exposure was measured using standard pumps (set at 15 liters per minute), cassettes, and tubing. Hand wipes had field recoveries above 90% at all fortification levels. Cotton union suits had recoveries of 48% to 73% depending upon the fortification levels. The air sampling media had a recovery of 81% at 10X LOQ which was the lowest level tested. Laboratory recoveries were above 90% for all the types of dosimeters, at all levels tested, including the LOQ. For dermal dosimeters, handwipes, and air tubes, the limit of detection (LOD) was 0.5 µg, the limit of quantitation (LOQ) was 1.0 µg.

Table C-102: MRID 45528801 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	No	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Both dermal and inhalation exposure are included since both are recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-103: MRID 45528801 – Data Summary

Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
A	0.015	1.36	0.00041	90.7	0.0274
A	0.015	2.09	0.00048	139.3	0.0318
A	0.015	0.89	0.00043	59.3	0.0285
B	0.015	2.59	0.00034	172.7	0.0229
B	0.015	1.31	0.00037	87.3	0.0246
B	0.015	1.01	0.00033	67.3	0.0222
C	0.015	0.44	0.00043	29.3	0.0290
C	0.015	0.29	0.00041	19.3	0.0275
C	0.015	1.51	0.00039	100.7	0.0263
D	0.015	0.37	0.00039	24.7	0.0264
D	0.015	0.25	0.00038	16.7	0.0259
D	0.015	0.74	0.00037	49.3	0.0247
E	0.015	2.55	0.00039	170.0	0.0264
E	0.015	6.35	0.00036	423.3	0.0242
E	0.015	0.53	0.00047	35.3	0.0316

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm). All samples were non-detects. Reported as ½ LOD (0.01 ug/m^3).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of dipping pets or animals in a dilute liquid pesticide solution, the following limitations are noted:

- All inhalation samples were non-detects. One-half the limit of detection (0.5 μg) was used.
- Each individual handled the same amount of active ingredient making analysis of the relationship between exposure and the amount of active ingredient handled (the underlying basis of unit exposures) difficult.
- The use of 15 liters per minute is much higher than the standard setting of 1- 2 liters per minute and could complicate air sampling.

Scenario Summary

Table C-104: Scenario Description and Available Exposure Studies	
Formulation	Liquids (emulsifiable concentrates, soluble concentrates, etc.)
Equipment/Application Method	Sponge
Application Site(s)	Pets/animals
Available Exposure Studies	McKeown, K. (2001); MRID 45528801

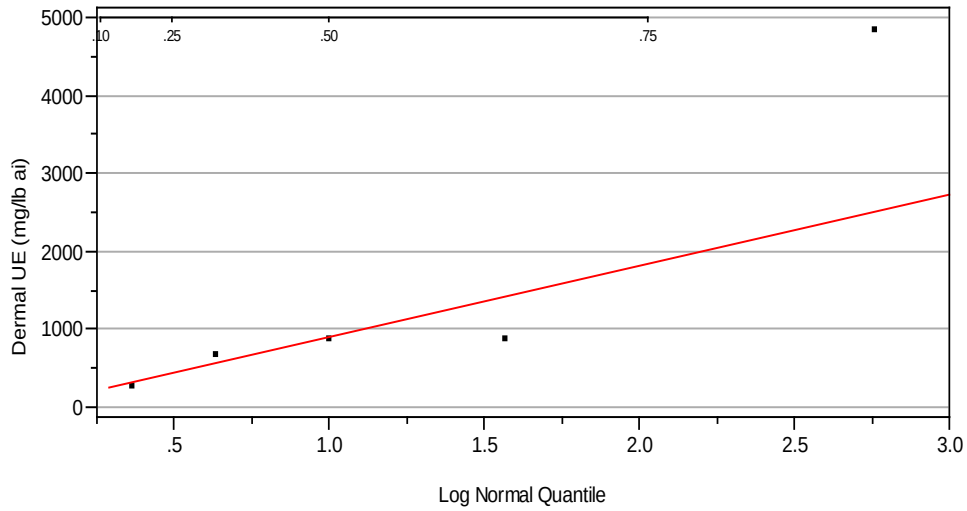
Table C-105: Unit Exposures (mg/lb ai) – Liquid Sponge Applications		
Statistic	Dermal	Inhalation
50th percentile	917	0.20
75th percentile	1860	0.24
95th percentile	5150	0.31
99th percentile	10500	0.37
99.9th percentile	23400	0.45
AM (SD)	1600 (2250)	0.21 (0.055)
GM (GSD)	917 (2.9)	0.20 (1.3)
Range	267 – 4842	0.143 – 0.268
N	5	5

Dermal Unit Exposure Data Summary: The recommended dermal unit exposures for applications of liquid pesticide formulations using a sponge is based on a lognormal distribution fit with exposure monitoring data from McKeown, K. (2001) [EPA MRID 45528801]. McKeown, K. (2001) monitored 5 applications of a liquid pesticide solution for approximately 4 to 5 minutes using a sponge. This was the only available study for this exposure scenario.

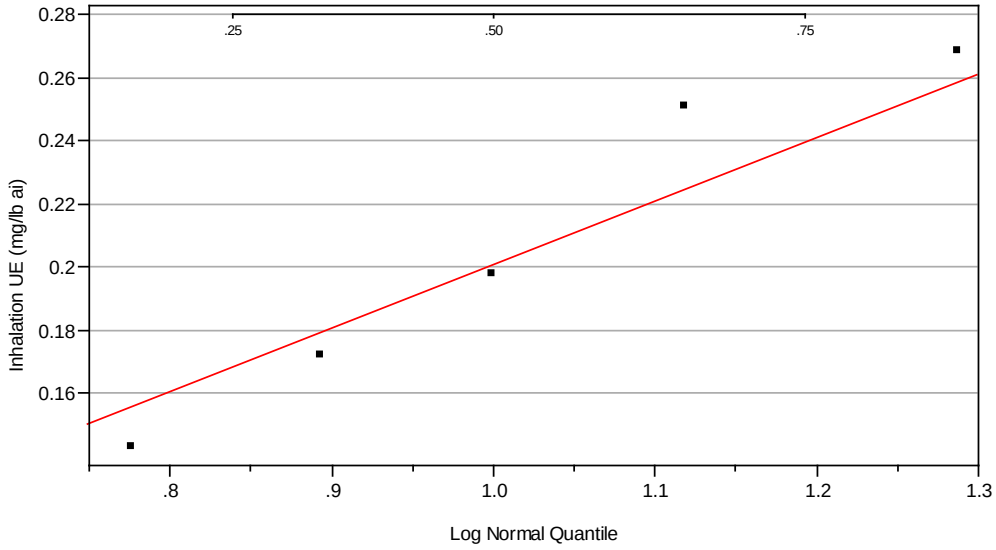
Inhalation Unit Exposure Data Summary: The recommended dermal unit exposures for applications of liquid pesticide formulations using a sponge is based on a lognormal distribution fit with exposure monitoring data from McKeown, K. (2001) [EPA MRID 45528801]. McKeown, K. (2001) monitored 5 applications of a liquid pesticide solution for approximately 4 to 5 minutes using a sponge. This was the only available study for this exposure scenario.

Lognormal Probability Plots

Legend: ■ = McKeown, K. (2001)



Legend: ■ = McKeown, K. (2001)



Available Handler Exposure Studies

Table C-106: Exposure Study Identification Information	
Citation	McKeown, K. (2001) Determination of Dermal and Inhalation Exposures to Tetrachlorvinphos (TCVP) During the Application of a Dipping Solution to a Dog: Lab Project Number: TX 76384: 1557: ML01-0925-HMT. Unpublished study prepared by The Hartz Mountain Corporation, Morse Laboratories, Inc. and Sharp Veterinary Research. 258 p.
EPA MRID	45528801
ORETF Code	NA
EPA Review	D279176
	Contractor (Versar, Inc.) review 1/7/02
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Five individuals were monitored while applying a liquid solution (active ingredient TCVP) using a sponge to 5 dogs (for a total of 5 application events). Each application event, lasting only 4 to 5 minutes, consisted of mixing the solution (2 oz of product in a 1 gallon container; 3.29% TCVP), placing the dog in a tub, applying the solution to the dog with a sponge, then removing the dog from the tub. Dermal exposure was measured using a whole body dosimeter (underneath a short-sleeve shirt and shorts) and hand washes. Inhalation exposure was measured using standard pumps (set at 15 liters per minute), cassettes, and tubing. Hand wipes had field recoveries above 90% at all fortification levels. Cotton union suits had recoveries of 48% to 73% depending upon the fortification levels. The air sampling media had a recovery of 81% at 10X LOQ which was the lowest level tested. Laboratory recoveries were above 90% for all the types of dosimeters, at all levels tested, including the LOQ. For dermal dosimeters, handwipes, and air tubes, the limit of detection (LOD) was 0.5 µg, the limit of quantitation (LOQ) was 1.0 µg.

Table C-107: MRID 45528801 – Checklist and Use Recommendation for		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	No	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Both dermal and inhalation exposure are included since both are recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-108: MRID 45528801 – Data Summary

Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
A	0.0024	0.63	0.00050	267	0.209735
B	0.0019	1.26	0.00058	664	0.305605
C	0.0016	7.69	0.00052	4842	0.326541
D	0.0024	2.08	0.00042	870	0.17405
E	0.0019	1.61	0.00045	868	0.240907

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of applying dilute liquid pesticide solutions to pets or animals with a sponge, the following limitations are noted:

- All inhalation samples were non-detects. One-half the limit of detection (0.5 μg) was used.
- Each individual handled approximately the same amount of active ingredient making analysis of the relationship between exposure and the amount of active ingredient handled (the underlying basis of unit exposures) difficult.
- The use of 15 liters per minute is much higher than the standard setting of 1- 2 liters per minute and could complicate air sampling.

Scenario Summary

Table C-109: Scenario Description and Available Exposure Studies	
Formulation	Liquids (emulsifiable concentrates, soluble concentrates, etc.)
Equipment/Application Method	Hose-end sprayer
Application Site(s)	outdoors (lawns, gardens, trees/bushes, perimeter, mounds/nests, aquatic areas)
Available Exposure Studies	Solomon, K. R., Harris, S. A, Stephenson, G. R. (1993).
	Klonne, D. (1999); MRID 44972201
	Merricks, D.L. (1998); MRID 44518501
	Merricks, D.L. (1997); MRID 44459801
	Rosenheck, L. (2000); MRID 45184305

Table C-110: Unit Exposures (mg/lb ai) – Liquid Hose-end Sprayer Applications

Statistic	Lawns / Mounds / Nests / Aquatic areas		Gardens / Trees / Perimeter	
	Dermal	Inhalation	Dermal	Inhalation
50th percentile	8.61	0.015	37	0.0012
75th percentile	16.2	0.027	69	0.0017
95th percentile	40.5	0.064	180	0.0029
99th percentile	76.9	0.12	340	0.0043
99.9th percentile	158	0.23	710	0.0065
AM (SD)	13.4 (16)	0.022 (0.024)	58 (71)	0.0014 (0.00082)
GM (GSD)	8.61 (2.56)	0.015 (2.4)	37 (2.6)	0.0012 (1.7)
Range	0.874 – 49	0.003 – 0.082	5.0 – 280	0.0004 – 0.0062
N	42	41	40	60

Dermal Unit Exposure Data Summary

Gardens, Trees, and Perimeter Treatments: The recommended dermal unit exposures for applications of liquid pesticide formulations using a dial-type hose-end sprayer to gardens, trees, and perimeters of houses is based on a lognormal distribution fit with exposure monitoring data from Merricks, D.L. (1998) [EPA MRID 44518501] and Merricks, D.L. (1997) [EPA MRID 44459801]. Merricks, D.L. (1998) monitored 20 applications of a liquid formulation for approximately 20 minutes to citrus trees and shrubs using a dial-type hose-end sprayer. Merricks, D.L. (1997) monitored 40 applications of a liquid formulation for approximately 20 minutes to tomato and cucumber gardens using a dial-type hose-end sprayer.

Lawns, Insect Mounds and Nests, and Aquatic Areas: The recommended dermal unit exposures for applications of liquid pesticide formulations using a dial-type hose-end sprayer to lawns, insect mounds and nests, and aquatic areas is based on a lognormal distribution fit with exposure monitoring data from Klonne, D. (1999) [EPA MRID 44972201] and Rosenheck, L. (2000) [EPA MRID 45184305]. Klonne, D. (1999) monitored 30 applications of a liquid pesticide formulation for approximately 75 minutes to approximately 5000 ft^2 of residential lawns using a dial-type hose-end sprayer. Rosenheck, L. (2000) monitored 12 applications of a liquid pesticide formulation ranging from 18 to 78 minutes to approximately 5000 ft^2 of residential lawns using a conventional

hose-end sprayer. These studies best represents residential use for this scenario and the exposure monitoring enabled representation of the type of clothing a homeowner or amateur applicator would wear (i.e., shorts, short-sleeve shirt, no chemical-resistant gloves).

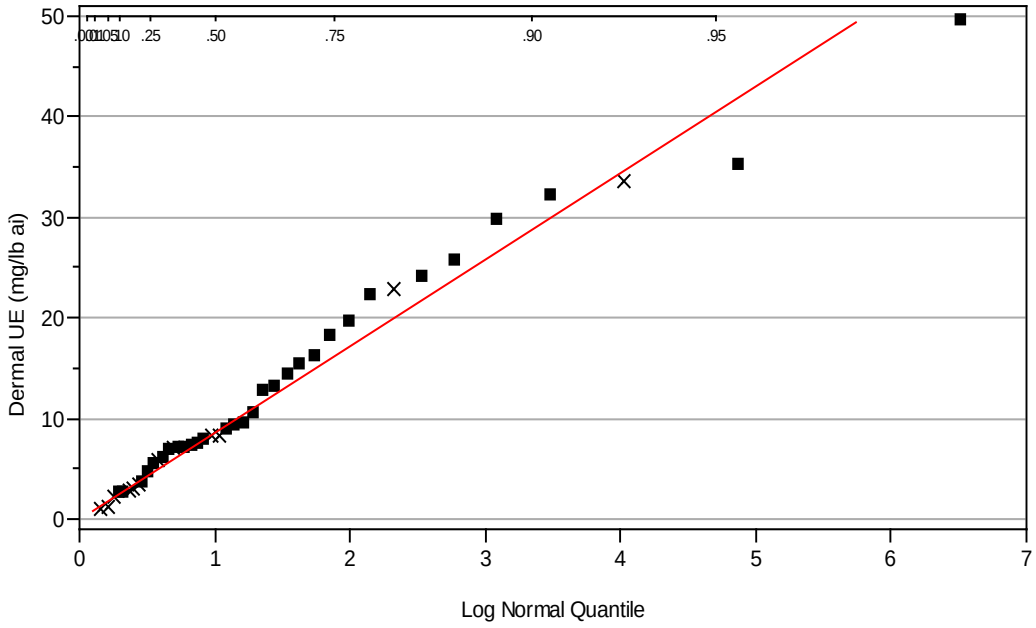
Inhalation Unit Exposure Data Summary

Gardens, Trees, and Perimeter Treatments: The recommended inhalation unit exposures for applications of liquid pesticide formulations using a dial-type hose-end sprayer to gardens, trees, and perimeters of houses is based on a lognormal distribution fit with exposure monitoring data from Merricks, D.L. (1998) [EPA MRID 44518501] and Merricks, D.L. (1997) [EPA MRID 44459801]. Merricks, D.L. (1998) monitored 20 applications of a liquid formulation for approximately 20 minutes to citrus trees and shrubs using a dial-type hose-end sprayer. Merricks, D.L. (1997) monitored 40 applications of a liquid formulation for approximately 20 minutes to tomato and cucumber gardens using a dial-type hose-end sprayer. Of the available studies these were most representative of residential uses for this scenario.

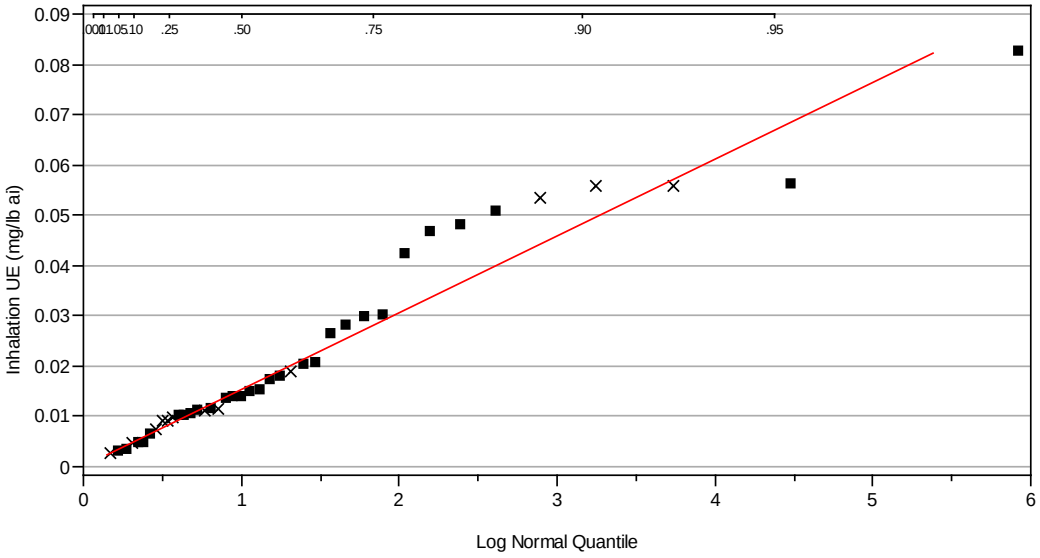
Lawns, Insect Mounds and Nests, and Aquatic Areas: The recommended inhalation unit exposures for applications of liquid pesticide formulations using a dial-type hose-end sprayer to lawns, insect mounds and nests, and aquatic areas is based on a lognormal distribution fit with exposure monitoring data from Klonne, D. (1999) [EPA MRID 44972201] and Rosenheck, L. (2000) [EPA MRID 45184305]. Klonne, D. (1999) monitored 30 applications of a liquid pesticide formulation for approximately 75 minutes to approximately 5000 ft^2 of residential lawns using a dial-type hose-end sprayer. Rosenheck, L. (2000) monitored 12 applications of a liquid pesticide formulation ranging from 18 to 78 minutes to approximately 5000 ft^2 of residential lawns using a conventional hose-end sprayer. Of the available studies these were the most representative of residential uses for this scenario.

Lognormal Probability Plots

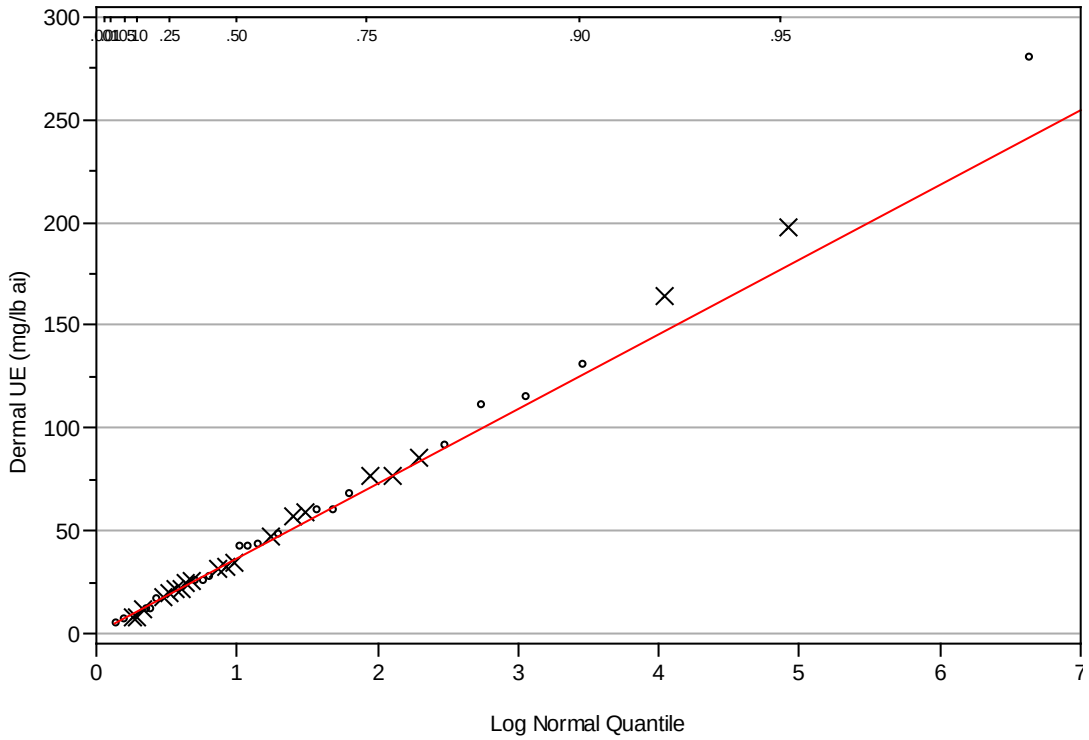
Turf/Mounds/Nests/Aquatic Legend: ■ = Klonne, D. (1999); X = Rosenheck, L. (2000)



Turf/Mounds/Nests/Aquatic Legend: ■ = Klonne, D. (1999); X = Rosenheck, L. (2000)



Gardens & Trees/Perimeter Legend: X = Merricks, D.L. (1997); O = Merricks, D.L. (1998)



Gardens & Trees/Perimeter Legend: X = Merricks, D.L. (1997); O = Merricks, D.L. (1998)

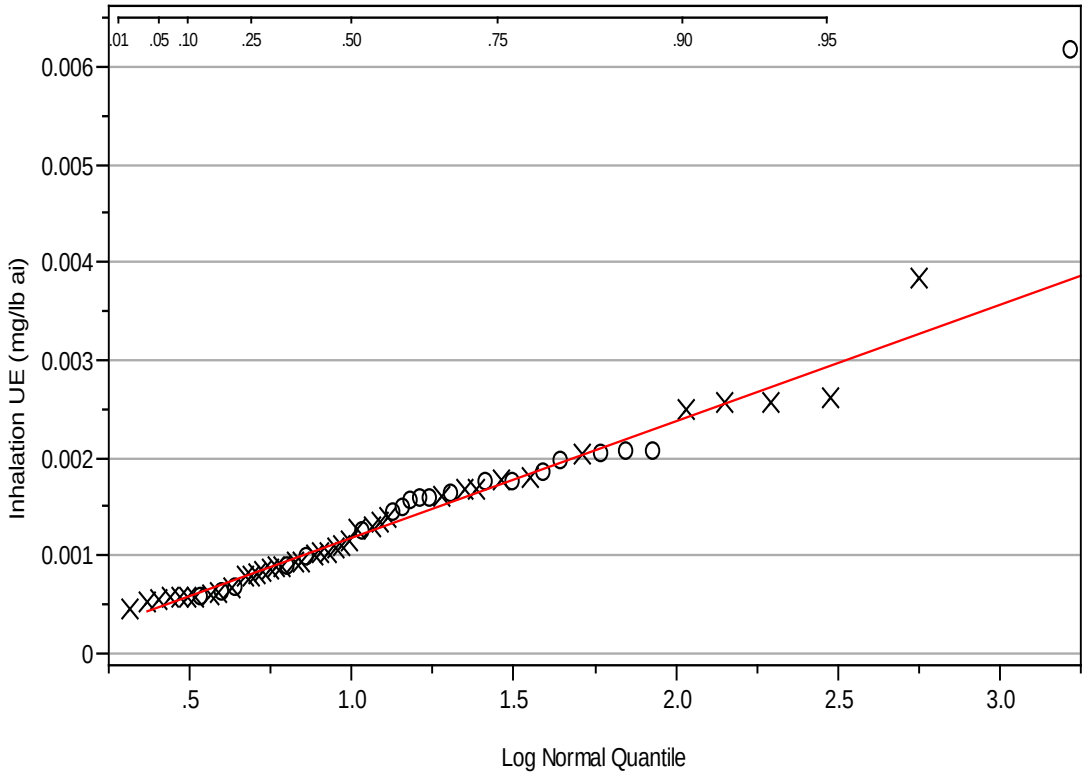


Table C-111: Available Exposure Study Identification Information	
Citation	Solomon, K. R., Harris, S. A, Stephenson, G. R. (1993). Applicator And Bystander Exposure To Home Garden And Landscape Pesticides. American Chemical Society, 1993, pp. 262-273
EPA MRID	none
ORETF Code	NA
EPA Review	none
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: A total 20 application events were monitored while loading and applying a liquid concentrate formulation (active ingredient 2, 4-D) using a hose-end sprayer. Eleven of the applications were conducted while wearing "protective" clothing, while 9 applications were conducted while wearing "normal" clothing. The exact nature of the clothing worn was not provided. Each individual handled approximately 0.08 – 3 lbs of 2, 4-D per application. Exposure was measured using biomonitoring with passive monitoring only conducted for inhalation exposure using standard pumps (set at 1 liter per minute), cassettes, and tubing. Recoveries from field fortifications of exposure sampling matrices were generally above 85%.

Table C-112: Solomon, et al. (1993) – Checklist and Use Recommendation for		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**No**	**No**

Data Summary: A summary of the data from this study is not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Limitations: Any data limitations associated with the exposure data in this study are not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Table C-113: Exposure Study Identification Information	
Citation	Klonne, D. (1999). Integrated Report on Evaluation of Potential Exposure to Homeowners and Professional Lawn Care Operators Mixing, Loading, and Applying Granular and Liquid Pesticides to Residential Lawns. Sponsor/Submitter: Outdoor Residential Exposure Task Force
EPA MRID	44972201
ORETF Code	OMA004
EPA Review	Memo from G. Bangs to D. Fuller (3/5/03)
	D261948

	D287251
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: A total of 30 application events were collected from 30 individuals using passive dosimetry (inner and outer whole body dosimeters, hand washes, face/neck wipes, and personal inhalation monitors). Each test subject poured a 32 fl. oz. plastic container into a dial-type sprayer (DTS), which was then screwed onto the end of the hose. Each application consisted of treating approximately 5000 ft^2 of residential lawns and handling approximately 0.5 lb active ingredient (diazinon) over the course of 75 minutes. Dermal exposure was measured using inner and outer whole body dosimeters, hand washes, and face/neck washes, such that exposure can be constructed for various clothing scenarios (including a short-sleeve shirt, shorts, and no chemical-resistant gloves). Inhalation exposure was measured using standard personal air monitoring devices set at 1.5 liters per minute. All fortified samples and field samples collected on the same study day were stored frozen and analyzed together, eliminating the need for storage stability determination. Lab spike recoveries for all matrices were in the range of 87-103%. Mean field fortification recoveries ranged from 79 to 104%.

Table C-114: MRID 44972201 – Checklist and Use Recommendation

Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Both dermal and inhalation exposure are included since both are recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-115: MRID 44972201 – Data Summary

Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
3	0.5	1.29	0.007	2.58	0.014
4	0.5	9.01	--	18.03	--
7	0.5	12.80	0.025	25.60	0.050
8	0.5	7.60	0.015	15.21	0.030
10	0.5	5.20	0.005	10.40	0.010
14	0.5	3.52	0.008	7.04	0.016
15	0.5	2.97	0.021	5.94	0.042
16	0.5	6.56	0.015	13.12	0.030
18	0.5	3.60	0.014	7.19	0.028

Table C-115: MRID 44972201 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
20	0.5	4.65	0.007	9.30	0.014
24	0.5	2.25	0.010	4.49	0.020
25	0.5	24.72	0.041	49.44	0.082
27	0.5	4.70	0.028	9.40	0.056
28	0.5	8.04	0.023	16.07	0.046
30	0.5	14.78	0.005	29.57	0.010
34	0.5	4.39	0.005	8.77	0.010
35	0.5	17.55	0.002	35.10	0.004
36	0.5	11.98	0.002	23.96	0.004
39	0.5	3.40	0.007	6.81	0.014
40	0.5	7.14	0.006	14.28	0.012
43	0.5	1.74	0.002	3.48	0.004
44	0.5	3.72	0.003	7.44	0.006
47	0.5	6.32	0.007	12.65	0.014
49	0.5	11.05	0.024	22.09	0.048
50	0.5	3.94	0.013	7.88	0.026
54	0.5	9.73	0.009	19.45	0.018
55	0.5	2.65	0.002	5.29	0.004
56	0.5	1.31	0.005	2.62	0.010
59	0.5	16.03	0.010	32.06	0.020
60	0.5	3.49	0.009	6.99	0.018

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of residential applications of liquid concentrate formulations using a hose-end sprayer, the following limitations are noted:

- Each individual handled the same amount of active ingredient, making analysis of the relationship between exposure and the amount of active ingredient handled (the underlying basis of unit exposures) difficult.

Table C-116: Exposure Study Identification Information	
Citation	Merricks, D.L. (1998). Carbaryl Mixer/Loader/Applicator Exposure Study During Application of RP-2 Liquid (21%) to Fruit Trees and Ornamental Plants
EPA MRID	44518501
ORETF Code	OMA005
EPA Review	Memo from G. Bangs to D. Fuller (3/5/03)
	D287251
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Twenty individuals were monitored while loading and applying a liquid formulation (21% carbaryl) to citrus trees and shrubs using a hose-end sprayer. Each application consisted of pouring the formulation into a dial-type sprayer (DTS), screwing it onto the garden

hose and spraying the trees and shrubs. The activity lasted less than 20 minutes and the amount of carbaryl handled ranged from 0.02 to 0.09 lbs. Dermal exposure was measured using inner and outer whole body dosimetry and hand washes (individuals were monitored without gloves). Inhalation exposure was measured using standard pumps (set at 2 liters per minute), cassettes, and tubing. Field fortification recoveries for passive dosimeters averaged 88.3% for inner and 76.2% for outer dosimeters. Face and neck wipe fortifications averaged 82.5%. Handwash fortifications averaged 93.6% and air sampler tube fortification was 91.8%. Laboratory method validation for each matrix fell within the acceptable range of 70 to 120%. The limit of quantitation (LOQ) was 1.0 µg/sample for all media except the inhalation monitors where the LOQ was 0.01 µg/sample. The limit of detection (LOD) was 0.5 µg/sample for all media except the inhalation monitors where the LOQ was 0.005 µg/sample.

Table C-117: MRID 44518501 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Both dermal and inhalation exposure are included since both are recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-118: MRID 44518501 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
A	0.026	0.19	0.000042	7.3	0.0016
B	0.020	2.25	0.000042	112.5	0.0021
C	0.066	8.71	0.000042	132.0	0.0006
D	0.052	14.65	0.000084	281.7	0.0016
E	0.027	1.64	0.000167	60.7	0.0062
F	0.025	0.31	0.000042	12.4	0.0017
G	0.020	1.38	0.000042	69.0	0.0021
H	0.022	0.99	0.000042	45.0	0.0019
I	0.021	0.90	0.000042	42.9	0.0020
J	0.020	0.99	0.000042	49.5	0.0021
K	0.035	0.42	0.000044	12.0	0.0013
L	0.046	0.23	0.000042	5.0	0.0009
M	0.042	2.51	0.000042	59.8	0.0010
N	0.090	3.80	0.000134	42.2	0.0015
O	0.029	0.75	0.000042	25.9	0.0015
P	0.027	3.08	0.000042	114.1	0.0016

Table C-118: MRID 44518501 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
Q	0.062	1.60	0.000042	25.8	0.0007
R	0.024	2.20	0.000042	91.7	0.0018
S	0.073	1.22	0.000043	16.7	0.0006
T	0.024	0.66	0.000042	27.5	0.0018

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of residential applications of liquid concentrate formulations using a hose-end sprayer, the following limitations are noted:

- Seventeen of 20 inhalation exposure measurements were non-detects. Use of ½ the limit of detection (0.01 µg) was necessary, thus introducing uncertainty.

Table C-119: Exposure Study Identification Information	
Citation	Merricks, D.L. (1997). Carbaryl Mixer/Loader/Applicator Exposure Study during Application of RP-2 Liquid (21%), Sevin® Ready to Use Insect Spray or Sevin® 10 Dust to Home Garden Vegetables
EPA MRID	44459801
ORETF Code	OMA006
EPA Review	Memo from G. Bangs to D. Fuller (3/5/03)
	D287251
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Forty individuals were monitored while mixing, loading, and applying a liquid formulation (21% carbaryl) to tomato and cucumber gardens using a hose-end sprayer. Each application consisted of pouring the formulation into a dial-type sprayer (DTS), screwing it onto the garden hose and spraying the garden. The activity lasted less than 20 minutes and the amount of carbaryl handled ranged from 0.02 to 0.11 lbs. Dermal exposure was measured using inner and outer whole body dosimetry and hand washes (20 individuals were monitored without gloves). Inhalation exposure was measured using standard pumps (set at 2 liters per minute), cassettes, and tubing. Field fortification recoveries for passive dosimeters averaged 84.3% for inner dosimeters and 77.7% for outer dosimeters. Face and neck wipe field fortifications averaged 84.8%. Both handwash and inhalation tube field fortification averaged >90%. Laboratory method validation for each matrix fell within the acceptable range of 70 to 120%. The limit of quantitation (LOQ) was 1.0 µg/sample for all media except the inhalation monitors where the LOQ was 0.01 µg/sample. The limit of detection (LOD) was 0.5 µg/sample for all media except the inhalation monitors where the LOQ was 0.005 µg/sample.

Table C-120: MRID 44459801 – Checklist and Use Recommendation for		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type,	Yes	

Table C-120: MRID 44459801 – Checklist and Use Recommendation for		
Study Criteria	Exposure Component	
	Dermal	Inhalation
and amount of active ingredient handled?		
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Both dermal and inhalation exposure are included since both are recommended for use in residential handler exposure assessment. Note that only dermal exposure data representative of individuals wearing short-sleeve shirt, shorts, shoes, socks, and no chemical-resistant gloves are presented. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-121: MRID 44459801 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
P2	0.11	3.43	0.000142	31.2	0.0013
Q2	0.08	3.59	0.000042	44.9	0.0005
T2	0.05	0.96	0.000042	19.2	0.0009
U2	0.03	1.92	0.000042	64.0	0.0017
V2	0.05	2.90	0.000043	58.0	0.0009
W2	0.08	6.30	0.000146	78.8	0.0018
Z2	0.05	1.18	0.000084	23.6	0.0018
A3	0.05	1.63	0.000134	32.6	0.0026
B3	0.04	0.79	0.000041	19.8	0.0010
C3	0.05	0.92	0.000042	18.4	0.0008
F3	0.07	2.34	0.000042	33.4	0.0006
G3	0.05	4.30	0.000125	86.0	0.0025
H3	0.03	0.73	0.000043	24.3	0.0014
I3	0.07	4.21	0.000042	60.1	0.0006
M3	0.03	0.20	0.000042	6.7	0.0016
L3	0.04	7.16	0.000094	179.0	0.0026
N3	0.05	8.33	0.000042	166.6	0.0008
O3	0.1	1.06	0.000042	10.6	0.0004
R3	0.05	1.09	0.000134	21.8	0.0025
S3	0.02	0.18	0.000042	9.0	0.0017
A	0.05	--	0.000042	--	0.0008
B	0.04	--	0.000042	--	0.0011
G	0.04	--	0.000042	--	0.0011
C	0.05	--	0.000042	--	0.0008
J	0.04	--	0.000042	--	0.0011
D	0.07	--	0.000042	--	0.0006
M	0.02	--	0.000042	--	0.0020
N	0.08	--	0.000042	--	0.0005

Table C-121: MRID 44459801 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
Q	0.03	--	0.000042	--	0.0013
R	0.04	--	0.000042	--	0.0010
U	0.04	--	0.000043	--	0.0010
V	0.07	--	0.000042	--	0.0006
Y	0.05	--	0.000042	--	0.0009
Z	0.04	--	0.000042	--	0.0009
C2	0.05	--	0.000042	--	0.0009
D2	0.07	--	0.000041	--	0.0006
G2	0.01	--	0.000042	--	0.0038
H2	0.07	--	0.000042	--	0.0006
K2	0.03	--	0.000042	--	0.0013
L2	0.06	--	0.000042	--	0.0006

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of residential applications of liquid concentrate formulations using a hose-end sprayer, the following limitations are noted:

- Thirty-six of 40 inhalation exposure measurements were non-detects. Use of ½ the limit of detection (0.01 µg) was necessary, thus introducing uncertainty.

Table C-122: Exposure Study Identification Information	
Citation	Rosenheck, L. (2000) Determination of Exposure During the Mixing, Loading and Application of Liquid Diazinon to Residential Turf Through the Use of Passive Dosimetry and Biological Monitoring: Lab Project Number 767-98: I024480NAU950T. Unpublished study prepared by Development Resources/Chemical Support Department, Novartis Crop Protection, Inc. 574 p.
EPA MRID	45184305
ORETF Code	NA
EPA Review	D268247

MRID = Master Record Identification
ORETF = Outdoor Residential Exposure Task Force

Study Description: Twelve non-professional volunteers were monitored while making applications of a liquid pesticide formulation (22.4% diazinon) with a conventional hose-end sprayer to approximately 5000 ft^2 of lawn. The applications ranged from 18 to 78 minutes with all individuals 0.5 lbs of active ingredient (diazinon). Dermal exposure was measured using whole body dosimetry (100% cotton union suit) worn under shorts and a T-shirt, hand washes, and face/neck wipes. No chemical-resistant gloves were worn. Inhalation exposure was measured using standard pumps (set at 1.5 liters per minute), cassettes, and tubing. Field fortification recoveries for the cotton union suit dosimeters averaged 99%, face and neck wipe fortifications averaged 89.1%, handwash fortifications averaged 75% and air sampler tube fortification was 109%. Laboratory method validation for each matrix fell within the acceptable range of 70 to 120%. The limit of quantitation (LOQ) was 1.0 µg/sample for the cotton

dosimeters, 0.5 µg/sample for the face/neck wipes, 1.0 µg/sample for the hand washes and 0.01 µg/sample for the inhalation monitors.

Table C-123: MRID 45184305 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Both dermal and inhalation exposure are included since both are recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-124: MRID 45184305 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
18	0.5	1.07	0.0278	2.14	0.0557
17	0.5	16.72	0.0056	33.44	0.0111
16	0.5	4.12	0.0012	8.23	0.0024
19	0.5	4.06	0.0094	8.11	0.0187
27	0.5	1.63	0.0057	3.26	0.0114
24	0.5	1.35	0.0036	2.70	0.0071
25	0.5	2.84	0.0267	5.68	0.0534
26	0.5	11.36	0.0046	22.71	0.0091
20	0.5	3.48	0.0049	6.96	0.0098
21	0.5	0.58	0.0022	1.17	0.0045
29	0.5	0.44	0.0045	0.87	0.0089
30	0.5	1.42	--	2.84	--

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of residential applications of liquid concentrate formulations using a conventional hose-end sprayer, the following limitations are noted:

- Each individual handled the same amount of active ingredient, making analysis of the relationship between exposure and the amount of active ingredient handled (the underlying basis of unit exposures) difficult.

Scenario Summary

Table C-125: Scenario Description and Available Exposure Studies	
Formulation	Liquids (emulsifiable concentrates, soluble concentrates, etc.)
Equipment/Application Method	Backpack sprayer
Application Site(s)	outdoors (lawns, gardens, trees/bushes, perimeter, mounds/nests, aquatic areas)
Available Exposure Studies	PHED 471
	PHED 1024
	Beard, K.K. (1997); MRID 44339801
	PHED 9010
	PHED 9011
	PHED 9004
	PHED 9003
	Schneider et al (1999)
	King, C.; Prince, P. (1995); MRID 43623202
	Spencer et al (2000); MRID 46852112
	Stewart, P., et al. (1999)
	PHED 9012

Table C-126: Unit Exposures (mg/lb ai) – Liquid Backpack Sprayer Applications		
Statistic	Dermal	Inhalation
50^{th} percentile	25	0.09
75^{th} percentile	85	0.17
95^{th} percentile	490	0.43
99^{th} percentile	1700	0.83
99.9^{th} percentile	6600	1.7
AM (SD)	130 (630)	0.140 (0.14)
GM (GSD)	25 (6.04)	0.09 (2.63)
Range	0.72 – 540	0.0142 – 0.29
N	26	16

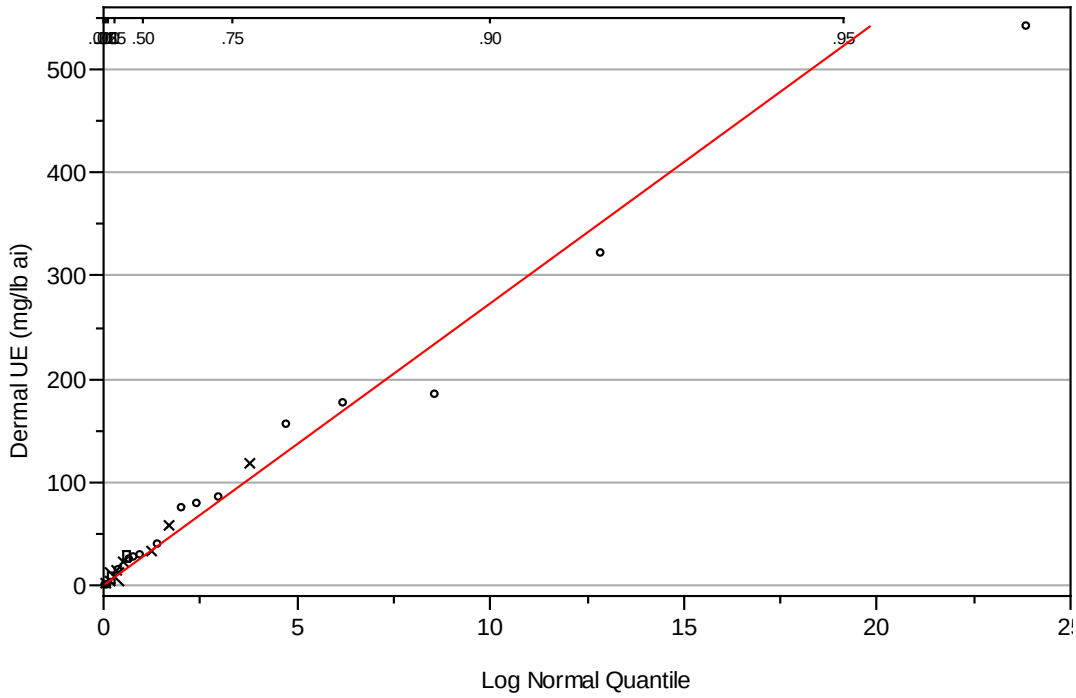
Dermal Unit Exposure Summary: The recommended dermal unit exposures for applications of liquid pesticide formulations using a backpack sprayer is based on a lognormal distribution fit with exposure monitoring data from PHED 471, PHED 1024, and Beard, K.K. (1997) [EPA MRID 44339801]. PHED 471 monitored 9 applications of 3, 2-gallon liquid pesticide solutions for approximately 47 minutes to poultry litter using a backpack sprayer. PHED 1024 monitored 2 applications of a liquid pesticide formulation to greenhouse plants hanging overhead, on the floor, or on benches for approximately 1.5 hours using a backpack sprayer. Beard, K.K. (1997) monitored 15 applications of a liquid pesticide formulation to approximately 6000 ft^2 of Christmas tree farms in Michigan, Pennsylvania, and Connecticut for approximately 4 hours using a backpack sprayer. While no studies available were considered representative of homeowner applications using a backpack sprayer, the exposure monitoring in these studies enabled representation of the type of clothing a homeowner or amateur applicator would wear (i.e., shorts, short-sleeve shirt, no chemical-resistant gloves). Additionally, a composite dataset was used as the exposures in the studies were generally of the same magnitude.

Inhalation Unit Exposure Summary: The recommended inhalation unit exposures for applications of liquid pesticide formulations using a backpack sprayer is based on a lognormal

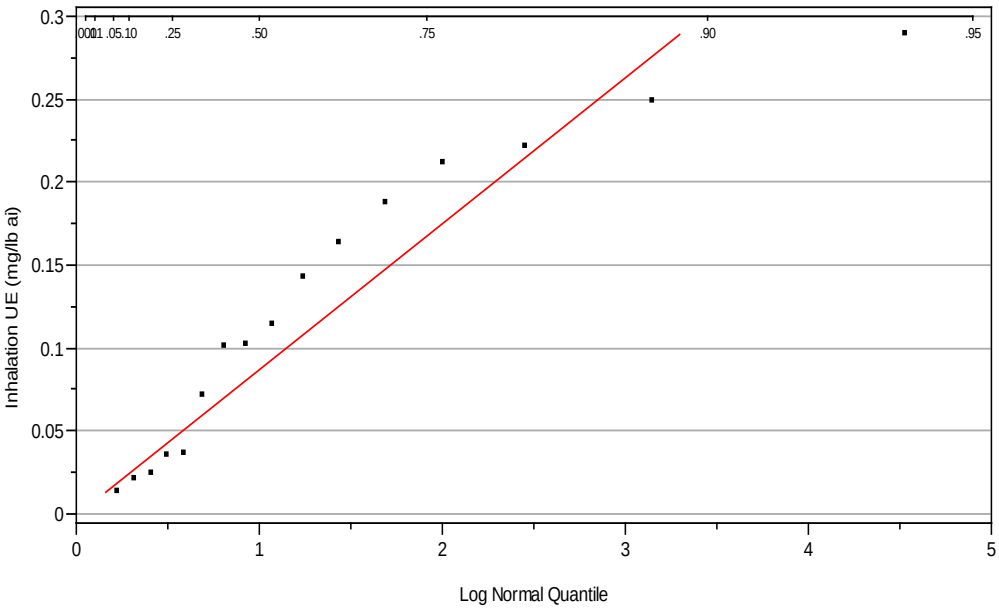
distribution fit with exposure monitoring data from King, C.; Prince, P. (1995) [EPA MRID 43623202; AH605]. King, C.; Prince, P. (1995) monitored 16 applications of a liquid pesticide formulation for approximately 63-94 minutes to greenhouse ornamentals in Florida, Maryland, and California. No studies adequately represented homeowner applications using a backpack sprayer. This study was therefore selected as it resulted in the highest inhalation exposure estimates of the available studies.

Lognormal Probability Plots

Legend: O = Beard, K.K. (1997); X = PHED 471; ■ = PHED 1024



Legend: ■ = King, C., Prince, P., (1995)



Available Handler Exposure Studies

Table C-127: Exposure Study Identification Information	
Citation	PHED 471
EPA MRID	NA
ORETF Code	NA
EPA Review	none
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Nine individuals were monitored while applying a liquid formulation to poultry litter using a backpack sprayer. Each applicator mixed and applied 3, 2-gallon solutions (equal to approximately 0.052 lbs active ingredient); a task that lasted on average 47 minutes. Dermal exposure was measured using gauze patches (both inside and outside normal work clothing) and cotton gloves (underneath chemical-resistant gloves) for hand exposure. Inhalation exposure was measured using standard pumps (set at 2 liters per minute), cassettes, and tubing. An average of 84.9 ± 5.2% (n=18) was recovered from field fortified patches, 79.3 ± 7.3% from gloves and 84.0 ± 16.8% from foam air filters. The overall average recovery from laboratory fortified control samples was 87 ± 12.0% for alpha-cellulose gauze patches, 75 ± 11.6% for cotton gloves, and 89 ± 10.5% for foam air filters.

Table C-128: PHED 471 – Checklist and Use Recommendation for		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**No**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Note that only dermal exposure data are presented as inhalation exposure data from this study is not recommended for the purposes of residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-129: PHED 471 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
CC	0.048	0.362	--	7.54	--
DD	0.048	0.035	--	0.73	--
EE	0.048	0.109	--	2.27	--
FF	0.048	2.69	--	56.04	--
GG	0.048	5.65	--	117.71	--

Table C-129: PHED 471 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
HH	0.048	1.58	--	32.92	--
II	0.048	0.68	--	14.17	--
JJ	0.048	1.08	--	22.50	--
KK	0.048	0.18	--	3.75	--

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm). All samples were non-detects.
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of residential applications of liquid concentrate formulations using a backpack sprayer, the following limitations are noted:

- All monitored individuals wore chemical-resistant gloves, thus a back-calculation using a 90% protection factor to "bare hands" exposure was necessary.
- The study was conducted using workers in a poultry house, so use for residential handler exposure assessments introduces uncertainty.

Table C-130: Exposure Study Identification Information	
Citation	PHED 1024
EPA MRID	NA
ORETF Code	NA
EPA Review	none

MRID = Master Record Identification
ORETF = Outdoor Residential Exposure Task Force

Study Description: Two individuals were monitored while applying a liquid formulation to greenhouse plants hanging overhead or on the floor or on benches using a backpack sprayer. Each applicator sprayed over 100 gallons of solution, corresponding to 0.13 lbs of active ingredient handled. Each application event generally lasted 1.5 hours. Dermal exposure was measured using gauze patches (both inside and outside normal work clothing) and hand rinses (underneath chemical-resistant gloves) for hand exposure. Inhalation exposure was measured using standard pumps (set at 1.5 liters per minute), cassettes, and tubing. Recoveries from field fortifications of exposure sampling matrices were generally above 90%.

Table C-131: PHED 1024 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory	Yes	Yes

Table C-131: PHED 1024 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
recovery samples adequate)?		
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**No**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Note that only dermal exposure data are presented as inhalation exposure data from this study is not recommended for the purposes of residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-132: PHED 1024 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
L	0.13	0.56	--	4.30	--
N	0.13	3.39	--	26.10	--

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of residential applications of liquid concentrate formulations using a backpack sprayer, the following limitations are noted:

- All monitored individuals wore chemical-resistant gloves, thus a back-calculation using a 90% protection factor to "bare hands" exposure was necessary.
- The study was conducted using workers in a greenhouse, so use for residential handler exposure assessments introduces uncertainty.

Table C-133: Exposure Study Identification Information	
Citation	Beard, K.K. (1997)Evaluation of Applicator Exposures to SURFLAN® A.S. During Mixing, Loading, and Application with Backpack Sprayers
EPA MRID	44339801
ORETF Code	NA
EPA Review	D284121
	D242325
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Fifteen individuals (14 loader/applicators, 1 mixer/loader/applicator) were monitored while applying a liquid formulation of oryzalin to Christmas tree farms in Michigan, Pennsylvania, and Connecticut using a backpack sprayer. Each application was at least 4 hours and each worker treated an area of at least 6000 ft^2 handling from 5 to 70 lbs of oryzalin. Dermal exposure was measured using whole body dosimetry (both outside and underneath normal work clothing) and hand exposure was measured using wipes. Inhalation exposure was measured using standard pumps (set at 1 liter per minute), cassettes, and tubing. The average

recoveries for spikes prepared with the filter/tube combinations, denim, long underwear, socks and hand wipes were 106 ± 5.1%, 113 ± 4.7%, 102 ± 7.2%, 93.3 ± 56%, and 84 ± 8.3%, respectively. The average recovery for spikes prepared with coverall portions was 85 ± 15%, for spikes prepared with long underwear portions was 104 ± 22%, for spikes prepared with pairs of socks was 87 ± 17%.

Table C-134: MRID 44339801 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**No**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Note that only dermal exposure data are presented as inhalation exposure data from this study is not recommended for the purposes of residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-135: MRID 44339801 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
1	8.3	226	--	27.21	--
2	8.3	222	--	26.80	--
3	68.6	63	--	0.92	--
4	8.3	245	--	29.57	--
5	8.3	12	--	1.41	--
7	16	2957	--	184.82	--
8	16	8673	--	542.06	--
9	16	1285	--	80.32	--
10	16	2841	--	177.54	--
11	16	5171	--	323.16	--
13	4.9	770	--	157.11	--
14	4.9	419	--	85.57	--
15	4.9	376	--	76.71	--
16	4.9	203	--	41.44	--
17	23.3	359	--	15.40	--

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of residential applications of liquid concentrate formulations using a backpack sprayer, the following limitations are noted:

- All monitored individuals wore chemical-resistant gloves, thus a back-calculation using a 90% protection factor to "bare hands" exposure was necessary.
- The study was conducted using workers at a Christmas tree farm, so use for residential handler exposure assessments introduces uncertainty.

Table C-136: Exposure Study Identification Information	
Citation	PHED 9010
EPA MRID	NA
ORETF Code	NA
EPA Review	none
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Eight workers were monitored on 5 separate days (for a total of 40 monitored application events) while applying a pesticideto grass cover in a Malaysian plantation. Each application was approximately 3 – 4 hours and each applicator handled approximately 1 lb of active ingredient. Dermal exposure was measured using whole body dosimetry (outside normal work clothing only) and hand exposure was measured using wipes. Inhalation exposure was measured using standard pumps (set at 2 liters per minute), cassettes, and tubing. Field recovery from all sampling materials ranged from 79% to 92%.

Table C-137: PHED 9010 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**No**	**No**

Data Summary: A summary of the data from this study is not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Limitations: Any data limitations associated with the exposure data in this study are not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Table C-138: Exposure Study Identification Information

Citation	PHED 9011
EPA MRID	NA
ORETF Code	NA
EPA Review	none
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Five workers were monitored during 4 applications of a pesticide to grass cover in a Malaysian plantation using backpack sprayers. The application time and amount of active ingredient handled were unclear based on the study report. Dermal exposure was measured using gauze patches (most placed outside normal work clothing only). Hand exposure was not measured. Inhalation exposure was measured for only 9 of the 20 application events using standard pumps (set at 2 liters per minute), cassettes, and tubing. Only laboratory recoveries were reported which averaged 59%.

Table C-139: PHED 9011 – Checklist and Use Recommendation

Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	No	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	No	No
Should this study be recommended for use in residential handler exposure assessments?	**No**	**No**

Data Summary: A summary of the data from this study is not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Limitations: Any data limitations associated with the exposure data in this study are not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Table C-140: Exposure Study Identification Information

Citation	PHED 9004
EPA MRID	NA
ORETF Code	NA
EPA Review	none
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Six workers were monitored for a total of 12 application events during applications of a pesticide to grassland in England using a backpack sprayer. Each application consisted of spraying 3, 16 liter tanks over the course of 1 day. The amount of active ingredient handled ranged from 0.5 to 5 lbs per application. The application time was not reported in the

study report. Dermal exposure was measured for 9 of the 12 applications using whole body dosimetry (outside normal work clothing only) and cotton gloves. Inhalation exposure was measured for 3 of the 12 applications using standard pumps (set at 3 liters per minute), cassettes, and tubing. Laboratory recoveries were generally above 85%, although field recoveries were not reported.

Table C-141: PHED 9004 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	No	No
Should this study be recommended for use in residential handler exposure assessments?	**No**	**No**

Data Summary: A summary of the data from this study is not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Limitations: Any data limitations associated with the exposure data in this study are not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Table C-142: Exposure Study Identification Information	
Citation	PHED 9003
EPA MRID	NA
ORETF Code	NA
EPA Review	none
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Ten workers were monitored during 2 applications of a pesticide to weeds in a Sri Lankan tea plantation using a backpack sprayer. Each application consisted of spraying 4 tank loads over the course of approximately 1 hour. Each worker handled approximately 0.05 lbs of active ingredient per application. Dermal exposure was measured using whole body dosimetry (outside normal work clothing only) and cotton gloves. Inhalation exposure was not measured. Field recovery summary from the light procedural recoveries are for sock 90% and for glove 110%, and for dark procedural recoveries are for sock 94% and for glove 85%.

Table C-143: PHED 9003 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	

Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	No	No
Should this study be recommended for use in residential handler exposure assessments?	**No**	**No**

Data Summary: A summary of the data from this study is not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Limitations: Any data limitations associated with the exposure data in this study are not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Table C-144: Exposure Study Identification Information	
Citation	Schneider et al (1999). Exposure of Hand Applicators to Glyphosate in Forest Settings, 1995
EPA MRID	none
ORETF Code	NA
EPA Review	none
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Ten individuals were monitored during 2 days of glyphosate applications in forests using backpack sprayers. Each day of applications was approximately 6 to 8 hours (with each worker applying at least 20 tank loads) and each individual handled between 2 and 3 lbs of glyphosate per day. Dermal exposure was measured using a long-sleeve t-shirt and knee-length socks (underneath normal work clothing only) and hand wipes. All workers wore chemical-resistant gloves. Inhalation exposure was measured using standard pumps (set at 2 liters per minute), cassettes, and tubing. Field recoveries were generally above 75%.

Table C-145: Schneider, et al (1999) – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**No**	**No**

Data Summary: A summary of the data from this study is not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Limitations: Any data limitations associated with the exposure data in this study are not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Table C-146: Exposure Study Identification Information	
Citation	King, C.; Prince, P. (1995) Chlorothalonil Worker Exposure During Application of Daconil 2787 Flowable Fungicide in Greenhouses: Lab Project Number: 5968-94-0104-CR-001: 94-0104: SDS-2787. Unpublished study prepared by Ricerca, Inc.
	AHETF study: AH605
EPA MRID	43623202
ORETF Code	NA
EPA Review	D393093
	Contractor review (Versar, Inc.) 8/4/11
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Sixteen backpack applications in greenhouses – 6 workers in Florida, and 5 each in Maryland and California – were monitored. Each application was approximately 63 to 94 minutes and consisted of each individual mixing, loading, and applying 3 tank loads (approximately 0.1 lbs chlorothalonil) to ornamental plants. Dermal exposure was measured using inner whole body dosimetry (underneath normal work clothing) and hand rinses. All workers wore chemical-resistant gloves. Inhalation exposure was measured using standard pumps (set at 2 liters per minute), cassettes, and tubing. Inhalation samples in Maryland were adjusted for the average background level (0.051 μg) following previous use of the product. Field fortified travel spikes had mean recoveries greater than or equal to 77% for each site and matrix. Weathered samples had recoveries greater than or equal to 75% at higher fortification levels. Recoveries ranged between 30 to 70% for alpha-cellulose patches, dosimeter patches, and air monitoring samples. Analytical laboratory generated recovery samples were analyzed concurrently with the worker exposure samples as a check on losses due to the extraction procedure. These samples had a mean recovery of 100% with a standard deviation of 9.7%.

Table C-147: Checklist and Use Recommendation for MRID 43623202		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**No**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Note that only inhalation exposure data are presented as the dermal exposure data are not recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-148: MRID 43623202 – Data Summary

Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
1	0.086	--	0.0098	--	0.1145
2	0.098	--	0.0099	--	0.1009
3	0.065	--	0.0144	--	0.2218
4	0.081	--	0.0235	--	0.2896
5	0.092	--	0.0195	--	0.2121
1A	0.085	--	0.0139	--	0.1638
6	0.106	--	0.0015	--	0.0142
7A	0.063	--	0.0014	--	0.0218
8	0.064	--	0.0030	--	0.0361
9	0.094	--	0.0033	--	0.0353
10	0.065	--	0.0016	--	0.0247
11	0.071	--	0.0133	--	0.1878
12	0.057	--	0.0142	--	0.2487
13	0.053	--	0.0076	--	0.1425
14	0.099	--	0.0101	--	0.1019
15	0.076	--	0.0055	--	0.0720

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of residential applications of liquid concentrate formulations using a backpack sprayer, the following limitations are noted:

- The study was conducted using workers in a greenhouse, so use for residential handler exposure assessments introduces uncertainty.

Table C-149: Exposure Study Identification Information

Citation	Spencer et al (2000). HS-1769. Exposure of Hand Applicators to Triclopyr in Forest Settings, 1995
EPA MRID	46852112
ORETF Code	NA
EPA Review	Contractor (Versar, Inc.) review 9/30/03

MRID = Master Record Identification
ORETF = Outdoor Residential Exposure Task Force

Study Description: Ten individuals were monitored during 2 applications of triclopyr in forests using backpack sprayers. Each application consisted of loading and applying 3 tank loads over

the course of approximately 6 hours with each individual handling approximately 3 lbs of triclopyr per application. Dermal exposure was measured using a long-sleeve t-shirt and knee-length socks (underneath normal work clothing only) and hand wipes. All workers wore chemical-resistant gloves. Inhalation exposure was measured using standard pumps (set at 2 liters per minute), cassettes, and tubing. The average field fortification recoveries from air filters was 58.98% with a standard deviation of 20.95%, from wipes was 95.90% with a standard deviation of 8.67%, from socks was 85.62% with a standard deviation of 7.98%, and from T-shirt was 98.23% with a standard deviation of 5.06%.

Table C-150: MRID 46852112 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	No
Should this study be recommended for use in residential handler exposure assessments?	**No**	**No**

Data Summary: A summary of the data from this study is not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Limitations: Any data limitations associated with the exposure data in this study are not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Table C-151: Exposure Study Identification Information	
Citation	Stewart, P., T. Fears, H.F. Nicholson, B.C. Kross, L. K. Ogilvie, S.H. Zahm, M.H. Ward and A. Blair (1999) Exposure Received From Application Of Animal Insecticides. American Industrial Hygiene Association Journal. 60:208-212
EPA MRID	none
ORETF Code	NA
EPA Review	none
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Two farmers were monitored while applying insecticides to animals using a backpack sprayer. Each application ranged from approximately 1 to 200 liters of solution and varied among 6 active ingredients. Clothing worn varied between farmers. Dermal exposure was measured using a fluorescent dye video-imaging technique. Inhalation exposure was not measured.

Table C-152: Stewart, et al (1999) – Checklist and Use Recommendation	
Study Criteria	Exposure Component

	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	No
Should this study be recommended for use in residential handler exposure assessments?	**No**	**No**

Data Summary: A summary of the data from this study is not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Limitations: Any data limitations associated with the exposure data in this study are not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Table C-153: Exposure Study Identification Information	
Citation	PHED 9012
EPA MRID	NA
ORETF Code	NA
EPA Review	none
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Four workers were monitored during 5 applications of a pesticide to grass cover in a Malaysian plantation using backpack sprayers. The application time and amount of active ingredient handled were unclear based on the study report. Dermal exposure was measured using gauze patches (most placed outside normal work clothing only). Hand exposure was not measured. Inhalation exposure was measured using standard pumps (set at 2 liters per minute), cassettes, and tubing. Only laboratory recoveries were reported (59%). [Note: This data comes from the same study as PHED 9011 – monitoring conducted at different times.]

Table C-154: PHED 9012 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	No	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	No	No
Should this study be recommended for use in residential handler exposure	**No**	**No**

assessments?		

Data Summary: A summary of the data from this study is not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Limitations: Any data limitations associated with the exposure data in this study are not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Scenario Summary

Table C-155: Scenario Description and Available Exposure Studies	
Formulation	Ready-to-use (RTU)
Equipment/Application Method	Hose-end sprayer
Application Site(s)	outdoors (lawns, gardens, trees/bushes, perimeter, mounds/nests, aquatic areas)
Available Exposure Studies	Klonne, D. (1999); MRID 44972201
	Rosenheck, L. (2000); MRID45184305

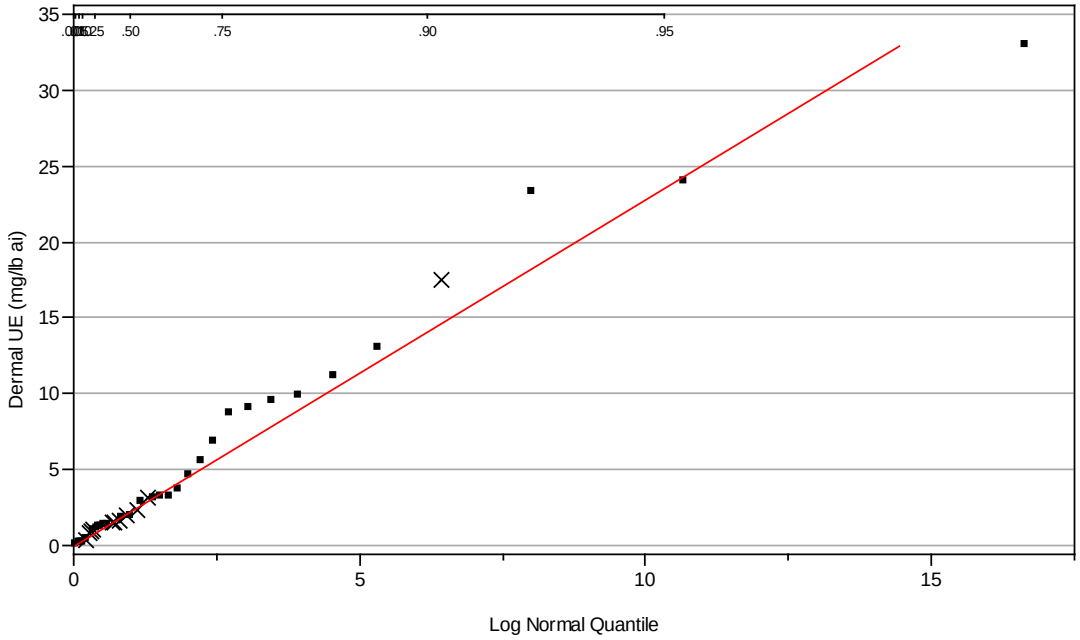
Table C-156: Unit Exposures (mg/lb ai) – RTU Hose-end Sprayer Applications		
Statistic	Dermal	Inhalation
50th percentile	2.28	0.015
75th percentile	5.96	0.036
95th percentile	23.6	0.121
99th percentile	62.2	0.285
99.9th percentile	184	0.745
AM (SD)	6.26 (16)	0.034 (0.066)
GM (GSD)	2.28 (4.14)	0.015 (3.52)
Range	0.078 – 33.0	0.00067 – 0.156
N	41	41

Dermal Unit Exposure Summary: The recommended dermal unit exposures for applications using a RTU hose-end sprayer is based on a lognormal distribution fit with exposure monitoring data from Klonne, D. (1999) [EPA MRID 44972201] and Rosenheck, L. (2000) [EPA MRID 45184305]. Klonne, D. (1999) monitored 30 applications of pesticide formulations to approximately 5000 ft^2 of residential lawns for approximately 75 minutes using a RTU hose-end sprayer. Rosenheck, L. (2000) monitored 11 applications of ready-to-use liquid formulations to approximately 5000 ft^2 of lawns for 32 to 119 minutes. These studies were representative of homeowner or amateur applications for this scenario and the exposure monitoring enabled representation of the type of clothing a homeowner or amateur applicator would wear (i.e., shorts, short-sleeve shirt, no chemical-resistant gloves). Additionally, a composite dataset was used as the exposures in the studies were generally of the same magnitude.

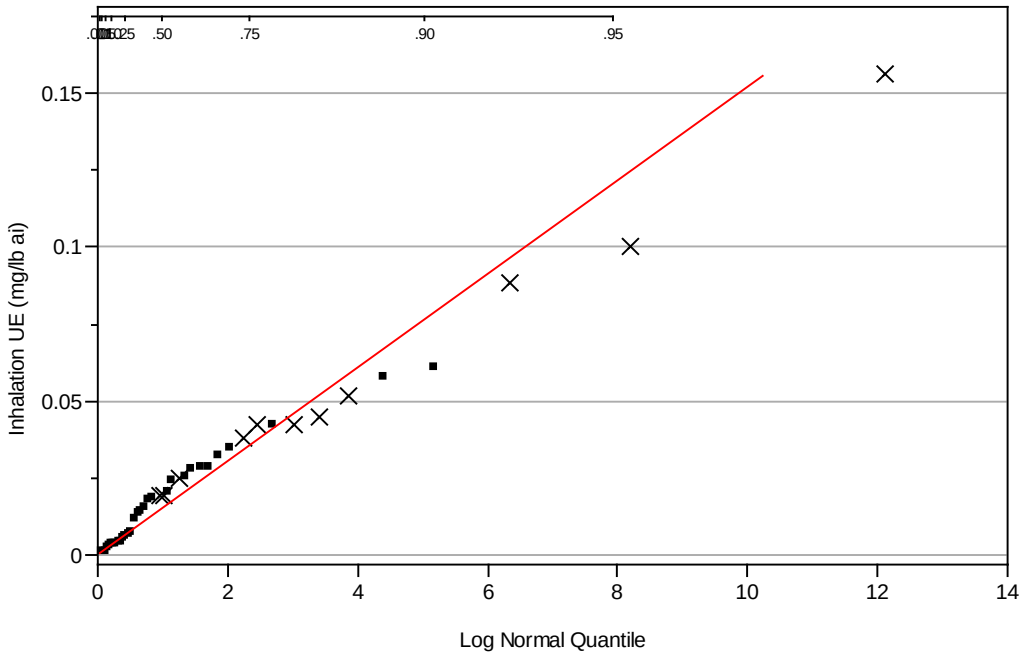
Inhalation Unit Exposure Summary: The recommended inhalation unit exposures for applications using a RTU hose-end sprayer is based on a lognormal distribution fit with exposure monitoring data from Klonne, D. (1999) [EPA MRID 44972201] and Rosenheck, L. (2000) [EPA MRID 45184305]. Klonne, D. (1999) monitored 30 applications of pesticide formulations to approximately 5000 ft^2 of residential lawns for approximately 75 minutes using a RTU hose-end sprayer. Rosenheck, L. (2000) monitored 11 applications of ready-to-use liquid formulations to approximately 5000 ft^2 of lawns for 32 to 119 minutes. These studies were representative of homeowner or amateur applications for this scenario and a composite dataset was formed despite Rosenheck, L. (2000) resulting in higher estimates of inhalation exposure.

Lognormal Probability Plots

Legend: ■ = Klonne, D. (1999); X = Rosenheck, L. (2000)



Legend: ■ = Klonne, D. (1999); X = Rosenheck, L. (2000)



Available Handler Exposure Studies

Table C-157: Exposure Study Identification Information	
Citation	Klonne, D. (1999). Integrated Report on Evaluation of Potential Exposure to Homeowners and Professional Lawn Care Operators Mixing, Loading, and Applying Granular and Liquid Pesticides to Residential Lawns. Sponsor/Submitter: Outdoor Residential Exposure Task Force.
EPA MRID	44972201
ORETF Code	OMA004
EPA Review	D261948
	EPA Memo from G. Bangs to D. Fuller (3/5/03)
	D287251
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: A total of 30 application events were monitored for 30 different volunteers using passive dosimetry (inner and outer whole body dosimeters, hand washes, face/neck wipes, and personal inhalation monitors). Each test subject screwed a ready-to-use (RTU) 32 fl. oz. plastic container onto the end of the hose and treated approximately 5000 ft^2 of residential lawns. Each applicator handled approximately 0.5 lb active ingredient (diazinon) over the course of 75 minutes. Dermal exposure was measured using inner and outer whole body dosimeters, hand washes, and face/neck washes, such that exposure can be constructed for various clothing scenarios (including a short-sleeve shirt, shorts, and no chemical-resistant gloves). Inhalation exposure was measured using standard personal air monitoring devices set at 1.5 liters per minute. All fortified samples and field samples collected on the same study day were stored frozen and analyzed together, eliminating the need for storage stability determination. Concurrent lab spikes produced mean recoveries in the range of 78-125% for the various matrices. Mean field fortification recoveries ranged from 76% to 110% for all matrices. Mean percent field fortification recovery for outer dosimeter with a spike level of 50 µg was 80.6% with a standard deviation of 7.95%, of 500 µg was 79.4% with a standard deviation of 19.3%, and of 5000 µg was 75.5% with a standard deviation of 5.81%. Mean percent field fortification recovery for inner dosimeter with a spike level of 5 µg was 99.3% with a standard deviation of 10.7%, and of 50 µg was 89.5% with a standard deviation of 8.33%. Mean percent field fortification recovery for hand wash with a spike level of 5 µg was 83.7% with a standard deviation of 9.13%, of 25 µg was 83.9% with a standard deviation of 10.0%, and of 100 µg was 85.6% with a standard deviation of 11.1%. Mean percent field fortification recovery for neck/face wash with a spike level of 5 µg was 102% with a standard deviation of 2.81, of 10 µg was 101% with a standard deviation of 13.9%, and of 25 µg was 93.0% with a standard deviation of 2.93%.

Table C-158: MRID 44972201 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	

Table C-158: MRID 44972201 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Both dermal and inhalation exposure are included since both are recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-159: MRID 44972201 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
1	0.5	0.11	0.0090	0.21	0.0180
2	0.5	3.42	0.0120	6.84	0.0240
5	0.5	16.50	0.0303	33.00	0.0606
6	0.5	0.93	0.0059	1.86	0.0117
9	0.5	1.56	0.0142	3.12	0.0285
11	0.5	1.60	0.0173	3.20	0.0346
12	0.5	0.62	0.0126	1.23	0.0252
13	0.5	0.69	0.0141	1.37	0.0282
17	0.5	0.65	0.0016	1.30	0.0033
19	0.5	0.50	0.0091	1.00	0.0183
21	0.5	4.75	0.0159	9.49	0.0318
22	0.5	0.58	0.0030	1.17	0.0061
23	0.5	1.62	0.0101	3.23	0.0201
26	0.5	4.90	0.0209	9.80	0.0418
29	0.5	2.74	0.0288	5.49	0.0575
31	0.5	6.52	0.0026	13.05	0.0053
32	0.5	0.97	0.0010	1.94	0.0019
33	0.5	4.52	0.0019	9.04	0.0038
37	0.5	1.86	0.0077	3.72	0.0155
38	0.5	5.59	0.0037	11.17	0.0074
41	0.5	0.04	0.0003	0.08	0.0007
42	0.5	11.63	0.0006	23.26	0.0011
45	0.5	2.28	0.0016	4.56	0.0032
46	0.5	0.11	0.0071	0.22	0.0142
48	0.5	1.43	0.0138	2.86	0.0276
51	0.5	0.61	0.0017	1.22	0.0034
52	0.5	4.35	0.0033	8.71	0.0067
53	0.5	0.21	0.0013	0.41	0.0026
57	0.5	11.97	0.0066	23.94	0.0132
58	0.5	0.09	0.0021	0.17	0.0043

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of residential applications of ready-to-use formulations using a hose-end sprayer, the following limitations are noted:

- Each individual handled the same amount of active ingredient, making analysis of the relationship between exposure and the amount of active ingredient handled (the underlying basis of unit exposures) difficult.

Table C-160: Exposure Study Identification Information	
Citation	Rosenheck, L. (2000) Determination of Exposure During the Mixing, Loading and Application of Liquid Diazinon to Residential Turf Through the Use of Passive Dosimetry and Biological Monitoring: Lab Project Number 767-98: I024480NAU950T. Unpublished study prepared by Development Resources/Chemical Support Department, Novartis Crop Protection, Inc. 574 p.
EPA MRID	45184305
ORETF Code	NA
EPA Review	D268247
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Eleven non-professional volunteers were monitored while making applications of a liquid pesticide formulation (22.4% diazinon) with a ready-to-use hose-end sprayer to approximately 5000 ft^2 of lawn. The applications ranged from 32 to 119 minutes with all individuals 0.5 lbs of active ingredient (diazinon). Dermal exposure was measured using whole body dosimetry (100% cotton union suit) worn under shorts and a T-shirt, hand washes, and face/neck wipes. No chemical-resistant gloves were worn. Inhalation exposure was measured using standard pumps (set at 1.5 liters per minute), cassettes, and tubing. Field fortification recoveries for the cotton union suit dosimeters averaged 99%, face and neck wipe fortifications averaged 89.1%, handwash fortifications averaged 75% and air sampler tube fortification was 109%. Laboratory method validation for each matrix fell within the acceptable range of 70 to 120%. The limit of quantitation (LOQ) was 1.0 µg/sample for the cotton dosimeters, 0.5 µg/sample for the face/neck wipes, 1.0 µg/sample for the hand washes and 0.01 µg/sample for the inhalation monitors.

Table C-161: MRID 45184305 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Both dermal and inhalation exposure are included since both are recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-162: MRID 45184305 – Data Summary

Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
2	0.5	1.522	0.0501	3.04	0.1002
3	0.5	0.163	0.0122	0.33	0.0245
4	0.5	0.706	0.0096	1.41	0.0191
12	0.5	0.446	0.0223	0.89	0.0445
7	0.5	0.701	0.0779	1.40	0.1559
5	0.5	0.774	0.0212	1.55	0.0423
6	0.5	0.397	0.0094	0.79	0.0187
14	0.5	0.474	0.0189	0.95	0.0379
15	0.5	0.95	0.0209	1.90	0.0418
13	0.5	2.854	0.0145	17.42	0.0884
46	0.5	1.15	0.0256	2.30	0.0512

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of residential applications of liquid concentrate formulations using a conventional hose-end sprayer, the following limitations are noted:

- Each individual handled the same amount of active ingredient, making analysis of the relationship between exposure and the amount of active ingredient handled (the underlying basis of unit exposures) difficult.

Scenario Summary

Table C-163: Scenario Description and Available Exposure Studies	
Formulation	Ready-to-use (RTU)
Equipment/Application Method	Trigger-pump sprayer
Application Site(s)	outdoors (lawns, gardens, trees/bushes, perimeter, mounds/nests, aquatic areas), indoors (plants, cracks and crevices), pets/animals
Available Exposure Studies	Merricks, D.L. (1997); MRID 44459801
	Meo, N.; Gonzalez, C.; Mester, T. (1997); MRID 44433302
	Knarr, R.D. (1988); MRID 41054701
	Barnekow, D.E.; Cook, W.L.; Meitl, T.J.; Shurdut, B.A. (1999); MRID 44739301

Table C-164: Unit Exposures (mg/lb ai) – Liquid Trigger-pump sprayer Applications				
Statistic	Outdoors / Indoors		Pets/Animals	
	Dermal	Inhalation	Dermal	Inhalation
50th percentile	54	0.046	510	2.2
75th percentile	103	0.077	990	4.0
95th percentile	260	0.16	2600	9.6
99th percentile	490	0.26	5000	18
99.9th percentile	1020	0.46	10500	36
AM (SD)	85.1 (103)	0.061 (0.053)	820 (1040)	3.3 (3.7)
GM (GSD)	54.2 (2.56)	0.046 (2.10)	510 (2.7)	2.2 (2.5)
Range	11.0 – 253	0.016 – 0.21	101 – 2400	0.30 – 8.4
N	20	70	16	16

Dermal Unit Exposure Summary

Outdoor and Indoor Environments: The recommended dermal unit exposures for applications of liquid pesticide formulations using a trigger-pump sprayer to outdoor and indoor environments is based on a lognormal distribution fit with exposure monitoring data from Merricks, D.L. (1997) [EPA MRID 44459801]. Merricks, D.L. (1997) monitored 40 applications to tomatoes and cucumbers using a ready-to-use (RTU) trigger-spray bottle. While other studies were available which potentially could represent residential applications, the exposure monitoring in this study enabled the best representation of the type of clothing a homeowner or amateur applicator would wear (i.e., shorts, short-sleeve shirt, no chemical-resistant gloves).

Pets and Animals: The recommended dermal unit exposures for applications of liquid pesticide formulations using a trigger-pump sprayer to pets or animals is based on a lognormal distribution fit with exposure monitoring data from Meo, N. et al (1997) [EPA MRID 44433302]. Meo, N. et al (1997) monitored 16 applications by commercial pet groomers treating 8 dogs for approximately 38-72 minutes using a ready-to-use (RTU) trigger-spray bottle. This is the only study available for this exposure scenario.

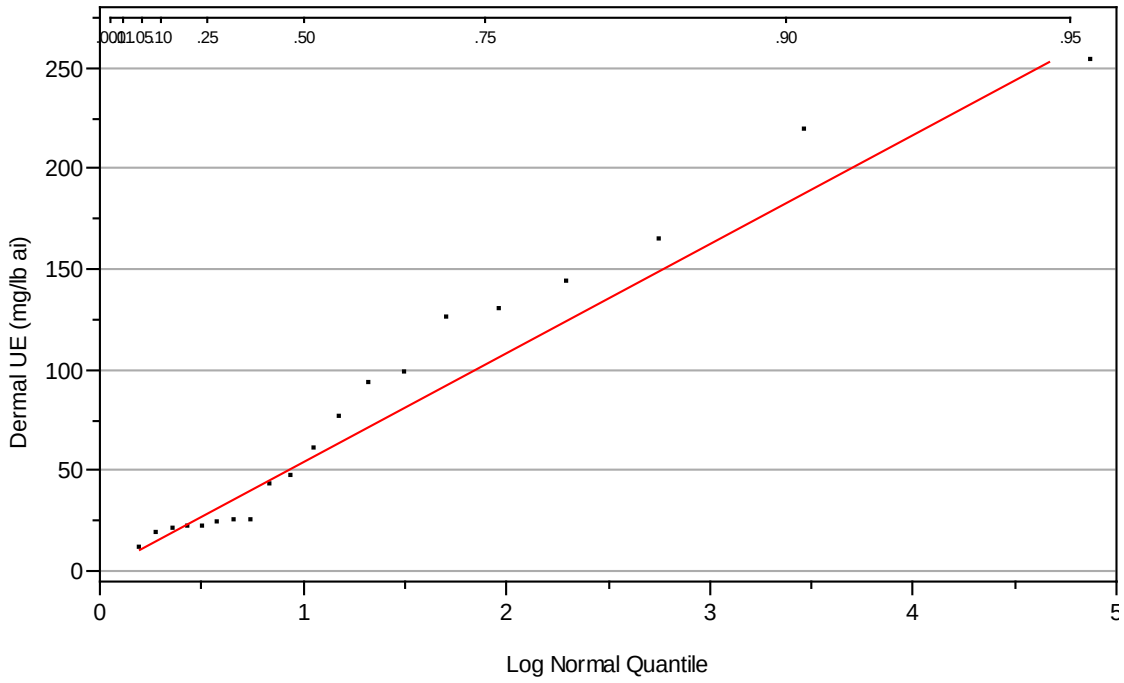
Inhalation Unit Exposure Summary

Outdoor and Indoor Environments: The recommended inhalation unit exposures for applications of liquid pesticide formulations using a trigger-pump sprayer to outdoor and indoor environments is based on a lognormal distribution fit with exposure monitoring data from Merricks, D.L. (1997) [EPA MRID 44459801], Knarr, R.D. (1998) [EPA MRID 41054701], and Barnekow, D.E., et al (1999) [EPA MRID 47739301]. Merricks, D.L. (1997) monitored 40 applications to tomatoes and cucumbers using a ready-to-use (RTU) trigger-spray bottle. Knarr, R.D. (1998) monitored 5 applications of a liquid pesticide formulation to door frames, screens, patios, and stoops for approximately 9-21 minutes using a trigger sprayer attached to a ½ gallon container with an 18-inch hose. Barnekow, D.E., et al (1999) monitored 15 applications of a liquid pesticide formulation to outdoor foundations, perimeters, and flower beds for approximately 1 hour using a 24 oz. ready-to-use trigger spray bottle. All available studies were considered reasonably representative of residential application inhalation exposure, and, since they were generally of the same magnitude, combined into a single dataset.

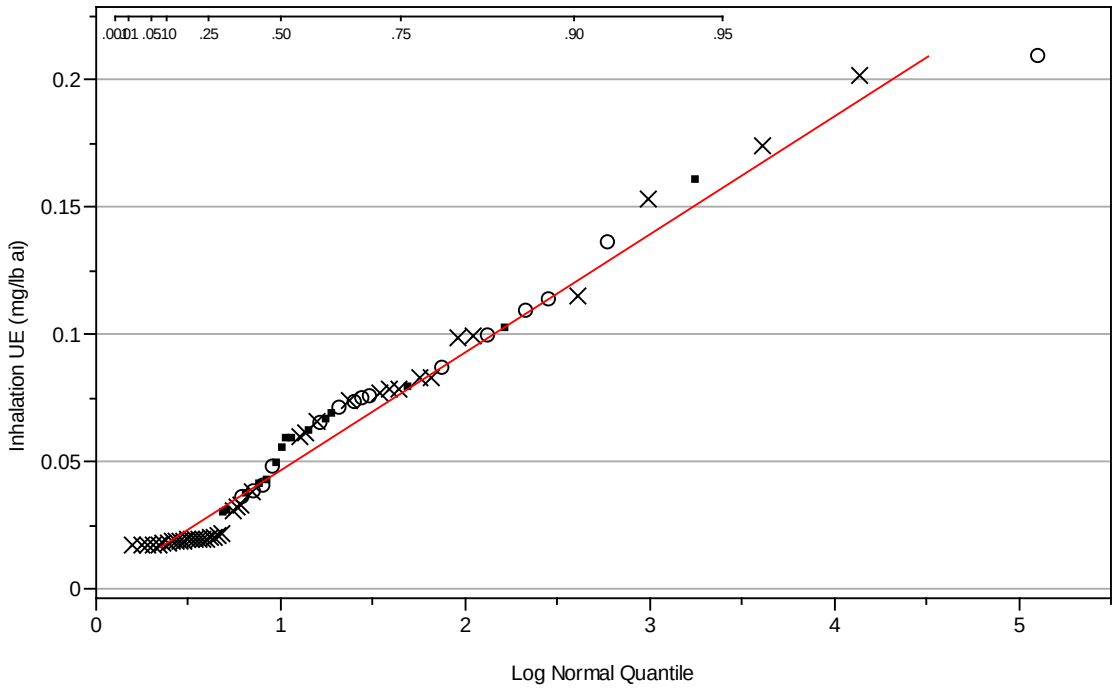
Pets and Animals: The recommended inhalation unit exposures for applications of liquid pesticide formulations using a trigger-pump sprayer to pets or animals is based on a lognormal distribution fit with exposure monitoring data from Meo, N. et al (1997) [EPA MRID 44433302]. Meo, N. et al (1997) monitored 16 applications by commercial pet groomers treating 8 dogs for approximately 38-72 minutes using a ready-to-use (RTU) trigger-spray bottle. This is the only study available for this exposure scenario.

Lognormal Probability Plots

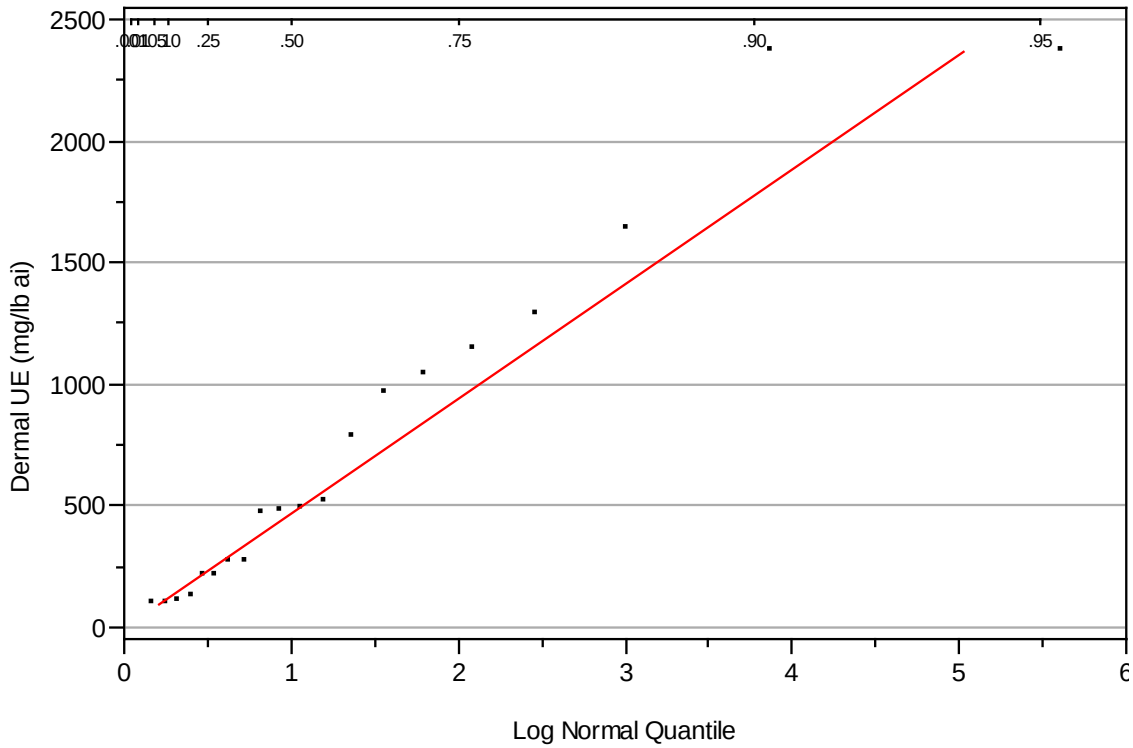
Outdoor/Indoor Environments Legend: ■ = Merricks, D.L. (1997)



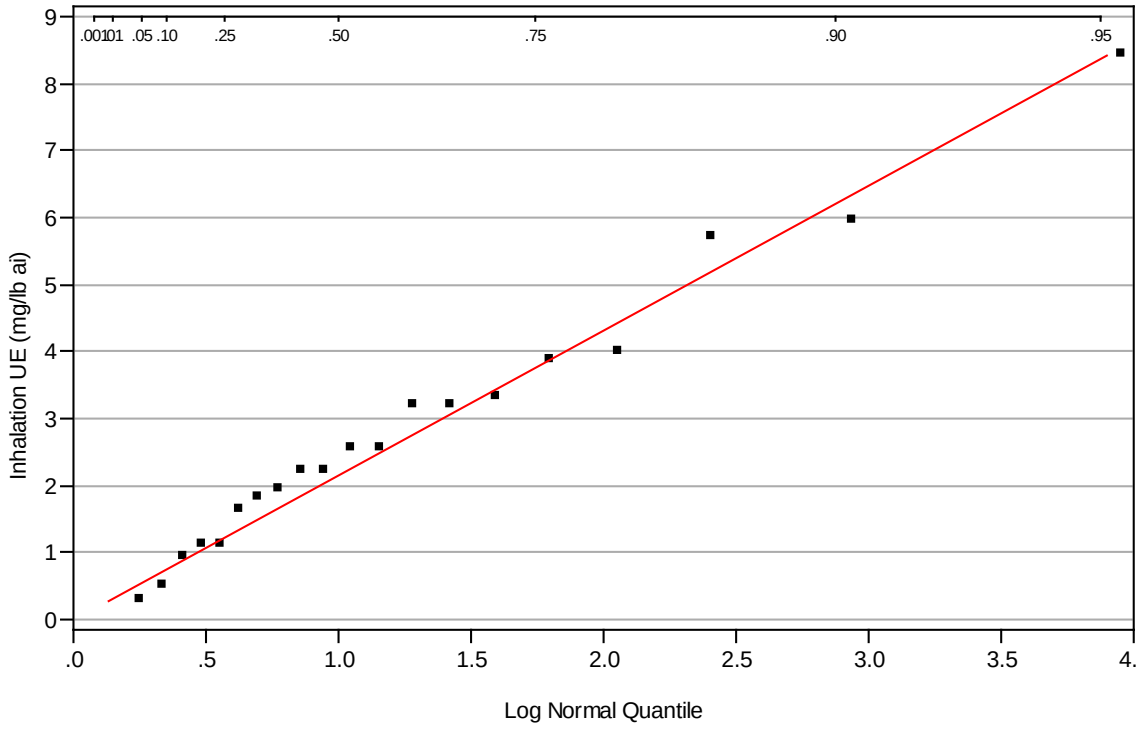
Outdoor/Indoor Environments Legend: ■ = Barnekow, D.E. et al (1997); O = Knarr, R.D. (1998); X = Merricks, D.L. (1997)



Pets/Animals Legend: ■ = Meo, N. et al (1997)



Pets/Animals Legend: ■ = Meo, N. et al (1997)



Available Handler Exposure Studies

Table C-165: Exposure Study Identification Information	
Citation	Merricks, D.L. (1997). Carbaryl Mixer/Loader/Applicator Exposure Study during Application of RP-2 Liquid (21%), Sevin® Ready to Use Insect Spray or Sevin® 10 Dust to Home Garden Vegetables
EPA MRID	44459801
ORETF Code	OMA006
EPA Review	EPA Memo from G. Bangs to D. Fuller (3/5/03)
	D287251
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Forty individuals were monitored while spraying tomatoes and cucumbers using a ready-to-use (RTU) trigger-spray bottle (i.e., no mixing was necessary). Each application was approximately 20 minutes and consisted of approximately 2 lbs formulation (approximately 0.24 gallons; 0.002 lbs carbaryl) to garden plants. Dermal exposure was measured using inner and outer whole body dosimetry and hand washes (20 individuals were monitored without gloves). Inhalation exposure was measured using standard pumps (set at 2 liters per minute), cassettes, and tubing. Field fortification recoveries for passive dosimeters averaged 84.3% for inner dosimeters and 77.7% for outer dosimeters. Face and neck wipe field fortifications averaged 84.8%. Both handwash and inhalation tube field fortification averaged >90%. Laboratory method validation for each matrix fell within the acceptable range of 70 to 120%. The limit of quantitation (LOQ) was 1.0 µg/sample for all media except the inhalation monitors where the LOQ was 0.01 µg/sample. The limit of detection (LOD) was 0.5 µg/sample for all media except the inhalation monitors where the LOQ was 0.005 µg/sample.

Table C-166: MRID 44459801 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Both dermal and inhalation exposure are included since both are recommended for use in residential handler exposure assessment. Note that only dermal exposure data representative of individuals wearing short-sleeve shirt, shorts, shoes, socks, and no chemical-resistant gloves are presented. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-167: MRID 44459801 – Data Summary

Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
R2	0.0024	0.30	0.000418	126	0.1739
S2	0.0022	0.13	0.000334	61	0.1532
T2	0.0028	0.70	0.000163	253	0.0592
U2	0.0025	0.33	0.000251	129	0.0989
X2	0.0020	0.29	0.000167	143	0.0824
Y2	0.0022	0.20	0.000042	93	0.0191
Z2	0.0020	0.33	0.000167	165	0.0824
A3	0.0022	0.17	0.000251	76	0.1149
D3	0.0021	0.05	0.000042	24	0.0202
E3	0.0022	0.10	0.000042	47	0.0188
F3	0.0021	0.05	0.000042	24	0.0195
G3	0.0022	0.22	0.000084	98	0.0375
J3	0.0022	0.05	0.000042	25	0.0191
K3	0.0021	0.05	0.000167	21	0.0782
M3	0.0020	0.04	0.000042	20	0.0208
L3	0.0022	0.48	0.000042	219	0.0191
P3	0.0022	0.02	0.000042	11	0.0193
Q3	0.0022	0.04	0.000042	18	0.0186
R3	0.0022	0.09	0.000041	43	0.0189
S3	0.0022	0.05	0.000041	22	0.0187
E	0.0025	--	0.000042	--	0.0166
F	0.0025	--	0.000042	--	0.0169
I	0.0022	--	0.000042	--	0.0186
H	0.0028	--	0.000084	--	0.0301
K	0.0025	--	0.000042	--	0.0165
L	0.0024	--	0.000042	--	0.0177
O	0.0024	--	0.000043	--	0.0180
P	0.0020	--	0.000042	--	0.0213
S	0.0025	--	0.000042	--	0.0168
T	0.0025	--	0.000042	--	0.0165
W	0.0026	--	0.000167	--	0.0654
X	0.0025	--	0.000501	--	0.2013
A2	0.0024	--	0.000042	--	0.0177
B2	0.0026	--	0.000251	--	0.0980
E2	0.0023	--	0.000167	--	0.0736
F2	0.0022	--	0.000167	--	0.0766
I2	0.0027	--	0.000086	--	0.0319
J2	0.0026	--	0.000084	--	0.0327
M2	0.0027	--	0.000167	--	0.0611
N2	0.0021	--	0.000167	--	0.0782

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of exposure during use of ready-to-use trigger sprayers, the following limitations are noted:

- An estimated 90% of all dermal exposure samples (underneath the individuals clothing) were non-detects. One-half the limit of detection (1.0 μg) was used.

- Nineteen of 40 inhalation samples were non-detects. One-half the limit of detection (0.01 μg) was used.

Table C-168: Available Exposure Study Identification Information	
Citation	Meo, N.; Gonzalez, C.; Mester, T. (1997) Dermal and Inhalation Exposure of Commercial Pet Groomers During Application of Frontline Spray Treatment: Final Report: Lab Project Number: MERIAL 445 SAFXT046: SAFX046: PDA9705. Unpublished study prepared by ABC Labs., California and Animal Appeal Grooming Shop & Case Veterinary Hospital. 1066 p.
EPA MRID	44433302
ORETF Code	NA
EPA Review	Contractor (Versar, Inc.) review; 4/27/98
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Sixteen different commercial pet groomers were monitored while treating dogs with fipronil, an active ingredient used to control fleas and ticks, using a ready-to-use (RTU) trigger-spray bottle. Each application consisted of treating 8 dogs by holding the dog with one hand and spraying with the other, including rubbing the spray into the dog's fur. Application times ranged from 38 to 72 minutes and the amount of fipronil applied ranged from approximately 0.002 to 0.007 lbs. Dermal exposure was measured using inner whole body dosimetry (underneath pants, a short-sleeved shirt, and a smock) and cotton gloves underneath household latex gloves. Inhalation exposure was measured using standard pumps (set at 1.5 liters per minute), cassettes, and tubing. Field fortification samples of each matrix were fortified with diluted formulated product at the test site and subjected to the same conditions as the replicate samples. Average recoveries (triplicate samples) at each fortification level (low, medium, high) for each matrix ranged from 81.6% to 105.9%.

Table C-169: MRID 44433302 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Both dermal and inhalation exposure are included since both are recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-170: MRID 44433302 – Data Summary			
Person ID	AaiH[1]	Exposure (mg)	Unit Exposure (mg/lb ai)[4]

	(lbs)	Dermal[2]	Inhalation[3]	Dermal	Inhalation
1	0.0033	0.72	0.007	218.18	2.12
2	0.0024	5.64	0.003	2350.00	1.25
3	0.0033	0.33	0.008	100.00	2.42
4	0.0035	0.94	0.011	268.57	3.14
5	0.0047	2.17	0.039	461.70	8.30
6	0.0064	3.31	0.026	517.19	4.06
7	0.0037	5.97	0.003	1613.51	0.81
8	0.0025	0.29	0.010	116.00	4.00
9	0.0036	1.74	0.001	483.33	0.28
10	0.0065	7.48	0.012	1150.8	1.8
11	0.0038	3.95	0.022	1039.5	5.8
12	0.0025	0.31	0.001	124.0	0.4
13	0.0033	1.59	0.011	481.8	3.3
14	0.0053	5.07	0.009	956.6	1.7
15	0.0019	1.49	0.011	784.2	5.8
16	0.0060	7.78	0.012	1296.7	2.0

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of exposure during use of ready-to-use trigger sprayers, the following limitations are noted:

- The study monitored professional/commercial pet groomers and may not be representative of the exposure an individual at home would experience while treating their pets.
- The individuals monitored wore long pants, long-sleeve shirts, and chemical-resistant gloves. Therefore, back-calculations using standard penetration factors to represent exposure to people wearing shorts, a short-sleeve shirt and no chemical-resistant gloves were necessary.

Table C-171: Exposure Study Identification Information	
Citation	Knarr, R.D. (1988). Exposure of Applicators to Propoxur During Trigger-Pump Spray Applications of a Liquid Product
EPA MRID	41054701
ORETF Code	NA
EPA Review	D287251
	Contractor (Versar, Inc.) review; 9/29/89
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Three individuals were monitored for each of 5 applications using a trigger sprayer attached to a ½ gallon container with an 18-inch hose to treat the outside of homes (door frames, screens, patios, stoops, etc.). Applications ranged from 9 to 21 minutes and the amount of active ingredient (propoxur) handled ranged from 0.01 to 0.025 lbs. Dermal exposure was measured using gauze patches (underneath normal work clothing) and hand washes. All individuals wore chemical-resistant gloves. Inhalation exposure was measured using standard pumps (set at 1 liter per minute), cassettes, and tubing. Average laboratory recovery for all

media ranged from 99.2% to 109%. Patches and filters were fortified at 1 µg/sample while hand rinses were fortified at either 200 or 1000 µg/sample. Average field recovery results ranged from 90.3% to 102.2%. Patches were fortified at levels from 1 to 50 µg/sample, hand rinses were fortified at 200 µg/sample, and filters were fortified at 0.2 µg/sample.

Table C-172: MRID 41054701 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**No**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Only inhalation exposure results are presented as dermal exposure monitoring was not recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-173: MRID 41054701 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
A	0.0188	--	0.0026	--	0.136
A	0.0188	--	0.0016	--	0.087
A	0.0250	--	0.0016	--	0.065
A	0.0250	--	0.0019	--	0.075
A	0.0250	--	0.0052	--	0.210
B	0.0188	--	0.0019	--	0.100
B	0.0188	--	0.0013	--	0.071
B	0.0250	--	0.0029	--	0.114
B	0.0250	--	0.0019	--	0.076
B	0.0206	--	0.0015	--	0.074
C	0.0100	--	0.0004	--	0.038
C	0.0188	--	0.0008	--	0.041
C	0.0188	--	0.0009	--	0.048
C	0.0131	--	0.0014	--	0.109
C	0.0250	--	0.0009	--	0.036

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: No limitations were identified for this study.

Table C-174: Exposure Study Identification Information	
Citation	Barnekow, D.E.; Cook, W.L.; Meitl, T.J.; Shurdut, B.A. (1999). Exposure to Chlorpyrifos While Applying a Ready to Use Formulation. January 14, 1999. Laboratory Project Study ID: HEA 976046.
EPA MRID	44739301
ORETF Code	NA
EPA Review	D252733
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Fifteen individuals were monitored during applications to outdoor areas of houses (foundations, perimeters, flower beds) using a ready-to-use trigger spray bottle (24 oz.; 0.5% chlorpyrifos). Applications lasted 1 hour or until 5 bottles were exhausted, whichever was longer. Dermal exposure was measured using whole body dosimetry (underneath long pants, short-sleeve shirt) and hand washes (no chemical-resistant gloves were worn). Inhalation exposure was measured using standard pumps (set at 1.5 liters per minute), cassettes, and tubing. Laboratory recoveries for coveralls resulted in a mean percent recovery of 94.3% and RSD of 5.1%, while recoveries for handwash had a mean percent recovery of 107.6% and RSD of 3.9%. Field recoveries for coveralls resulted in a mean percent recovery of 99.1 and RSD of 4.7%, while recoveries for handwash had a mean percent recovery of 93.6% and RSD of 5.1%.

Table C-175: MRID 44739301 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**No**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Note that only inhalation exposure data are presented as the dermal exposure data are not recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-176: MRID 44739301 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
1	0.036	--	0.0024	--	0.066
2	0.030	--	0.0012	--	0.041
3	0.030	--	0.0016	--	0.055

Table C-176: MRID 44739301 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
4	0.036	--	0.0022	--	0.062
5	0.038	--	0.0022	--	0.059
6	0.037	--	0.0029	--	0.079
7	0.015	--	0.0024	--	0.161
8	0.030	--	0.0018	--	0.058
9	0.035	--	0.0036	--	0.102
10	0.037	--	0.0011	--	0.030
11	0.038	--	0.0011	--	0.030
12	0.023	--	0.0016	--	0.069
13	0.038	--	0.0016	--	0.042
14	0.038	--	0.0014	--	0.037
15	0.037	--	0.0018	--	0.049

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: No limitations were identified in this study.

Scenario Summary

Table C-177: Scenario Description and Available Exposure Studies	
Formulation	Ready-to-use (RTU)
Equipment/Application Method	Shampoo
Application Site(s)	Pets/animals, children
Available Exposure Studies	Mester, T.C. (1998); MRID 44658401
	Selim, S. (2005); MRID 46601001

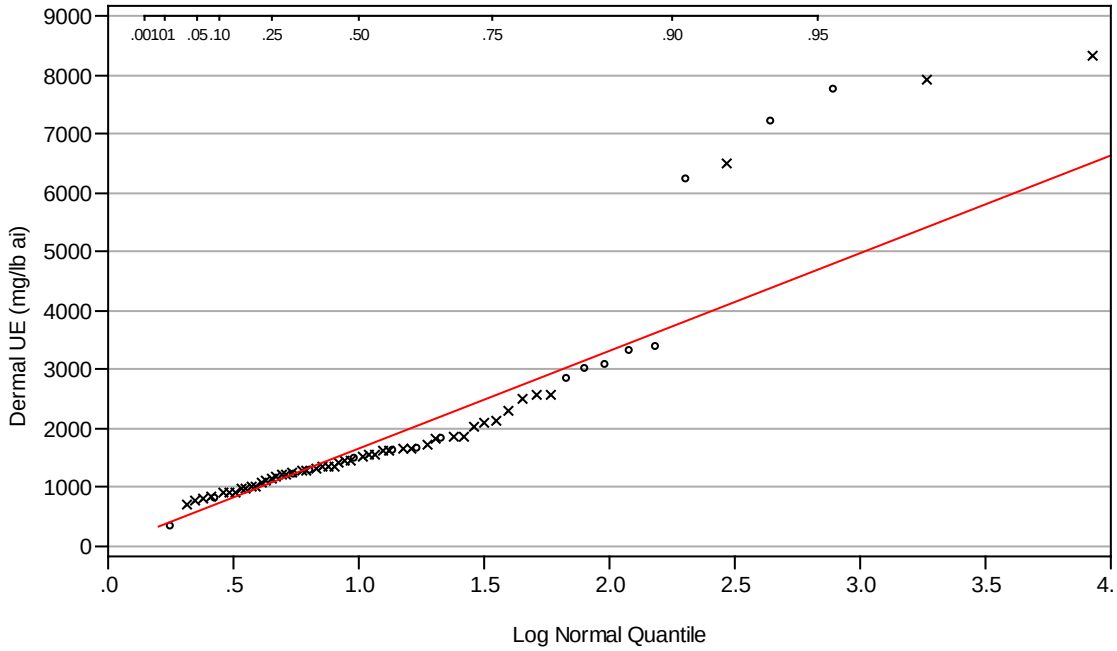
Table C-178: Unit Exposures (mg/lb ai) – RTU Shampoo Applications		
Statistic	Dermal	Inhalation
50th percentile	1700	0.169
75th percentile	2500	0.342
95th percentile	4700	0.942
99th percentile	7200	1.92
99.9th percentile	12000	4.26
AM (SD)	2000 (1400)	0.29 (0.41)
GM (GSD)	1700 (1.9)	0.17 (2.8)
Range	340 – 8300	0.0197 – 0.496
N	64	16

Dermal Unit Exposure Summary: The recommended dermal unit exposures for shampoo applications of liquid pesticide formulations to pets, animals, or children is based on a lognormal distribution fit with exposure monitoring data from Mester, T.C. (1998) [EPA MRID 44658401] and Selim, S. (2005) [EPA MRID 46601001]. Mester, T.C. (1998) monitored 16 applications by commercial pet groomers of shampoo to 8 dogs for approximately 149-295 minutes. Selim, S. (2005) monitored 16 shampoo applications to one dog each for approximately 30 minutes. Both studies were considered reasonably representative of activities related to shampooing pets and both had limitations with respect to exposure monitoring representing the type of clothing a homeowner or amateur applicator would wear (i.e., shorts, short-sleeve shirt, no chemical-resistant gloves). Additionally, since the exposure results were generally of the same magnitude, the datasets were combined.

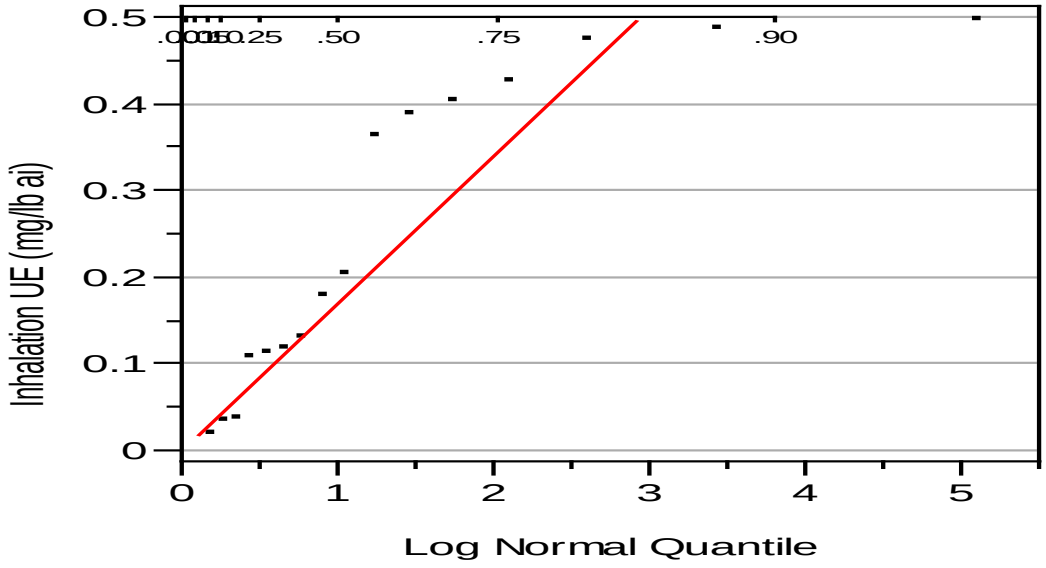
Inhalation Unit Exposure Summary: The recommended inhalation unit exposures for shampoo applications of liquid pesticide formulations to pets, animals, or children is based on a lognormal distribution fit with exposure monitoring data from Mester, T.C. (1998) [EPA MRID 44658401]. Mester, T.C. (1998) monitored 16 applications by commercial pet groomers of shampoo to 8 dogs for approximately 149-295 minutes. Another available study did not monitor inhalation exposure.

Lognormal Probability Plots

Legend: O = Mester, T.C. (1998); X = Selim, S. (2005)



Legend: ■ = Mester, T.C. (1998)



Available Handler Exposure Studies

Table C-179: Exposure Study Identification Information	
Citation	Mester, T.C. (1998). Dermal Exposure and Inhalation Exposure to Carbaryl by Commercial Pet Groomers During Applications of Adams ™ Carbaryl Shampoo
EPA MRID	44658401
ORETF Code	NA
EPA Review	D287251
	Contractor (Versar, Inc.) review 12/4/98
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Sixteen different commercial pet groomers were monitored while treating dogs with carbaryl, an active ingredient used to control fleas and ticks, using a ready-to-use (RTU) disposable shampoo bottle. Each application consisted of treating 8 dogs by soaking (2-3 minutes), treating with the shampoo, letting the shampoo sit for 5 minutes, then rinsing, drying and combing the dog. Application times for treating all 8 dogs ranged from 149 to 295 minutes and the amount of carbaryl applied ranged from approximately 0.0008 to 0.008 lbs. Dermal exposure was measured using inner whole body dosimetry (underneath pants, a short-sleeved shirt and a smock) and hand washes (no chemical-resistant gloves were worn). Inhalation exposure was measured using standard pumps (set at 1.5 liters per minute), cassettes, and tubing. Laboratory control samples for hand wash solutions were fortified with carbaryl with four rates of concurrent recovery determination, which ranged in percent recovery from 88% to 120%, with a mean percent recovery of 104% and a standard deviation of 8.7%. Field fortifications for hand wash solutions were prepared at three spiking levels, with a mean of all three spiking levels at 100% and a standard deviation of 5.9%. Laboratory control samples for whole body dosimeters were fortified with carbaryl with two rates for concurrent recovery determination, which ranged in percent recovery from 91% to 119%, with a mean percent recovery of 107% and a standard deviation of 6.9%. Field fortification samples for whole body dosimeters were prepared at three spiking levels with a mean of all three spiking levels at 83% and a standard deviation of 5.0%.

Table C-180: MRID 44658401 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Both dermal and inhalation exposure are included since both are

recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-181: MRID 44658401 – Data Summary

Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
1	0.0050	15.36	0.00196	3072	0.3878
2	0.0015	11.72	0.00005	7813	0.0332
3	0.0020	2.61	0.00086	1305	0.4256
4	0.0044	5.51	0.00057	1252	0.1291
5	0.0036	10.40	0.00065	2889	0.1788
6	0.0027	3.99	0.00054	1478	0.2036
7	0.0015	4.49	0.00059	2993	0.4031
8	0.0008	5.13	0.00041	6413	0.4958
9	0.0013	2.20	0.00005	1692	0.0378
10	0.0039	27.88	0.00140	7149	0.3627
11	0.0021	1.76	0.00022	838	0.1066
12	0.0082	15.00	0.00097	1829	0.1185
13	0.0025	8.29	0.00118	3316	0.4732
14	0.0025	8.60	0.00005	3440	0.0197
15	0.0016	2.54	0.00076	1588	0.4865
16	0.0043	1.44	0.00048	335	0.1129

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of exposure during shampoo applications, the following limitations are noted:

- The study monitored professional/commercial pet groomers and may not be representative of the exposure an individual at home would experience while treating their pets.
- The individuals monitored wore long pants, long-sleeve shirts, a smock and chemical-resistant gloves. Therefore, back-calculations using standard penetration factors to represent exposure to people wearing shorts, a short-sleeve shirt and no chemical-resistant gloves were necessary.

Table C-182: Exposure Study Identification Information

Citation	Selim, S. (2005) Human Exposure During and Following Use of a Pyrethrins/Piperonyl Butoxide/MGK-264 Shampoo Formulation on Dogs: Final Report. Project Number: 040154. Unpublished study prepared by Young Veterinary Research Services and Golden Pacific Laboratories, LLC (GPL). 466 p.
EPA MRID	46601001
ORETF Code	NA
EPA Review	D319806

MRID = Master Record Identification
ORETF = Outdoor Residential Exposure Task Force

Study Description: Sixteen individuals were monitored while treating dogs with a shampoo containing the active ingredients pyrethrins, piperonyl butoxide (PBO), and MGK-264. Each application took approximately 30 minutes and consisted of shampooing, rinsing, and drying a single dog. The amount of active ingredient ranged from 12 mg (pyrethrins) to 663 mg (PBO). Dermal exposure was measured using a t-shirt (no inner dosimeter, so exposure represents bare upper body) and hand washes or wipes (no chemical-resistant gloves were worn) both immediately following the treatment and 4 hours after. Lower body exposure was not measured. Inhalation exposure was not measured. Overall average laboratory recoveries for PYI (pyrethrins) ranged from 83.5% (shampoo rinse) to 98.0% (paper towels), for PBO (piperonyl butoxide) ranged from 84.2% (dog hair) to 98.6% (shampoo rinse), for MGK 264 ranged from 86.3% (hand washes) to 98.2% (paper towels). For CDCA, the overall average recovery was 92.1%. Field fortification samples were not discussed in the Study Report.

Table C-183: MRID 46601001 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	Yes	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	No
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**No**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Note that only dermal exposure data are presented as inhalation exposure was not measured. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-184: MRID 46601001 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
A1 (PY)	0.000056	0.063	--	1125	--
A2 (PY)	0.000049	0.063	--	1286	--
A3 (PY)	0.000063	0.080	--	1270	--
A4 (PY)	0.000060	0.058	--	967	--
A5 (PY)	0.000027	0.031	--	1148	--
A6 (PY)	0.000039	0.063	--	1615	--
A7 (PY)	0.000039	0.255	--	6538	--
A8 (PY)	0.000048	0.048	--	1000	--
A9 (PY)	0.000049	0.124	--	2531	--
A10 (PY)	0.000052	0.105	--	2019	--
A11 (PY)	0.000051	0.051	--	1000	--
A12 (PY)	0.000040	0.064	--	1600	--
A13 (PY)	0.000080	0.114	--	1425	--
A14 (PY)	0.000047	0.062	--	1319	--

Table C-184: MRID 46601001 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
A15 (PY)	0.000051	0.045	--	882	--
A16 (PY)	0.000056	0.042	--	750	--
A1 (PBO)	0.00103	1.25	--	1214	--
A2 (PBO)	0.00089	1.20	--	1348	--
A3 (PBO)	0.00116	1.41	--	1216	--
A4 (PBO)	0.00109	1.16	--	1064	--
A5 (PBO)	0.00049	0.74	--	1510	--
A6 (PBO)	0.00071	1.48	--	2085	--
A7 (PBO)	0.00072	5.67	--	7875	--
A8 (PBO)	0.00088	1.86	--	2114	--
A9 (PBO)	0.00090	2.24	--	2489	--
A10 (PBO)	0.00095	1.74	--	1832	--
A11 (PBO)	0.00094	0.83	--	883	--
A12 (PBO)	0.00073	1.12	--	1534	--
A13 (PBO)	0.00146	2.07	--	1418	--
A14 (PBO)	0.00086	1.08	--	1256	--
A15 (PBO)	0.00092	0.90	--	978	--
A16 (PBO)	0.00101	0.80	--	792	--
A1 (MGK-264)	0.00035	0.646	--	1846	--
A2 (MGK-264)	0.00030	0.493	--	1643	--
A3 (MGK-264)	0.00040	0.678	--	1695	--
A4 (MGK-264)	0.00037	0.450	--	1216	--
A5 (MGK-264)	0.00017	0.273	--	1606	--
A6 (MGK-264)	0.00024	0.552	--	2300	--
A7 (MGK-264)	0.00025	2.055	--	8220	--
A8 (MGK-264)	0.00030	0.461	--	1537	--
A9 (MGK-264)	0.00031	0.786	--	2535	--
A10 (MGK-264)	0.00033	0.596	--	1806	--
A11 (MGK-264)	0.00032	0.288	--	900	--
A12 (MGK-264)	0.00025	0.338	--	1352	--
A13 (MGK-264)	0.00050	0.725	--	1450	--
A14 (MGK-264)	0.00029	0.331	--	1141	--
A15 (MGK-264)	0.00032	0.266	--	831	--
A16 (MGK-264)	0.00035	0.244	--	697	--

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of exposure during shampoo applications, the following limitations are noted:

- Dermal exposure to the legs was not measured. However, since dermal exposure was measured using the t-shirt that the individuals were wearing (i.e., measurements represent a bare upper body), the potential overrepresentation of the upper body exposure likely compensates for the lack of lower body measurements.

Scenario Summary

Table C-185: Scenario Description and Available Exposure Studies	
Formulation	Ready-to-use (RTU)
Equipment/Application Method	Spot-on
Application Site(s)	Pets/animals
Available Exposure Studies	Meo, N.; Gonzalez, C.; Belcher, T. (1997); MRID 44433303

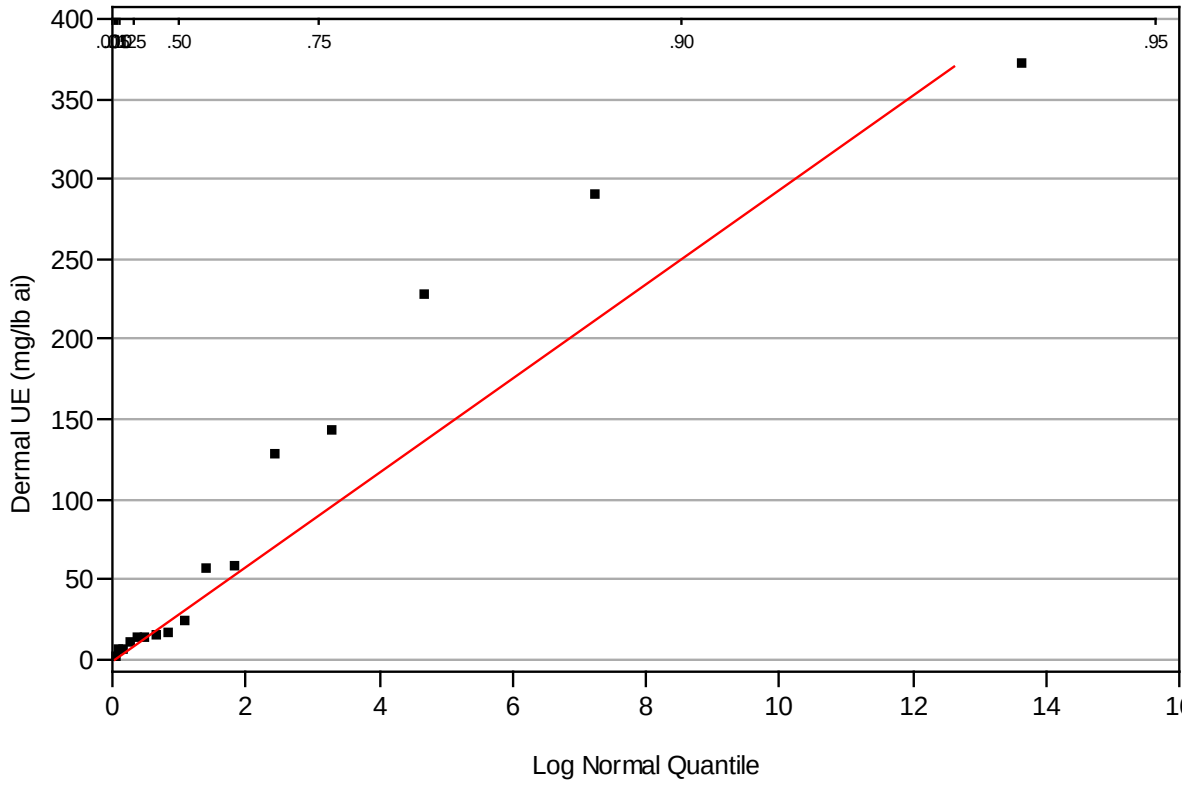
Table C-186: Unit Exposures (mg/lb ai) – RTU Spot-on Applications		
Statistic	Dermal	Inhalation
50th percentile	29	Inhalation exposure data during application of spot-on treatments is unavailable, however is considered negligible.
75th percentile	91	
95th percentile	460	
99th percentile	1400	
99.9th percentile	5100	
AM (SD)	120 (470)	
GM (GSD)	29 (5.3)	
Range	1.1 – 370	
N	16	

Dermal Unit Exposure Summary: The recommended dermal unit exposures for spot-on applications to pets or animals is based on a lognormal distribution fit with exposure monitoring data from Meo, N., et al (1997) [EPA MRID 44433303]. Meo, N., et al (1997) monitored 16 applications by commercial pet groomers to 8 dogs for approximately 14-32 minutes using a ready-to-use (RTU), disposable, snap-top, plastic-backed pipette. This was the only available monitoring study for this exposure scenario.

Inhalation Unit Exposure Summary: Inhalation exposure data during application of spot-on treatments is unavailable, however is considered negligible.

Lognormal Probability Plots

Legend: ■ = Meo, N. et al (1997)



Available Handler Exposure Studies

Table C-187: Exposure Study Identification Information	
Citation	Meo, N.; Gonzalez, C.; Belcher, T. (1997) Dermal Exposure of Commercial Pet Groomers During Application of Frontline Top Spot: Final Report: Lab Project Number: MERIAL 445 SAFXT047: SAFXT047: EC 97 390. Unpublished study prepared by ABC Labs., California and Animal Appeal Grooming Shop & Case Veterinary Hospital. 925 p.
EPA MRID	44433303
ORETF Code	NA
EPA Review	DER by W. Britton (EPA); no barcode
	Contractor review (Versar, Inc.) 9/9/08
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Sixteen different commercial pet groomers were monitored while treating dogs with fipronil, an active ingredient used to control fleas and ticks, using a ready-to-use (RTU), disposable, snap-top, plastic-backed pipette. Each application consisted of applying 2 or 3 pre-measured unit doses with a pipette to the neck area of each of 8 dogs with some groomers rubbing the material into the dogs' fur. Application times ranged from 14 to 32 minutes and the amount of fipronil applied ranged from approximately 0.001 to 0.004 lbs. Dermal exposure was measured using inner whole body dosimetry (underneath pants, a short-sleeved shirt and a smock) and cotton gloves underneath household latex gloves. Inhalation exposure was not measured. Data generated in the frozen stability phase of the study indicated that fipronil was stable in two dermal matrices after mean recoveries from field fortification samples which fell between 79% and 103% of theoretical concentration.

Table C-188: MRID 44433303 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	No
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**No**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Note that only dermal exposure data are presented as inhalation exposure was not measured. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-189: MRID 44433303 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation

Table C-189: MRID 44433303 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
1	0.00236	0.033	--	13.93	--
2	0.00207	0.032	--	15.59	--
3	0.00251	0.727	--	289.35	--
4	0.00162	0.090	--	55.40	--
5	0.00325	0.031	--	9.67	--
6	0.00162	0.037	--	23.03	--
7	0.00399	0.004	--	1.12	--
8	0.00177	0.252	--	142.25	--
9	0.00251	0.013	--	5.20	--
10	0.00148	0.084	--	56.94	--
11	0.00207	0.767	--	370.84	--
12	0.00192	0.024	--	12.56	--
13	0.00192	0.009	--	4.82	--
14	0.00266	0.337	--	126.71	--
15	0.00251	0.031	--	12.50	--
16	0.00266	0.603	--	226.66	--

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of exposure during spot-on pet treatments, the following limitations are noted:

- The study monitored professional/commercial pet groomers and may not be representative of the exposure an individual at home would experience while treating their pets.
- The individuals monitored wore long pants, long-sleeve shirts, a smock and chemical-resistant gloves. Therefore, back-calculations using standard penetration factors to represent exposure to people wearing shorts, a short-sleeve shirt and no chemical-resistant gloves were necessary.

Scenario Summary

Table C-190: Scenario Description and Available Exposure Studies	
Formulation	Ready-to-use (RTU)
Equipment/Application Method	Aerosol can
Application Site(s)	outdoors (gardens, trees/bushes, perimeter, mounds/nests, aquatic areas), indoors (general broadcast treatments, baseboards, cracks and crevices), pets/animals
Available Exposure Studies	PHED 521
	PHED 456
	Selim, S. (2002); MRID 46188618

Table C-191: Unit Exposures (mg/lb ai) – RTU Aerosol can Applications				
Statistic	Outdoors/Indoors		Pets/Animals	
	Dermal	Inhalation	Dermal	Inhalation
50th percentile	330	2.3	Studies measuring exposure while treating pets or animals using an aerosol can are unavailable. Therefore, the exposure studies recommended for use for treating pets or animals using RTU trigger-pump sprayers should be used as a surrogate.	
75th percentile	450	3.7		
95th percentile	720	7.4		
99th percentile	990	11		
99.9th percentile	1400	20		
AM (SD)	370 (180)	3.0 (2.4)		
GM (GSD)	330 (1.6)	2.3 (2.0)		
Range	140 – 1000	0.38 – 4.9		
N	15	15		

Dermal Unit Exposure Summary

Outdoor and Indoor Environments: The recommended dermal unit exposures for aerosol can applications to outdoor and indoor environments is based on a lognormal distribution fit with exposure monitoring data from PHED 521. PHED 521 monitored 15 applications to cracks, crevices, baseboards, under sinks, and behind appliances in 15 separate houses using an entire 16 oz. aerosol can. Though another study was available this study best represented the type of clothing a homeowner or amateur applicator would wear (i.e., shorts, short-sleeve shirt, no chemical-resistant gloves).

Pets and Animals: Dermal exposure monitoring data for aerosol can applications to pets and animals are unavailable; dermal unit exposures for trigger-sprayers applications to pets and animals are recommended as surrogate data.

Inhalation Unit Exposure Summary

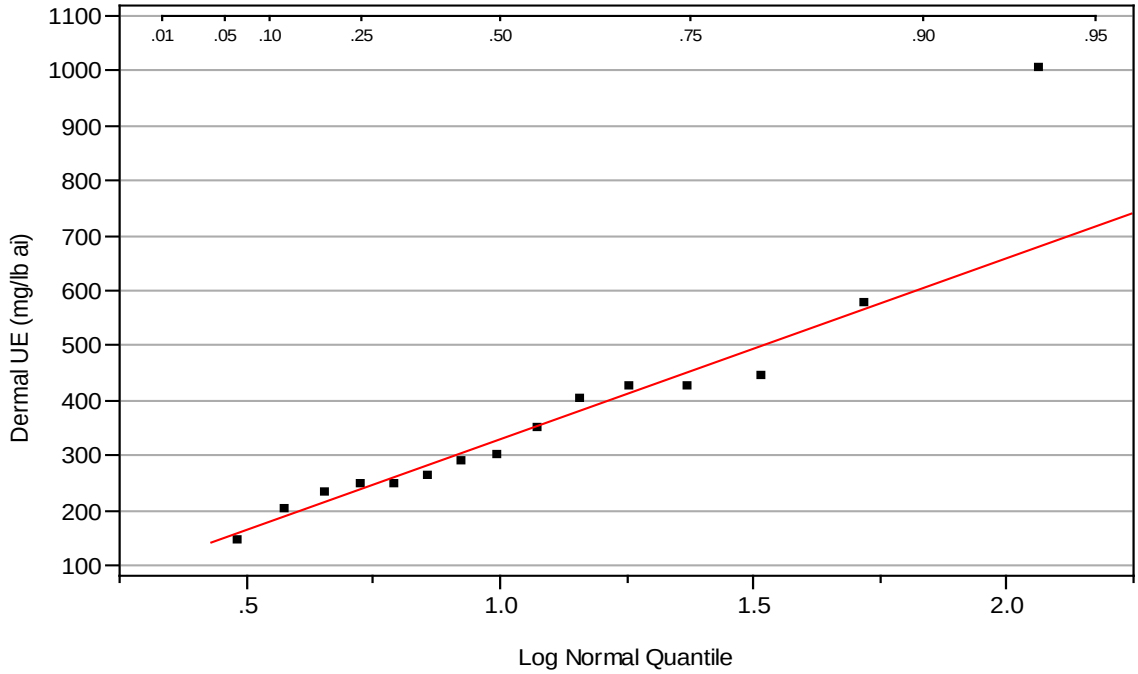
Outdoor and Indoor Environments: The recommended inhalation unit exposures for aerosol can applications to outdoor and indoor environments is based on a lognormal distribution fit with exposure monitoring data from PHED 456. PHED 456 monitored 15 applications to cracks, crevices, baseboards, under sinks, and behind appliances in 15 separate houses using an entire 16 oz. aerosol can. This study was selected for use for

inhalation exposure estimates due to its lack of non-detect samples compared with another available study.

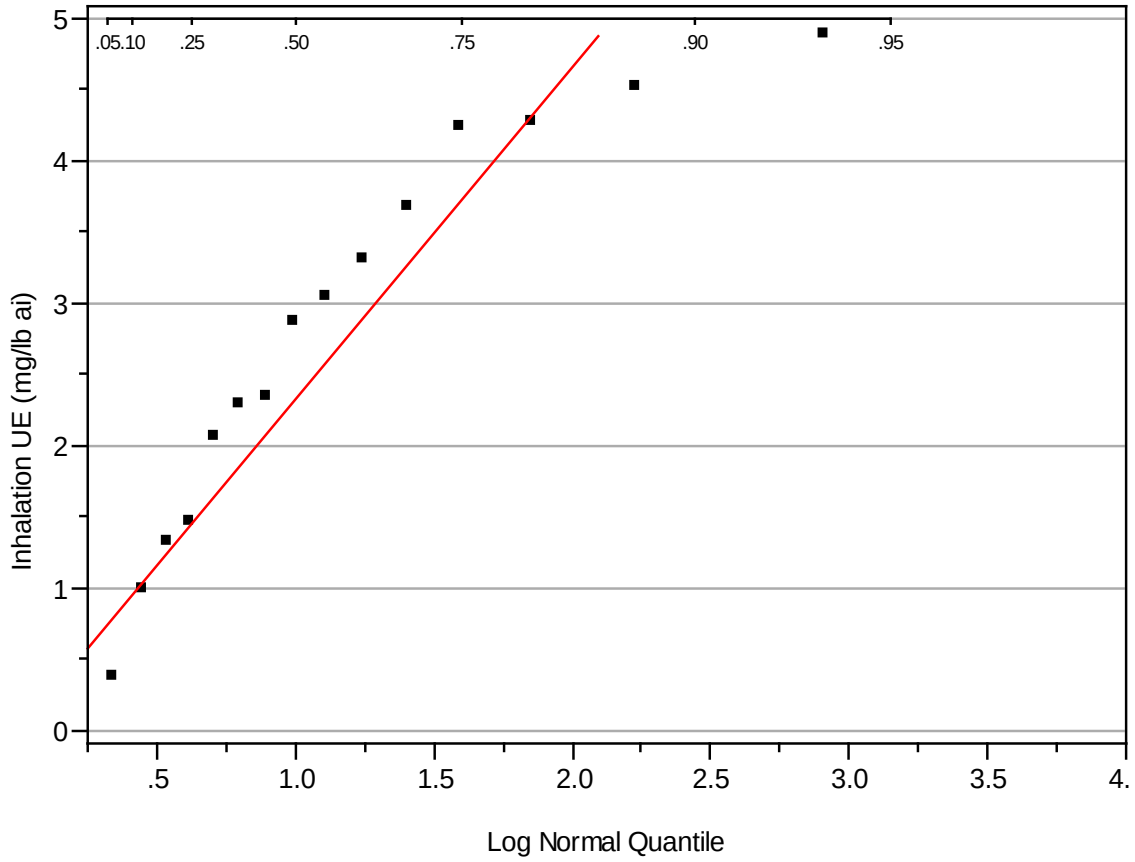
Pets and Animals: Inhalation exposure monitoring data for aerosol can applications to pets and animals is unavailable; inhalation unit exposures for trigger-sprayers applications to pets and animals is recommended as surrogate data.

Lognormal Probability Plots

Outdoor/Indoor Environments Legend: ■ = PHED 521



Outdoor/Indoor Environments Legend: ■ = PHED 456



Available Handler Exposure Studies

Table C-192: Available Exposure Study Identification Information	
Citation	PHED 521
EPA MRID	NA
ORETF Code	NA
EPA Review	none
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Five different individuals were monitored on 3 consecutive days while spraying an entire 16 oz. aerosol can (1% active ingredient) to cracks, crevices, baseboards, under sinks, and behind appliances in 15 separate houses. Dermal exposure was measured using gauze patches (both inside and outside normal work clothing) and hand rinses (without chemical-resistant gloves). Inhalation exposure was measured using standard pumps (set at 1 liter per minute), cassettes, and tubing. Thirteen of 15 inhalation samples were non-detects (limit of detection = 1 μg per sample). Recoveries from field fortifications of exposure sampling matrices were generally above 90%.

Table C-193: PHED 521 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**No**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Note that only dermal exposure data are presented as inhalation exposure data from this study is not recommended for the purposes of residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-194: PHED 521 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
A	0.01	4.25	--	425	--
A	0.01	2.99	--	299	--
A	0.01	2.88	--	288	--
B	0.01	2.61	--	261	--
B	0.01	4.43	--	443	--
B	0.01	1.42	--	142	--
C	0.01	5.77	--	577	--

Table C-194: PHED 521 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
C	0.01	4.01	--	401	--
C	0.01	10.02	--	1002	--
D	0.01	4.24	--	424	--
D	0.01	2.47	--	247	--
D	0.01	2.48	--	248	--
E	0.01	3.47	--	347	--
E	0.01	2.29	--	229	--
E	0.01	2.01	--	201	--

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of exposure during applications using aerosol cans, the following limitations are noted:

- The study monitored individuals during applications to indoor locations which introduces uncertainty when using the data to assess applications outdoors.

Table C-195: Exposure Study Identification Information	
Citation	PHED 456
EPA MRID	NA
ORETF Code	NA
EPA Review	none

MRID = Master Record Identification
ORETF = Outdoor Residential Exposure Task Force

Study Description: Three different individuals were monitored during 5 applications while spraying an entire 16 oz. aerosol can (1% active ingredient) to cracks, crevices, baseboards, under sinks, and behind appliances in homes. Each application lasted approximately 30 minutes. Dermal exposure was measured using gauze patches (both inside and outside normal work clothing) and hand rinses (underneath chemical-resistant gloves). Inhalation exposure was measured using standard pumps (set at 1 liter per minute), cassettes, and tubing. The average laboratory recovery values are as follows, 101% with a standard deviation of 3.1% for air filters, 98.8% with a standard deviation of 3.5% for gauze pads, 103% with a standard deviation of 0.9% for hand washes (200 µg) and 101% with a standard deviation of 3.5% for hand washes (1000 µg). Field recoveries of the technical active ingredient are reported for two separate sets of gauze pads in another propoxur exposure study for method validation. In that study, gauze pads were spiked with the technical active ingredient at a fortification level of 1.0 µg. The spiked pads were exposed to unspecified field conditions for 5 hours. The results of these field recoveries are as follows: the average recovery for the first set of gauze pads is 101% with a standard deviation of 3.5%, while for the second set of gauze pads is 84.5% with a standard deviation of 3.6%.

Table C-196: PHED 456 – Checklist and Use Recommendation	
Study Criteria	Exposure Component

	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**No**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Note that only inhalation exposure data are presented as dermal exposure data from this study is not recommended for the purposes of residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-197: PHED 456 – Data Summary

Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
A	0.0094	--	0.042	--	4.52
A	0.0094	--	0.031	--	3.31
A	0.0094	--	0.040	--	4.24
A	0.0094	--	0.027	--	2.88
A	0.0094	--	0.003	--	0.37
B	0.0094	--	0.040	--	4.27
B	0.0094	--	0.034	--	3.67
B	0.0094	--	0.029	--	3.05
B	0.0094	--	0.046	--	4.89
B	0.0094	--	0.021	--	2.29
C	0.0094	--	0.014	--	1.46
C	0.0094	--	0.019	--	2.06
C	0.0094	--	0.022	--	2.34
C	0.0094	--	0.009	--	0.99
C	0.0094	--	0.013	--	1.33

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of exposure during applications using aerosol cans, the following limitations are noted:

- The study monitored individuals during applications to indoor locations which introduces uncertainty when using the data to assess applications outdoors.

Table C-198: Exposure Study Identification Information

Citation	Selim, S. (2002) Measurement of Air Concentration, Dermal Exposure, and Deposition of Pyrethrin and Piperonyl Butoxide Following the Use of an Aerosol Spray
EPA MRID	46188618
ORETF Code	NA
EPA Review	none
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: One individual performed a total of 4 applications (2 per day) using an aerosol can to treat a 16 ft. x 16 ft. x 8 ft. room. Each application consisted of holding the can upright and spraying for approximately 10 seconds in a sweeping motion. It was unclear from the study report the amount of active ingredient handled per application. Dermal exposure was measured for hands only, using cotton gloves. Inhalation exposure was measured using standard pumps (set at 1 liter per minute), cassettes, and tubing. The overall average recoveries ± standard deviation of laboratory fortified controls for air sampling tubes were 83.5 ± 11.8% and 93.5 ± 12.1 % for PYI (pyrethrin) and PBO (piperonyl butoxide) respectively. The overall average recoveries ± standard deviation of laboratory fortified controls for cotton gloves were 83.0 ± 12.1% and 87.3 ± 9.52% for PYI (pyrethrin) and PBO (piperonyl butoxide) respectively. The overall average recoveries ± standard deviation of field fortified controls for air sampling tubes were 84.9 ± 8.87% for PYI (pyrethrin) and 93.6 ± 6.04% for PBO (piperonyl butoxide), and 79.6 ± 3.07% for PYI (pyrethrin) and 83.3 ± 6.64% for PBO (piperonyl butoxide) for cotton gloves.

Table C-199: MRID 46186618 – Checklist and Use Recommendation

Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	No	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**No**	**No**

Data Summary: A summary of the data from this study is not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Limitations: Any data limitations associated with the exposure data in this study are not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Scenario Summary

Table C-200: Scenario Description and Available Exposure Studies	
Formulation	Wettable Powder (WP)
Equipment/Application Method	Manually-pressurized handwand (also: pump sprayer)
Application Site(s)	outdoors (lawns, gardens, trees/bushes, perimeter, mounds/nests, aquatic areas), indoors (general broadcast treatments, baseboards, cracks and crevices)
Available Exposure Studies	Merricks, L. (1987); MRID 40504823
	PHED 458
	PHED 416

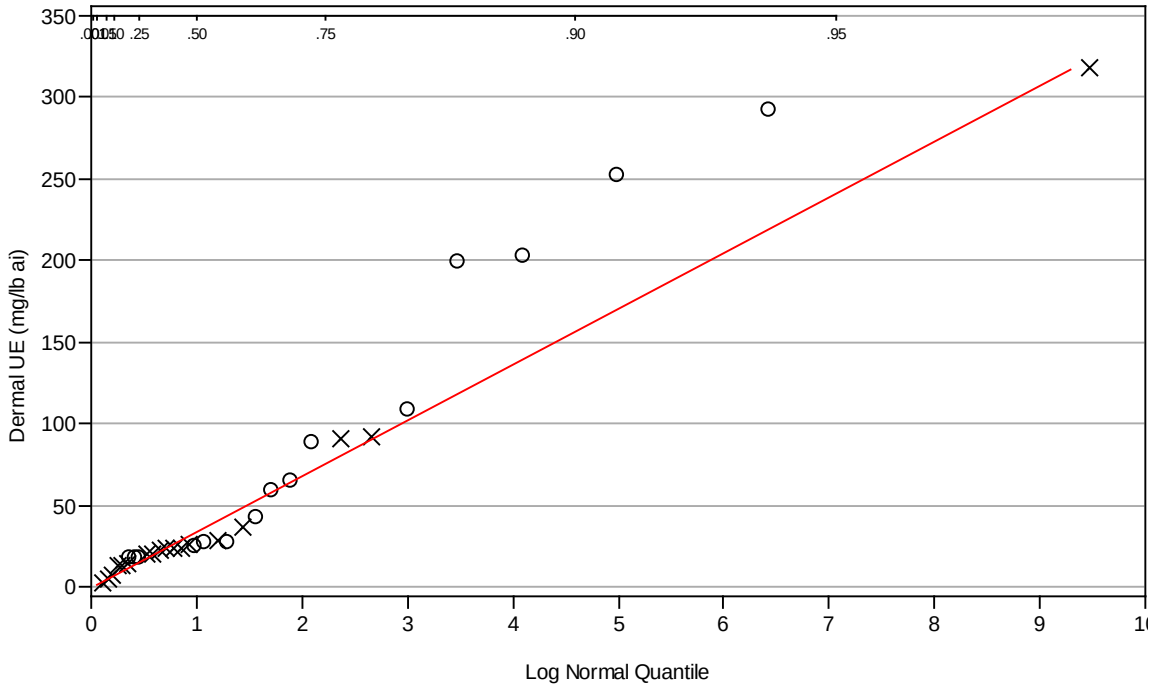
Table C-201: Unit Exposures (mg/lb ai) – WP Manually-pressurized Handwand Applications		
Statistic	Dermal	Inhalation
50th percentile	34	0.63
75th percentile	76	1.3
95th percentile	240	3.7
99th percentile	540	7.7
99.9th percentile	1300	18
AM (SD)	69 (120)	1.1 (1.67)
GM (GSD)	34 (3.30)	0.63 (2.9)
Range	2 – 320	0.17 – 5.1
N	33	16

Dermal Unit Exposure Summary: The recommended dermal unit exposures for applications of wettable powder pesticide formulations using a manually-pressurized handwand to outdoor and indoor environments is based on a lognormal distribution fit with exposure monitoring data from Merricks, L. (1987) [EPA MRID 40504823] and PHED 458. Merricks, L. (1987) monitored 18 applications of a wettable powder formulation in homes and commercial buildings with 2, 1-gallon "B&G stainless steel PCO sprayers" (i.e., a manually-pressurized handwand). PHED 458 monitored 16 applications of a wettable powder formulation in homes for approximately 1-2.5 hours using a 1-gallon hand compression sprayer. Both available studies were considered reasonable representations of residential applications for this scenario and the exposure monitoring allowed for representation of the type of clothing a homeowner or amateur applicator would wear (i.e., shorts, short-sleeve shirt, no chemical-resistant gloves). As the exposure results were generally of the same magnitude, the studies were combined as one dataset.

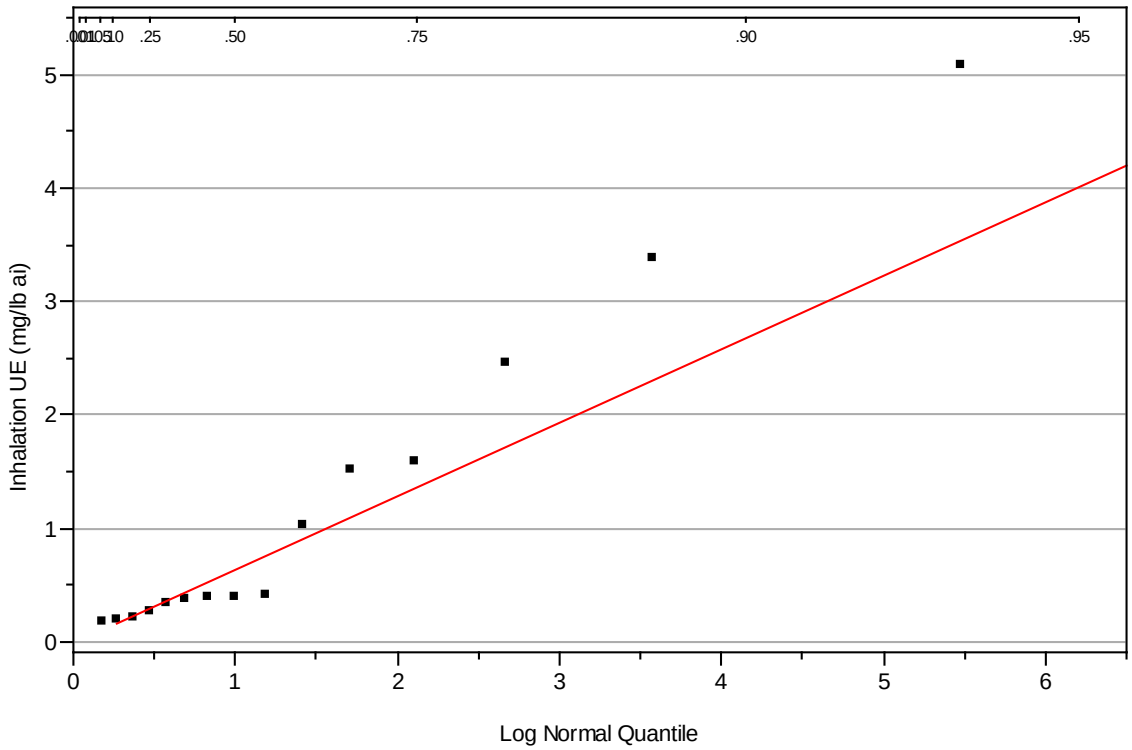
Inhalation Unit Exposure Summary: The recommended inhalation unit exposures for applications of wettable powder pesticide formulations using a manually-pressurized handwand to outdoor and indoor environments is based on a lognormal distribution fit with exposure monitoring data from PHED 458. PHED 458 monitored 16 applications of a wettable powder formulation in homes for approximately 1-2.5 hours using a 1-gallon hand compression sprayer. Another available study consisted of non-detect samples, so PHED 458 was selected for use.

Lognormal Probability Plot

Legend: O = PHED 458; X = Merricks, L. (1987)



Legend: ■ = PHED 458



Available Handler Exposure Studies

Table C-202: Exposure Study Identification Information	
Citation	Merricks, L. (1987). Potential Exposure to Acephate During and After Application of Orthene PCO Spray Concentrate by Commercial Pest Control Operators
EPA MRID	40504823
ORETF Code	NA
EPA Review	D270363
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Nine different individuals were monitored each at a home and in a commercial building (for a total of 18 application events) while mixing and applying a liquid solution (mixed from an acephate wettable powder formulation) using a "B&G stainless steel PCO sprayer" (i.e., a manually-pressurized handwand). Each applicator mixed 2, 1-gallon solutions and applied 1 quart to baseboards and cracks and crevices, handling approximately 80 gms of acephate (0.176 lbs). Dermal exposure was measured using gauze patches (both inside and outside normal work clothing) and cotton gloves for hand exposure. Inhalation exposure was measured using standard pumps (set at 1 liter per minute), cassettes, and tubing. All but one inhalation exposure sample was non-detect. The overall acephate recovery from control samples fortified in the laboratory and analyzed with field samples was 103% for alpha-cellulose, 101% for gloves, and 96% for polyurethane foam plugs. Overall recovery from laboratory fortified samples was 107% for gloves, 103% for alpha-cellulose, and 83% for polyurethane foam plugs.

Table C-203: MRID 40504823 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	Yes	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**No**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Note that only the dermal exposure data are presented as the inhalation exposure data are not recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-204: MRID 40504823 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
A	0.176	4.88	--	27.7	--
B	0.176	0.39	--	2.2	--

Table C-204: MRID 40504823 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
C	0.176	2.15	--	12.2	--
D	0.176	3.37	--	19.1	--
E	0.176	2.10	--	12.0	--
F	0.176	15.87	--	90.2	--
G	0.176	16.00	--	90.9	--
H	0.176	3.47	--	19.7	--
I	0.176	3.83	--	21.7	--
A	0.176	55.91	--	317.7	--
B	0.176	0.80	--	4.6	--
C	0.176	3.97	--	22.6	--
D	0.176	4.42	--	25.1	--
E	0.176	1.06	--	6.0	--
F	0.176	6.28	--	35.7	--
G	0.176	3.99	--	22.6	--
H	0.176	2.45	--	13.9	--
I	0.176	4.00	--	22.7	--

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of exposure during applications using a manually-pressurized handwand to mix, load, and apply wettable powder formulations, the following limitations are noted:

- The study monitored individuals during applications to indoor locations which introduces uncertainty when using the data to assess applications outdoors.
- An estimated 90% of (non-hand) dermal exposure measurements were non-detects (1/2 the limit of detection, 0.01 μg per sample was used).

Table C-205: Exposure Study Identification Information	
Citation	PHED 458
EPA MRID	NA
ORETF Code	NA
EPA Review	none

MRID = Master Record Identification
ORETF = Outdoor Residential Exposure Task Force

Study Description: Three separate individuals were monitored in multiple houses for a total of 16 application events while mixing, loading, and applying a wettable powder formulation (70% active ingredient) in homes using a 1-gallon hand compression sprayer. Each application ranged from 1 to 2.5 hours and the applicators handled from 0.1 to 0.25 lbs of active ingredient. Dermal exposure was measured using gauze patches (both inside and outside normal work clothing) and hand rinses to measure hand exposure. Inhalation exposure was measured using standard pumps (set at 1 liter per minute), cassettes, and tubing. Average laboratory recovery values for air filters were 92.5% with a 5.4% standard deviation, for gauze pads 108% with a 3.6% standard

deviation, for hand washes (200 µg) 99.2% with a 0.5% standard deviation, and for hand washes (1,000 µg) 97.3% with a 0.8% standard deviation. Field recovery experiments were not performed for this specific study. The registrant assumed that the indoor laboratory conditions were similar to the indoor environmental conditions of the study houses. However, temperature and humidity were not reported for the laboratory or the study houses to allow comparison of the indoor environments. Furthermore, the study report does not specify the length of time the gauze pads and hand rinse solutions were exposed to the laboratory conditions.

Table C-206: PHED 458 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	No	Yes
Should this study be recommended for use in residential handler exposure assessments?	**Yes**	**Yes**

Data Summary: The following table summarizes pertinent exposure information from the above referenced study. Both dermal and inhalation exposure are included since both are recommended for use in residential handler exposure assessment. The submitted study itself or corresponding analytical spreadsheets should be reviewed for further information.

Table C-207: PHED 458 – Data Summary					
Person ID	AaiH[1] (lbs)	Exposure (mg)		Unit Exposure (mg/lb ai)[4]	
		Dermal[2]	Inhalation[3]	Dermal	Inhalation
A	0.09	17.78	0.296	198	3.29
A	0.08	23.82	0.413	298	5.16
A	0.13	31.63	0.306	243	2.35
A	0.09	17.75	0.035	197	0.39
B	0.16	14.09	0.251	88	1.57
B	0.09	5.17	0.132	57	1.47
B	0.22	5.94	0.083	27	0.38
B	0.22	9.49	0.071	43	0.32
B	0.24	26.21	0.095	109	0.40
B	0.13	8.52	0.135	66	1.04
C	0.11	1.94	0.022	18	0.20
C	0.09	2.39	0.038	27	0.42
C	0.13	3.48	0.032	27	0.25
C	0.11	2.02	0.022	18	0.20
C	0.13	2.35	0.023	18	0.18

[1] Amount of active ingredient Handled.
[2] Representative of individuals wearing a short-sleeve shirt, shorts, shoes, socks and no chemical-resistant gloves.
[3] Inhalation exposure (mg) = mg collected/pump flow rate (Lpm) * Breathing Rate (16.7 Lpm).
[4] Unit Exposure = Exposure/AaiH.

Limitations: Though the above referenced study is useful for assessment of exposure during applications using a manually-pressurized handwand to mix, load, and apply wettable powder formulations, the following limitations are noted:

- The study monitored individuals during applications to indoor locations which introduces uncertainty when using the data to assess applications outdoors.
- The individuals monitored wore chemical-resistant gloves; therefore back-calculation using a standard penetration factor of 90% was required.

Table C-208: Exposure Study Identification Information	
Citation	PHED 416
EPA MRID	NA
ORETF Code	NA
EPA Review	none
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Four individuals were monitored while spraying greenhouse ornamentals using a hand pump sprayer – the loading and mixing of the wettable powder formulation into the sprayer tank was monitored separately. Each application lasted approximately 1 hour and consisted of spraying approximately 12 tank loads (3 gallons each) and handling approximately 1.2 lbs of active ingredient. Dermal exposure was measured using gauze patches (outside and underneath long-sleeve shirt and long pants) and hand rinses. All workers wore chemical-resistant gloves. Inhalation exposure was measured using standard pumps (set at 2 liters per minute), cassettes, and tubing. Mean laboratory control and spiked samples for handwash solutions, gauze pads, and air filters are 85.4%, 97.7%, and 119.3%, respectively. The average recovery for field spike samples for handwash solutions, gauze pads, and air filters were 89.4%, 96.8%, and 104.5% respectively.

Table C-209: PHED 416 – Checklist and Use Recommendation for		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	Yes	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	Yes	Yes
Should this study be recommended for use in residential handler exposure assessments?	**No**	**No**

Data Summary: A summary of the data from this study is not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Limitations: Any data limitations associated with the exposure data in this study are not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Scenario Summary

Table C-210: Scenario Description and Available Exposure Studies	
Formulation	Wettable Powder (WP)
Equipment/Application Method	Backpack sprayer
Application Site(s)	outdoors (lawns, gardens, trees/bushes, perimeter, mounds/nests, aquatic areas), indoors (general broadcast treatments, baseboards, cracks and crevices)
	Findlay, M.L. (1998); MRID 44493001

Table C-211: Unit Exposures (mg/lb ai) – WP Backpack Sprayer Applications		
Statistic	Dermal	Inhalation
50th percentile	Studies measuring exposure while mixing/loading/applying wettable powder formulations using a backpack sprayer are available, but not recommended for residential handler exposure assessment. Therefore, the exposure studies recommended for mixing/loading/applying wettable powder formulations using a manually-pressurized handwand should be used as a surrogate.	
75th percentile		
95th percentile		
99th percentile		
99.9th percentile		
AM (SD)		
GM (GSD)		
Range		
N		

Dermal Unit Exposure Summary: Dermal exposure monitoring data for applications of wettable powder formulations using backpack sprayer is available but not recommended for use in residential exposure assessments; dermal unit exposures for applications of wettable powder pesticide formulations using a manually-pressurized handwand are recommended as surrogate data.

Inhalation Unit Exposure Summary: Inhalation exposure monitoring data for applications of wettable powder formulations using backpack sprayer is available but not recommended for use in residential exposure assessments; inhalation unit exposures for applications of wettable powder pesticide formulations using a manually-pressurized handwand are recommended as surrogate data.

Available Handler Exposure Studies

Table C-212: Exposure Study Identification Information	
Citation	Findlay, M.L. (1998). Diquat: Worker Exposure During Mixing, Loading and Application of Reglone® with Knapsack Sprayers
EPA MRID	44493001
ORETF Code	NA
EPA Review	D222970
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Study Description: Four different workers were monitored on 5 different days while mixing, loading, and applying a wettable powder formulation (36.4% diquat) to banana plantations in Guatemala using backpack sprayers. Each application was approximately 6 hours and consisted of handling approximately 0.77 lbs diquat. Dermal exposure was measured using whole body dosimetry (the dosimeter served as the workers actual clothing; exposure representative of "no clothing") and hand washes underneath chemical-resistant gloves. Inhalation exposure was measured using standard pumps (set at 2 liters per minute), cassettes, and tubing. Laboratory fortified samples of cotton material with a fortification level of 25 µg/sample had a range of recovery (%) of 90-110, and a mean ± SD of recovery (%) of 99.4 ± 8.0; with a fortification level of 250 µg/sample had a range of recovery (%) of 70-99, and a mean ± SD of Recovery (%) of 89.8 ± 9.8. Samples of handwash solution with a fortification level of 10 µg/sample had a range of recovery (%) of 84-95, and a mean ± SD of recovery (%) of 90.7% ± 5.9; with a fortification level of 100 µg/sample had a range of recovery (%) of 82-105, and a mean ± SD of recovery (%) of 96.0 ± 9.4. Samples of air filters with a fortification level of 1.25 µg/sample had a range of recovery (%) of 98-98, and a mean ± SD of recovery (%) of 98.0 ±0; with a fortification level of 12.5 µg/sample had a range of recovery (%) of 90-104 and a mean ± SD of recovery (%) of 98.0 ± 7.2. The mean recovery of diquat from the clothing and handwash was 69% and 68%, respectively. On day one, the recovery of diquat from the clothing and handwash was 90% and 89%, and on day 2 the recovery was 80% and 125%, respectively. On days 3, 4, and 5, the recoveries were low at 59%, 56%, and 61%, respectively fro the clothing, and 54%, 45%, and 29%, respectively, for the handwash. The mean recovery of diquat from glass fibre filters prepared under field conditions was 77% and ranged from 70 – 81%.

Table C-213: MRID 44493001 – Checklist and Use Recommendation		
Study Criteria	Exposure Component	
	Dermal	Inhalation
Does the study provide detailed characteristics on the activity, equipment type, and amount of active ingredient handled?	Yes	
Does dermal exposure monitoring allow for construction of an exposure estimate for individuals wearing short-sleeve shirts, shorts, shoes, socks?	No	NA
Was exposure to the hands representative of bare hands?	No	NA
Was the study intended to simulate "residential" exposure via the scripted activity, amount of active ingredient handled, volunteers used, or the setting?	No	
Is the data of reasonable quality (i.e., are field fortification and laboratory recovery samples adequate)?	No	Yes
Should this study be recommended for use in residential handler exposure assessments?	**No**	**No**

Data Summary: A summary of the data from this study is not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

Limitations: Any data limitations associated with the exposure data in this study are not provided since it is not recommended for use in residential handler exposure assessment. The submitted study itself should be reviewed for further information.

C.2 Exposure Factors Used to Calculate Amount of Active Ingredient Handled

C.2.1 Gardens and Trees

Limited information is available for estimating the amount of active ingredient an individual will handle during a pesticide application. Additionally, this factor is likely highly chemical- and product-specific due to the both the application instructions and efficacy of the chemical. Nevertheless, in the absence of chemical- and/or product-specific information, generic information can be useful to enable an exposure assessment.

In the case of gardens and trees, both garden size and amount of volume sprayed can be used generically to estimate the amount of active ingredient handled.

C.2.1.1 Garden Size

For application rates in terms of area (e.g., 2 lbs active ingredient per 1000 square feet), the size of a garden can be used to estimate the amount of active ingredient handled per application. The table below summarizes the results of a survey (Johnson, et al., 1999) which included responses to a question regarding garden size.

Table C-214: Home Garden Size (ft^2)

N	(% response)				
	< 250	**250 – 749**	**750 – 2399**	**> 2400**	**DNK**
364	56.2	13.2	6.9	6.2	17.5

DNK = did not know
Source: Johnson, et al., 1999. National Gardening Association Survey (EPA MRID 44972202)

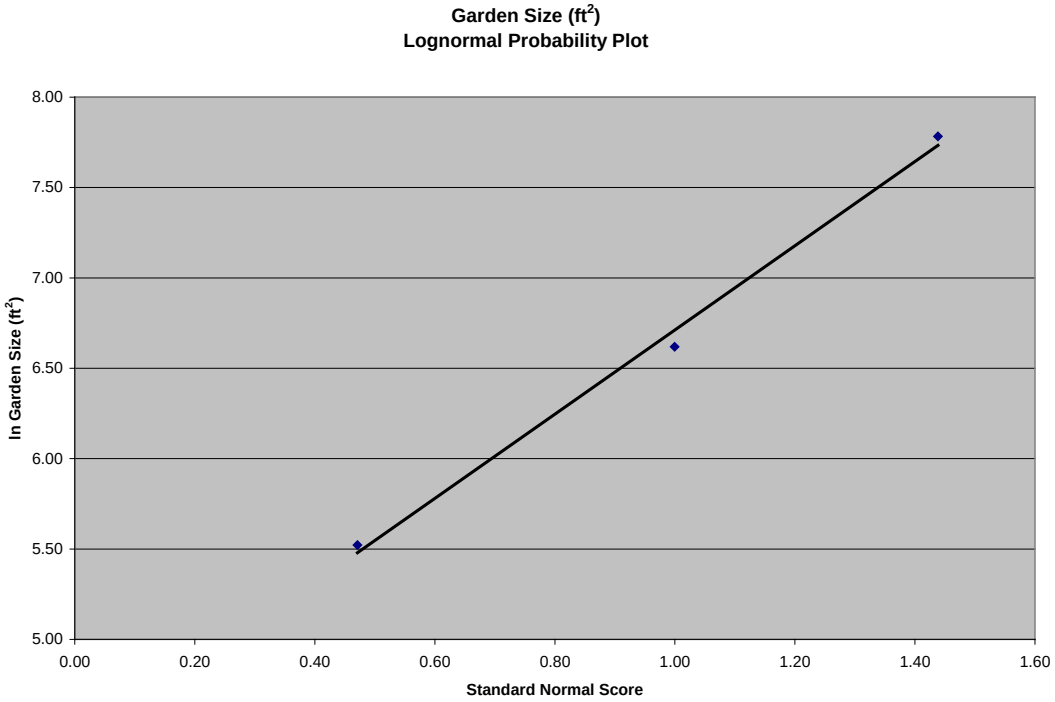
Because the actual responses are unavailable, the percent response values in the table above were adjusted based on the % "did not know" response (17.5%) and used as cumulative percentiles shown in the table below:

Table C-215: Home Garden Size (ft^2)

	(% response)			
	< 250	**250 – 749**	**750 – 2399**	**> 2400**
Reported % response	56.2	13.2	6.9	6.2
Adjusted % response[1]	68.1	16.0	8.4	7.5
Cumulative %tile	68.1	84.1	92.5	7.5
Standard Normal Score	0.471	0.999	1.44	NA

[1] Reported % response adjusted for 17.5% DNK response

The data were then fit to a lognormal distribution shown in the probability plot below:



Summary statistics based on the above distribution area provided in the table below.

Table C-216: Statistical Summary – Garden Size (ft^2)	
50^{th} percentile	80
75^{th} percentile	385
90^{th} percentile	1583
95^{th} percentile	3690
99^{th} percentile	18043
99.9^{th} percentile	106887
AM (SD)	1205 (18109)
GM (GSD)	80 (10.3)
Range	unknown
N	364
AM (SD) = arithmetic mean (standard deviation) GM (GSD) = geometric mean (geometric standard deviation)	

C.2.1.2 Hose-end Sprayer Application Volumes

An estimate for the amount of spray solution volume sprayed is necessary if the application rate is used in terms of active ingredient per volume solution. Such a rate would be used for spraying trees where an "area-based" approach would not be appropriate or useful. However, this factor is likely application method-specific (i.e., one might apply more solution using a hose-end sprayer than a sprinkler can) and explicit information on volumes sprayed in home applications is unavailable.

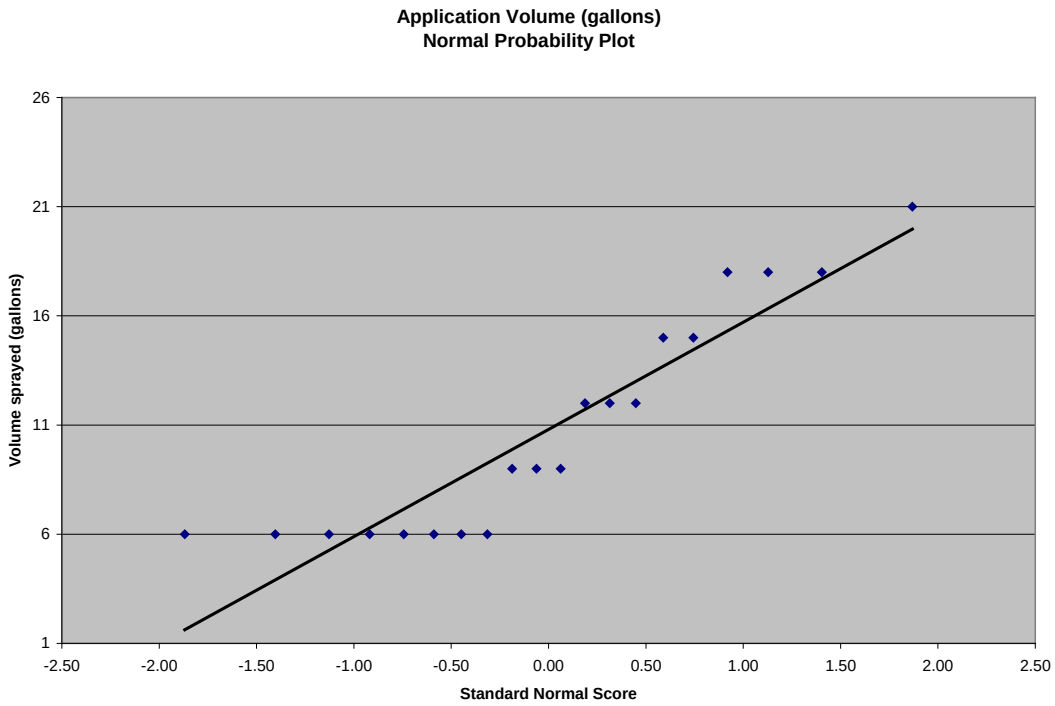
For hose-end sprayers, application volume was derived from a study measuring exposure during applications of liquid formulations to fruit trees and ornamental shrubs using a hose-end sprayer

(Merricks, 1998). For application rates in terms of active ingredient per volume (e.g., 0.1 lbs active ingredient per gallon spray solution), typically appropriate for assessing spray applications to trees and shrubs, estimates for volume of solution sprayed are derived from EPA MRID 44518501 where individuals sprayed ornamental citrus trees and shrubs using a hose-end sprayer and manually-pressurized-pressure handwand. Volumes sprayed for the hose-end sprayer were calculated using the study-specified water flow rate of 3 gallons per minute. Each application ranged from 2 to 7 minutes resulting in a range of spray volumes from 6 to 21 gallons. The table below provides a summary of the relevant information.

Table C-217: Application Volume Summary from EPA MRID 44518501

Applicator ID	Application Time (minutes)	Flow rate (gallons/minute)	Application volume (gallons)
A	3	3	9
B	4	3	12
C	6	3	18
D	5	3	15
E	2	3	6
F	3	3	9
G	2	3	6
H	2	3	6
I	2	3	6
J	2	3	6
K	2	3	6
L	4	3	12
M	4	3	12
N	7	3	21
O	6	3	18
P	2	3	6
Q	5	3	15
R	3	3	9
S	6	3	18
T	2	3	6

The data were fit to a normal distribution shown in the probability plot below.



Summary statistics for application volume are presented in the table below.

Table C-218: Statistical Summary – Hose-end Sprayer Application Volume (gallons)	
50th percentile	11
75th percentile	14
90th percentile	17
95th percentile	19
99th percentile	22
99.9th percentile	26
AM (SD)	11 (5.1)
GM (GSD)	10 (1.57)
Range	6 – 21
N	20
AM (SD) = arithmetic mean (standard deviation) GM (GSD) = geometric mean (geometric standard deviation)	

For all other applications, reliable information on the amount of product used is unavailable. For manually-pressurized handwands, backpacks, and sprinkler cans a uniform distribution of 2 to 5 gallons is recommended. For aerosol cans and trigger-sprayers a uniform distribution of 0.5 to 2 cans/containers is recommended.

Appendix D Supporting Data Analysis and Documentation for Residential Post-Application Exposure Assessment

D.1 Indoor Fogger Settling Time

For indoor foggers, post-application inhalation exposure is not anticipated because the fogger labels typically require re-entry restrictions. If necessary, the time needed for particle settling can be calculated using Stokes law. The settling velocity (in m/s) is calculated as a function of the droplet diameter (m), the particle density (kg/m^3), the gravity constant (m/s^2) and the viscosity of air (kg/m-s). Information provided by manufacturers indicates that the particle size distribution for most total release foggers ranges from 15 micrometers (μm) to 60 μm. According to calculations of settling time versus droplet size, it will take 2 hours for a 15 micrometer particle to settle and 8 minutes for a 60 micrometer particle to settle from an eight-foot ceiling height, assuming 1% non-volatile ingredients. This calculation is based on the assumption that a 15 micrometer droplet will decrease to a 3 micrometer nuclei and a 60 micrometer droplet will decrease to a 13 micrometer nuclei due to evaporation.

Table D-1: Droplet Diameter After Evaporation (i.e., nuclei diameter)

Drop Diameter (μm)	Drop Radius (μm)[a]	% Non-volatiles[b]	Drop Volume (μm^3)[c]	Nuclei Volume (μm^3)[d]	Nuclei Radius (μm)[e]	Nuclei Diameter (μm)[f]
1	0.5	1%	1	0.01	0.11	0.22
5	2.5	1%	65	1	1	1
10	5	1%	523	5	1	2
15	**7.5**	**1%**	**1766**	**18**	**2**	**3**
20	10	1%	4187	42	2	4
30	15	1%	14130	141	3	6
40	20	1%	33493	335	4	9
50	25	1%	65417	654	5	11
60	**30**	**1%**	**113040**	**1130**	**6**	**13**
70	35	1%	179503	1795	8	15
80	40	1%	267947	2679	9	17
90	45	1%	381510	3815	10	19
100	50	1%	523333	5233	11	22

a. Drop radius = drop diameter / 2
b. Nuclei = non-volatile portion of droplet; assume percent non-volatiles of pesticide particle = 1%
c. Volume of sphere = 4/3 * π * (r^3)
d. Nuclei volume = drop volume * percent non-volatiles
e. Nuclei radius = (nuclei volume / (1.33 * π))^0.333
f. Nuclei diameter = nuclei radius * 2

Table D-2: Settling Time

Drop Diameter (μm)	Nuclei Diameter		Density of particles (kg/m^3)[b]	Gravity constant (m/s^2)	Viscosity of air (kg/m-s @ 25°C)	Settling Velocity (m/s)[c]	Settling Time (Release Height = 8 feet)		
	μm	m[a]					Seconds[d]	Minutes[e]	Hours[f]
1	0.22	2.2E-07	1000	9.807	1.86E-05	1.4E-06	1782494	29708	495
5	1.08	1.1E-06	1000	9.807	1.86E-05	3.4E-05	71530	1192	20

Table D-2: Settling Time									
Drop Diameter (μm)	Nuclei Diameter		Density of particles (kg/m^3)[b]	Gravity constant (m/s^2)	Viscosity of air (kg/m-s @ 25°C)	Settling Velocity (m/s)[c]	Settling Time (Release Height = 8 feet)		
	μm	m[a]					Seconds[d]	Minutes[e]	Hours[f]
10	2.16	2.2E-06	1000	9.807	1.86E-05	1.4E-04	17907	298	5
15	**3.23**	**3.2E-06**	**1000**	**9.807**	**1.86E-05**	**3.1E-04**	**7965**	**133**	**2**
20	4.31	4.3E-06	1000	9.807	1.86E-05	5.4E-04	4483	75	1
30	6.46	6.5E-06	1000	9.807	1.86E-05	1.2E-03	1994	33	1
40	8.61	8.6E-06	1000	9.807	1.86E-05	2.2E-03	1122	19	0.3
50	10.76	1.1E-05	1000	9.807	1.86E-05	3.4E-03	719	12	0.2
60	**12.91**	**1.3E-05**	**1000**	**9.807**	**1.86E-05**	**4.9E-03**	**499**	**8**	**0.14**
70	15.06	1.5E-05	1000	9.807	1.86E-05	6.6E-03	367	6	0.10
80	17.21	1.7E-05	1000	9.807	1.86E-05	8.7E-03	281	5	0.08
90	19.36	1.9E-05	1000	9.807	1.86E-05	1.1E-02	222	4	0.06
100	21.51	2.2E-05	1000	9.807	1.86E-05	1.4E-02	180	3	0.05
150	32.25	3.2E-05	1000	9.807	1.86E-05	3.0E-02	80	1	0.02
200	42.99	4.3E-05	1000	9.807	1.86E-05	5.4E-02	45	1	0.013
300	64.46	6.4E-05	1000	9.807	1.86E-05	1.2E-01	20	0.3	0.006
400	85.93	8.6E-05	1000	9.807	1.86E-05	2.2E-01	11	0.2	0.003
500	107.38	1.1E-04	1000	9.807	1.86E-05	3.4E-01	7	0.1	0.002

a. 1 μm = 1 x 10^{-6} m

b. Assumption based on literature search: (1) Bennett and Furtaw. 2004. Fugacity-Based Indoor Residential Pesticide Fate Model. Environmental Science & Technology, 38 (7): 2142-2152. (2) Lai and Nazaroff. 2000. Modeling Indoor Particle Deposition from Turbulent Flow onto Smooth Surfaces. J. Aerosol Sci. 31 (4): 463-476. (3) Riley et al. 2002. Indoor Particulate Matter of Outdoor Origin: Importance of Size-Dependent Removal Mechanisms. 36: 200-207.

c. Settling velocity (m/s) = [(density of particle, kg/m^3) * (nuclei diameter, m)^2 * (gravity constant, m/s^2)] / [18 * (viscosity of air, kg/m-s)]

d. Settling time from height of 8 feet in seconds = [8 ft * (0.3048 m/ft)] * (settling velocity, m/s)

e. Settling time in minutes = settling time in seconds / 60

f. Settling time in hours = settling time in minutes / 60

D.2 Background on Multi-Chamber Concentration and Exposure Model (MCCEM)

Indoor air concentrations can be calculated using a computer model, Multi- Chamber Concentration and Exposure Model (*MCCEM).* *MCCEM* is a model that is capable of calculating indoor air concentrations for various exposure durations. *MCCEM* contains a database of various default house data, such as air exchange rates, geographically based inter-room air flows, and house/room volumes. Unique house specifications may also be created according to the scenario being assessed.

Chemical source emission rates of pollutants are entered into the model and *MCCEM* can account for removal processes and the contribution of outdoor concentrations. The model is also capable of performing sensitivity analyses and Monte Carlo analyses. However, because this SOP is focused on high-end assessments, only the aspects of *MCCEM* determined to produce high end results are addressed herein. The essential aspects of *MCCEM* that must be defined to complete a high-end assessment include the following:

- type of house (selection based on number of stories and house volume),

- definition of zones for selected house (single or multi-zone up to 4 indoor zones),
- selection of model (run time and reporting intervals),
- selection/calculation of appropriate emission rate inputs for chemical/product, and
- selection of removal processes for the chemical/product (presence of sinks).

Input parameters can be adjusted according to scenarios unique to specific assessments, however, *Table D-3* includes *MCCEM* parameters that are appropriate for a high-end calculation. *MCCEM* requires further input to operate the model.

Table D-3: High-end Scenario Guidance for MCCEM

Use Scenario	House Selection (GN001)		Chamber Type (Number Zones)b	Durationc (days)			Emissions Parametersd		MCCEM Decay Ratee
	House Type/ Season	Air Exchange Ratea (xch/hr)		Run Time (days)	Time Steps (hours)		Type	Rate	
					Acute	Chronic			
Total Release Aerosolf	Generic/ Summer	0.18	Multi (2)	90	1	24	Instant Release	Total/hr	0
Indoor Space Spraysf	Generic/ Summer	0.18	Multi (2)	90	1	24	Instant Release	Total/h	0
Broadcast	Generic/ Summer	0.18	Multi (2)	90	1	24	Chinn Evaporation	Chinn Rate	0
Perimeter	Generic/ Summer	0.18	Multi (2)	90	1	24	Chinn Evaporation	Chinn Rate	0
Crack and Crevice	Generic/ Summer	0.18	Single (1)	90	1	24	Chinn Evaporation	Chinn Rate	0
Termiticides	Generic/ Summer	0.18	Single (1)	365			Chinn Evaporation	Chinn Rate	0
Carpet Dusting	Generic/ Summer	0.18	Multi (2)	90	1	24	Chinn Evaporation	Chinn Rate	0

a. The value of 0.18 ACH corresponds to the 10th percentile of the estimated national distribution for residential air exchange rates. (U.S. EPA 2011).
b. Chamber type is reflected in the house selection and must correlate with the Execution Mode (Step 8).
c. Duration refers to the length of time that the chemical exposure concentration is modeled, as well as the time steps for recording the calculated exposure concentration.
d. Instant release represents when a chemical is "thrown up" in the air of a residence as an aerosol immediately -- less than 1 hour; Chinn Evaporation is when a pesticide offgasses from the treated surfaces for several weeks; See Step 3 and the associated *Figure D-1* below for details concerning the calculation of Chinn release emission rates.
e. Decay rate is chemical specific. For high-end estimates the chemical is considered non-reactive.
f. These two use scenarios include the use of aerosol sprays for which this model may be an overestimation of air concentrations.

Step-by-step procedures for completing a high-end assessment using *MCCEM Version 1.2* are presented below.

Step 1: <u>House Tab:</u> Select the "Generic House" (House Code: GN001) option within the Residence Type section. This provides a conservative air exchange rate of 0.18 ACH.

Step 2: <u>Run Time:</u> The long-term model is appropriate for all high-end assessments. For the purposes of this SOP, 1-hour steps should be used for an acute endpoint while a 24-hour step should be used for a longer-term endpoint.

Step 3: Emission Rate & Exposure Zone Inputs: For the high-end assessment requirement, select "Constant" as the source model definition. Two emission mechanisms may be inputted for the constant emissions rate:

- For instant release scenarios, the emissions rate is calculated as the mass of product released per hour.
- For the Chinn type or long-term emission (e.g., offgassing from treated surfaces for several weeks), the emission rate is calculated based on an empirical relationship between evaporation time, vapor pressure, and molecular weight (Chinn, 1981). The equations used to calculate a Chinn Type emission rate and an example calculation are presented in *Figure D-1*.

Step 4: Sinks: No inputs are entered in this field. Unless information regarding the absorption rate and sink area for reversible and/or irreversible sinks are available to characterize the sink, the chemical is considered to be nonreactive.

Step 5: Activities: No contributions of occupant activities or breathing rates are entered.

Step 6: Dose: Dose is not calculated for high end estimates for the purposes of this SOP. No values are inputted.

Step 7: Monte Carlo Options: Ensure that "Apply Model Once" and "Randomly Select Seed" are selected. Monte Carlo Assessments are not conducted for the purpose of a high-end assessment.

Step 8: Options: Ensure that "Use Interzonal Airflow Rates Provided" ("Single Chamber Model" may be run if the application is throughout all rooms in the house) and the appropriate "Output Concentration Units" are selected. Unless initial concentration data exists, input parameters should be "0".

Step 9: Execute the Model: Run the model and save the output and data (.csv) files for review purposes.

Figure D-1: Calculation of Chinn Release Emission Rates

Calculate the mass of active ingredient applied (m) in grams during a single application event. Next calculate the Chinn Evaporation time using the following formula (Chinn, 1981):

$$d = \frac{145}{(mw * vp)^{0.9546}}$$

where:

d = Chinn evaporation time (hr);
mw = molecular weight of pesticide active ingredient (unitless); and
vp = vapor pressure (torr).

Finally, calculate the emission rate (g/hr) using the following formula

$$er = \frac{mw}{d}$$

Example:

3 gallons of solution containing 500 grams of ai with a vapor pressure of $5x10^{-4}$ torr and a molecular weight of 500 are applied in a typical crack-and-crevice scenario, then:

$$d = \frac{145}{(500 * 5 * 10^{-4})^{0.9546}} = 545 hours$$

and

$$er = \frac{500}{545} = 0.91 \frac{grams}{hour}$$

Selection of the proper air concentration value (AC_t) from *MCCEM* to be used in the exposure assessment depends on the inhalation toxicological endpoint (i.e., acute or chronic). The "average concentration in the Zone 1" is selected for an acute endpoint. This value is used even if a multi-chamber model run is completed because Zone 1 will have slightly higher concentration values as it will always be designated as the release zone. If the endpoint is chronic, the “Time-Weighted-Average (TWA)" value is selected for Zone 1.

D.3 Background on Well-Mixed Box Model

D.3.1 Outdoor Fogging/Misting Systems - Aerosol Spray Area Foggers

The well-mixed box (WMB) model was used to develop the exposure equation (5.5) for the aerosol spray area foggers post-application inhalation scenario. The WMB was used to model pesticide air concentrations within an enclosed, fixed volume (i.e. a box) over time after an initial aerosol spray application of an area fogger. The WMB model incorporates a number of simplifying assumptions: fresh air (having zero pesticide concentration) enters the box at a constant airflow rate, a turbulent internal airflow thoroughly mixes the fresh air with the pesticide-laden air resulting in a uniform pesticide air concentration within the box, and the perfectly mixed air exits the box at the same constant airflow rate (i.e. the inflow rate equals the outflow rate). Thus the outdoor area where the aerosol is being applied is assumed to be in an enclosed box, therefore, using the WMB model is conservative for estimation of exposures for an open patio or deck.

The removal of the aerosol from the box depends on airflow. For an outdoor scenario, the airflow, Q, is the product of the cross-sectional area and the wind velocity. The WMB model developed for this scenario models the pesticide air concentrations *after* an initial, instantaneous release of an aerosol spray area repellant. Only dissipation due to airflow into and out of the box is modeled. The mass balance within the box can be described by the following differential equation:

$$V\frac{dC}{dt} = -Q \cdot C$$

$$\frac{dC}{C} = -\frac{Q}{V}dt$$

where **C** is the air concentration, **Q** is the airflow (the product of the cross-sectional area of the box and the wind speed), and **V** is the volume of the box. Integrating the differential equation and simplifying and combining terms yields an equation describing the air concentration over time.

$$\int\frac{dC}{C} = -\int\frac{Q}{V}dt$$

$$\ln(C) = -\frac{Q}{V}t + a$$

$$e^{\ln(C)} = e^{-\frac{Q}{V}t+a}$$

where $A = e^a$ is a constant whose value is determined by the initial condition that at time t = 0, the pesticide air concentration is equal to initial air concentration, i.e. $C(0) = C_0$. Based on this initial constraint, the WMB model described above for modeling pesticide air concentrations over time can be written as follows:

$$C(t) = C_0 e^{-\frac{Q}{V}t} \qquad \text{(D.1)}$$

where **C(t)** is the air concentration at time **t**, $\mathbf{C_0}$ is the initial air concentration (i.e. concentration at time t=0), **Q** is the airflow (the product of the cross-sectional area of the box and the wind speed), and **V** is the volume of the box. The air concentration equation (D.1) is then used to calculate the exposure, E:

$$E = IR \int_0^{ET} C(t)dt \qquad \text{(D.2)}$$

The exposure, **E** is based on integrating equation (D.1) over the exposure time, **ET** which is then multiplied by an inhalation rate, **IR**. The final exposure equation is derived from equation (D.2) by performing the integration and simplifying terms.

$$E = IR \int_0^{ET} C_0 e^{-\frac{Q}{V}t} dt$$

$$E = IR \cdot C_0 \left(\frac{-1}{Q/V} \right) \left(e^{-\frac{Q}{V}(ET)} - e^{-\frac{Q}{V}(0)} \right)$$

$$E = \frac{IR \cdot C_0}{Q/V} \left(1 - e^{-\frac{Q}{V}(ET)} \right) \qquad \text{(D.3)}$$

The term $e^{-\frac{Q}{V}ET}$ in equation (D.3) represents the fraction of the initial concentration, $\mathbf{C_0}$ present in the treated area at the end of the exposure time, **ET**. To the extent that the pesticide rapidly dissipates, this term will rapidly approach zero. For this scenario, the assumed volume of the outdoor treated space is 20 × 20 × 8 ft^3 and the minimum flow rate is 52.5 ft^3/sec, which based on the minimum air velocity of 0.1 m/s and the cross sectional area of 20 × 8 ft^2 (~15 m^2) from *Table 5-3*. Given these values for **V** and **Q**, one can determine the time after which the term $e^{-\frac{Q}{V}t}$ would be less than 0.001 (i.e. the time after which less than 0.1% of the original concentration remains).

$$V = 20\,ft \times 20\,ft \times 8\,ft\,;\; Q = \left(20\,ft \times 8\,ft\right) \times 0.1 \frac{m}{s} \times 3.28 \frac{ft}{m}$$

$$e^{-\frac{Q}{V}t} = 0.001 \Rightarrow -\frac{Q}{V}t = \ln(0.001) \Rightarrow t = -\frac{\ln(0.001)\times V}{Q}$$

$$t = -\frac{\ln(0.001)\times(20\,ft \times 20\,ft \times 8\,ft)}{(20\,ft \times 8\,ft)\times 0.1\,{}^{m}\!/_{s} \times 3.28\,{}^{ft}\!/_{m}} = 421\,\text{sec} = 7.02\,\text{min}$$

The above calculation demonstrates that after an exposure time of about 7 minutes, less than 0.1% of the initial concentration would be left in the treated space. This implies that the released pesticide fog would be almost completely dissipated for any significant exposure time.

Therefore the term $e^{-\frac{Q}{V}ET}$ – in equation (D.3) approaches zero very quickly, and the exposure equation can be simplified to:

$$E = \frac{IR \cdot C_0}{{}^{Q}\!/_{V}} \qquad \text{(D.4)}$$

The initial concentration, $\mathbf{C_0}$, can be replaced by the term application rate, **AR** (which is specified to have units mg-AI/day for this scenario) divided by **V**, the volume of the treated space. Thus equation (D.4) can be rewritten as:

$$E = \frac{IR \cdot {}^{AR}\!/_{V}}{{}^{Q}\!/_{V}}$$

After canceling out the volume terms, the final exposure equation can be expressed as:

$$E = \frac{IR \cdot AR}{Q} \qquad \text{(D.5)}$$

D.3.2 Outdoor Fogging/Misting Systems - Candles, Coils, Torches, and Mats (CCTM)

The well-mixed box (WMB) model was used to develop exposure equation (5.12) for the candles, coils, torches, and mats (CCTM) post-application inhalation scenario. The CCTM scenario differs from the other exposure scenarios in this Outdoor Fogging/Misting System SOP section in that the WMB model includes a constant emission rate term during the exposure time and thus results in a more complicated exposure equation. The WMB was used to model pesticide air concentrations within an enclosed, fixed volume (i.e. a box) over time during the constant emission of a pesticide from a CCTM product. The WMB model incorporates a number of simplifying assumptions: fresh air (having zero pesticide concentration) enters the box at a constant airflow rate, a turbulent internal airflow thoroughly mixes the fresh air with the pesticide-laden air resulting in a uniform pesticide air concentration within the box, and the perfectly mixed air exits the box at the same constant airflow rate (i.e. the inflow rate equals the outflow rate). Thus the outdoor area where the aerosol is being applied is assumed to be in an enclosed box, therefore, using the WMB model is conservative for estimation of exposures for an open patio or deck.

The removal of the CCTM emission from the box depends on airflow. For an outdoor scenario, the airflow, Q is the product of the cross-sectional area and the wind velocity. The WMB model developed for this scenario models the pesticide air concentrations *during* a constant emission of pesticide from a CCTM product. Only constant emission and dissipation due to airflow into and out of the box is modeled. The mass balance within the box can be described by the following differential equation:

$$V\frac{dC}{dt} = V_E \cdot ER - Q \cdot C$$

$$\frac{dC}{dt} = \frac{V_E \cdot ER}{V} - \frac{Q}{V} \cdot C$$

where **C** is the air concentration, $\mathbf{V_E}$ is the vaporization efficiency, **ER** is the emission rate, **Q** is the airflow (the product of the cross-sectional area of the box and the wind speed), and **V** is the volume of the box. Based on the method of undetermined coefficients, the solution to this differential equation has the form:

$$C(t) = \frac{\frac{V_E \cdot ER}{V}}{\frac{Q}{V}} - A \cdot e^{-\frac{Q}{V}t}$$

$$C(t) = \frac{V_E \cdot ER}{Q} - A \cdot e^{-\frac{Q}{V}t}$$

where A is a constant whose value is determined by the initial condition that at time t = 0, the pesticide air concentration is equal to zero, i.e. C(0) = 0. Based on this initial constraint, the equation describing the air concentration over time can be written as:

$$C(t) = \frac{V_E \cdot ER}{Q} - \frac{V_E \cdot ER}{Q} e^{-\frac{Q}{V}t} \qquad \text{(D.6)}$$

Based on the WMB model described above, which is very similar to the box model described by Fan and Zhang (2001), the equation for modeling pesticide air concentrations over time is as follows:

$$C(t) = \frac{V_E \cdot ER}{Q}\left(1 - e^{-\frac{Q}{V}t}\right) \qquad \text{(D.7)}$$

where **C(t)** is the air concentration at time **t**, $\mathbf{V_E}$ is the vaporization efficiency, **ER** is the emission rate, **Q** is the airflow (the product of the cross-sectional area of the box and the wind speed), and **V** is the volume of the box. The air concentration equation is then used to calculate the exposure, **E**, which is based on integrating equation (D.7) over the exposure time, **ET** which is then multiplied by an inhalation rate, **IR**:

$$E = IR \int_0^{ET} C(t)dt \qquad \text{(D.8)}$$

The final exposure equation is derived from equation (D.8) by performing the integration and simplifying terms.

$$E = IR \int_0^{ET} \frac{V_E \cdot ER}{Q}\left(1 - e^{-\frac{Q}{V}t}\right)dt$$

$$E = \frac{IR \cdot V_E \cdot ER}{Q} \int_0^{ET}\left(1 - e^{-\frac{Q}{V}t}\right)dt$$

$$E = \frac{IR \cdot V_E \cdot ER}{Q} \int_0^{ET} 1dt - \int_0^{ET} e^{-\frac{Q}{V}t}dt$$

$$E = \frac{IR \cdot V_E \cdot ER}{Q}\left[(ET - 0) - \left(-\frac{V}{Q}\right)\left(e^{-\frac{Q}{V}(ET)} - e^{-\frac{Q}{V}(0)}\right)\right]$$

$$E = \frac{IR \cdot V_E \cdot ER}{Q}\left[ET - \left(\frac{V}{Q}\right)\left(1 - e^{-\frac{Q}{V}(ET)}\right)\right] \qquad \text{(D.9)}$$

As in equation (D.3), the term $e^{-\frac{Q}{V}ET}$ in equation (D.9) is less than one and approaches zero as exposure time, **ET** increases. To the extent that the pesticide air concentration rapidly approaches steady state, this term will rapidly approach zero. For this scenario, the assumed volume of the outdoor treated space is 15 × 15 × 8 ft^3 and the minimum flow rate is 39.4 ft^3/sec, which is based on the minimum air velocity of 0.1 m/s and the cross sectional area of 15 × 8 ft^2 (~11 m^2) from ***Table 5-4***. Given these values for **V** and **Q**, one can determine the time after which the term $1 - e^{-\frac{Q}{V}t}$ would be less than 0.001 (i.e. the time after which the air concentration is 99.9% of the steady-state value).

$$V = 15\,ft \times 15\,ft \times 8\,ft\,;\; Q = (15\,ft \times 8\,ft) \times 0.1 \,{}^{m}\!/_{s} \times 3.28 \,{}^{ft}\!/_{m}$$

$$e^{-\frac{Q}{V}t} = 0.001 \Rightarrow -\frac{Q}{V}t = \ln(0.001) \Rightarrow t = -\frac{\ln(0.001) \times V}{Q}$$

$$t = -\frac{\ln(0.001) \times (15\,ft \times 15\,ft \times 8\,ft)}{(15\,ft \times 8\,ft) \times 0.1 \,{}^{m}\!/_{s} \times 3.28 \,{}^{ft}\!/_{m}} = 316\,\text{sec} = 5.27\,\text{min}$$

The above calculation demonstrates that after an exposure time of less than 6 minutes, the air concentration would be more than 99.9% of the steady-state value in the treated space. This implies that the air flow would practically cease to dissipate the pesticide after any significant exposure time. Therefore the term $1 - e^{-\frac{Q}{V}ET}$ in equation (D.9) approaches zero very quickly. Thus the final exposure equation can be simplified to:

$$E = \frac{IR \cdot V_E \cdot ER}{Q}\left(ET - \frac{V}{Q}\right) \qquad \text{(D.10)}$$

D.3.3 Outdoor Fogging/Misting Systems - Outdoor Residential Misting Systems (ORMS)

The well-mixed box (WMB) model was used to develop exposure equation (5.19) for the outdoor residential misting systems (ORMS) post-application inhalation scenario[22]. The WMB model incorporates a number of simplifying assumptions: fresh air (having zero pesticide concentration) enters the box at a constant airflow rate, a turbulent internal airflow thoroughly mixes the fresh air with the pesticide-laden air resulting in a uniform pesticide air concentration within the box, and the perfectly mixed air exits the box at the same constant airflow rate (i.e. the inflow rate equals the outflow rate). Thus the outdoor area where the aerosol is being applied is assumed to be in an enclosed box, therefore, using the WMB model is conservative for estimation of exposures for an open patio, deck, or yard. Also, this scenario assumes instantaneous spray releases, that is, the total amount of aerosol released at each spray event is modeled to occur instantaneously.

The removal of the pesticide from the box depends on airflow. For an outdoor scenario, the airflow, Q is the product of the cross-sectional area and the wind velocity. The WMB model developed for this scenario models the pesticide air concentrations *after* multiple instantaneous aerosol spray releases at regular time intervals[23]. Only dissipation due to airflow into and out of the box is modeled. The mass balance within the box can be described by the following differential equation:

$$V\frac{dC}{dt} = -Q \cdot C$$

$$\frac{dC}{C} = -\frac{Q}{V}dt$$

where **C** is the air concentration, **Q** is the airflow (the product of the cross-sectional area of the box and the wind speed), and **V** is the volume of the box. Integrating the differential equation and simplifying and combining terms yields an equation describing the air concentration over time.

$$\int\frac{dC}{C} = -\int\frac{Q}{V}dt$$

$$\ln(C) = -\frac{Q}{V}t + a$$

$$e^{\ln(C)} = e^{-\frac{Q}{V}t+a}$$

[22] For the ORMS and animal barn scenarios, the WMB models describing the air concentrations over time have the same form. The parameterization of these models is the only difference. For the ORMS scenario, the decay rate constant is specified by the ratio of the airflow rate and the volume of the treated space; whereas for the animal barn scenario, the decay rate constant is specified by the air changes per hour.

[23] The regular spray applications are assumed to continue for the entire time spent outdoors.

$$C = A \cdot e^{-\frac{Q}{V}t}$$

where $A = e^a$ is a constant whose value is determined by the initial condition that at time t = 0, the pesticide air concentration is equal to initial air concentration, i.e. $C(0) = C_0$. Based on this initial constraint, A is set equal to C_0. The WMB model described above for the ORMS scenario is similar to the model used for aerosol area fogger scenario. In fact, the equation for modeling pesticide air concentrations over time after the first spray event (but before the second spray) is exactly the same as equation (D.1) except for the subscript on the left-hand side denoting the number of applications:

$$C_1(t) = C_0 e^{-\frac{Q}{V}t} \qquad \text{(D.11)}$$

where **C(t)** is the air concentration at time **t** after the initial spray, $\mathbf{C_0}$ is the initial air concentration (i.e. concentration at time t=0), **Q** is the airflow (the product of the cross-sectional area of the box and the wind speed), and **V** is the volume of the box.

Assuming the same amount of pesticide is released at each spray event, the equation describing the air concentrations after the second spray event ($t \geq T_{BA}$), but before the third spray ($t < 2 \times T_{BA}$) is:

$$C_2(t) = \left(C_0 + C_0 e^{-\frac{Q}{V}T_{BA}} \right) e^{-\frac{Q}{V}(t - T_{BA})} \qquad T_{BA} \leq t < (2 \times T_{BA}) \qquad \text{(D.12)}$$

where $\mathbf{T_{BA}}$ is the time between application. The first $\mathbf{C_0}$ term represents the (entire) air concentration released at the second spray event; the $C_0 e^{-\frac{Q}{V}T_{BA}}$ term represents the remaining air concentration from the first application at the time of the second spray event; and the $e^{-\frac{Q}{V}(t - T_{BA})}$ term specifies that the sum of the air concentrations (from the first and second spray events) will dissipate at the same decay rate constant, **Q/V**, but that the dissipation will begin at time $\mathbf{T_{BA}}$. The term $\mathbf{(t - T_{BA})}$ shifts the origin of dissipation process from zero to $\mathbf{T_{BA}}$.

The equation describing the air concentrations over time after a series of regularly-spaced spray events can be generalized for the $\mathbf{(n+1)^{th}}$ spray event as follows:

$$C_{n+1}(t) = \left(1 + e^{-\frac{Q}{V}T_{BA}} + e^{-\frac{Q}{V}(2 \times T_{BA})} + e^{-\frac{Q}{V}(3 \times T_{BA})} + \ldots + e^{-\frac{Q}{V}((n-1) \times T_{BA})} + e^{-\frac{Q}{V}(n \times T_{BA})} \right) C_0 e^{-\frac{Q}{V}(t - n \times T_{BA})} \qquad \text{(D.13)}$$

when $(n \times T_{BA}) \leq t < ((n+1) \times T_{BA})$, that is from the time of the $(n+1)^{th}$ spray event to the time just prior to the $(n+2)^{th}$ spray event[24]. By specifying $R = e^{-\frac{Q}{V}T_{BA}}$, equation (D.13) can be rewritten as

[24] Note that the 1st spray event occurs at time t = 0 (or $t = 0 \times T_{BA}$), the 2nd spray event at $t = T_{BA}$ (or $t = 1 \times T_{BA}$), the 3rd at $t = 2 \times T_{BA}$, the nth at $t = (n - 1) \times T_{BA}$, and the $(n + 1)^{th}$ at $t = n \times T_{BA}$.

$$C_{n+1}(t) = \left(1 + R + R^2 + R^3 + \ldots + R^{n-1} + R^n\right) C_0 e^{-\frac{Q}{V}(t - n \times T_{BA})} \qquad \text{(D.14)}$$

where the **R** term is the fraction of air concentration remaining from the previous spray event. The summation of these progressively higher order R terms is referred to as a geometric series. The resulting sum of which can be written as:

$$\left(1 + R + R^2 + R^3 + \ldots + R^{n-1} + R^n\right) = \frac{1 - R^{n+1}}{1 - R} \qquad \text{(D.15)}$$

By substituting equation (D.15) into (D.14), the general equation describing air concentrations after a series of **(n+1)** regularly-spaced spray events can be written as:

$$C_{n+1}(t) = \left(\frac{1 - R^{n+1}}{1 - R}\right) C_0 e^{-\frac{Q}{V}(t - n \times T_{BA})} \qquad \text{(D.16)}$$

After several spray events, the air concentration at the beginning of each dissipation period approaches a fixed value determined by the geometric series in equation (D.15). This value can be determined by allowing $n \to \infty$, which implies that $R^{n+1} \to 0$ since **R** < 1. Thus after a sufficient number of spray events, the general equation describing air concentrations after a series of **(n+1)** regularly-spaced spray events can be written as:

$$C_{n+1}(t) = \left(\frac{C_0}{1 - R}\right) e^{-\frac{Q}{V}(t - n \times T_{BA})} \qquad \text{(D.17)}$$

Since R < 1, the term $\frac{C_0}{1 - R} > C_0$. In other words, after a sufficient number of spray events, the (total) air concentration immediately after the spray event will approach a fixed value that is larger than the (initial) concentration released during the spray event (due to the remaining air concentration from previous spray events). Therefore, it is more health protective to calculate inhalation exposure after the total air concentration approaches this larger, fixed value (i.e. after a sufficient number of spray applications have occurred).

The air concentration equation (D.17) can be used to calculate the exposure, **E**, over the time period ($n \times T_{BA}$) to ($(n+1) \times T_{BA}$), that is, the *entire* time period from the $(n+1)^{th}$ spray event until the time just prior to the $(n+2)^{th}$ spray event (i.e. the next spray event). The exposure equation is based on integrating equation (D.17) and multiplying by an inhalation rate, **IR**.

$$E = IR \int_{n \times T_{BA}}^{(n+1) \times T_{BA}} C_{n+1}(t)\,dt$$

$$E = IR \int_{n \times T_{BA}}^{(n+1) \times T_{BA}} \left(\frac{C_0}{1 - R}\right) e^{-\frac{Q}{V}(t - n \times T_{BA})}\,dt$$

$$E = IR\left(\frac{C_0}{1-R}\right)\left(-\frac{V}{Q}\right)\left[e^{-\frac{Q}{V}(t-n\times T_{BA})}\right]_{n\times T_{BA}}^{(n+1)\times T_{BA}}$$

$$E = IR\left(\frac{C_0}{1-R}\right)\left(\frac{V}{Q}\right)\left[e^{-\frac{Q}{V}(n\times T_{BA}-n\times T_{BA})} - e^{-\frac{Q}{V}((n+1)\times T_{BA}-n\times T_{BA})}\right]$$

$$E = IR\left(\frac{C_0}{1-R}\right)\left(\frac{V}{Q}\right)\left[e^{-\frac{Q}{V}(0)} - e^{-\frac{Q}{V}(T_{BA})}\right]$$

$$E = IR\left(\frac{C_0}{1-R}\right)\left(\frac{V}{Q}\right)\left[1-R\right]$$

$$E = \frac{IR\cdot C_0\cdot V}{Q} \qquad \text{(D.18)}$$

Note that this exposure equation (D.18) is for an exposure time equal to the time between applications (T_{BA}), that is, exposure due to one spray event. If exposure is being calculated for an exposure time that is a whole number multiple of T_{BA}, that is, for multiple spray events, then a multiple of equation (D.18) can be used to calculate exposure over such an exposure time[25]. Thus to calculate exposure due to multiple spray events when the exposure time is a whole number multiple of the time between application, the following exposure equation can be used:

$$E = \frac{IR\cdot C_0\cdot V\cdot N_s}{Q} \qquad \text{(D.19)}$$

where $\mathbf{N_s}$ is the number of spray events. The number of spray events could be calculated from the exposure time, **ET** and the time between applications ($\mathbf{T_{BA}}$):

$$N_s = \frac{ET}{T_{BA}}$$

If $\mathbf{T_{BA}}$ is specified to have units hr/spray, then the inverse of this parameter could be termed the pulse rate (**PR**), which would have units spray/hr. Alternatively, N_s could be calculated from ET and PR as follows:

$$N_s = ET\cdot PR \qquad \text{(D.20)}$$

Substituting equation (D.20) into equation (D.19), the exposure equation over an exposure time equal to a whole number multiple of the time between applications becomes:

[25] For example, if the time between applications is one hour (i.e. $T_{BA} = 1$) and the exposure time is exactly four hours (ET = 4), then exposure over the four-hour exposure time would be equal to four times the exposure due to one spray event as calculated by equation (3.8).

$$E = \frac{IR \cdot C_0 \cdot V \cdot ET \cdot PR}{Q} \qquad \text{(D.21)}$$

Now consider exposure over some exposure time *less than* the time between applications. Again, the air concentration equation (D.17) can be used to calculate the exposure, **E**, over the time period $(n \times T_{BA})$ to $((n+\rho) \times T_{BA})$, where $0 < \rho < 1$; that is, some *fraction* of the time period from the (n+1)th spray event until some time prior to the (n+2)th spray event (i.e. the next spray event). The exposure equation is based on integrating equation (D.17) and multiplying by an inhalation rate, **IR**.

$$E = IR \int_{n \times T_{BA}}^{(n+\rho) \times T_{BA}} C_{n+1}(t)dt$$

$$E = IR \int_{n \times T_{BA}}^{(n+\rho) \times T_{BA}} \left(\frac{C_0}{1-R}\right) e^{-\frac{Q}{V}(t - n \times T_{BA})} dt$$

$$E = IR\left(\frac{C_0}{1-R}\right)\left(-\frac{V}{Q}\right)\left[e^{-\frac{Q}{V}(t - n \times T_{BA})}\right]_{n \times T_{BA}}^{(n+\rho) \times T_{BA}}$$

$$E = IR\left(\frac{C_0}{1-R}\right)\left(\frac{V}{Q}\right)\left[e^{-\frac{Q}{V}(n \times T_{BA} - n \times T_{BA})} - e^{-\frac{Q}{V}((n+\rho) \times T_{BA} - n \times T_{BA})}\right]$$

$$E = IR\left(\frac{C_0}{1-R}\right)\left(\frac{V}{Q}\right)\left[e^{-\frac{Q}{V}(0)} - e^{-\frac{Q}{V}(\rho \times T_{BA})}\right]$$

$$E = IR\left(\frac{C_0}{1-R}\right)\left(\frac{V}{Q}\right)\left[1 - R^{\rho}\right]$$

$$E = \frac{IR \cdot C_0 \cdot V}{Q} \cdot \frac{(1-R^{\rho})}{(1-R)} \qquad \text{(D.22)}$$

Note that this exposure equation (D.22) is for an exposure time equal to some fraction of the time between applications, that is, ($_{BA}$)× Combining equation (D.22) and equation (D.20), the exposure equation over an exposure time equal to a whole number multiple of T_{BA}, a general exposure equation for an exposure time of any duration can be expressed as:

$$E = \frac{IR \cdot C_0 \cdot V \cdot \text{int}(ET \cdot PR)}{Q} + \frac{IR \cdot C_0 \cdot V}{Q} \cdot \frac{(1-R^{frac(ET \cdot PR)})}{(1-R)}$$

$$E = \frac{IR \cdot C_0 \cdot V}{Q}\left[\text{int}(ET \cdot PR) + \frac{(1 - R^{frac(ET \cdot PR)})}{(1 - R)}\right] \qquad \text{(D.23)}$$

where $R = \text{e}^{-\frac{Q}{V}T_{BA}}$, **int(ET·PR)** is the integer (i.e. whole number) part of the product of the exposure time, ET and the pulse rate, PR (i.e. number of spray events per hour) and **frac(ET·PR)** is the fractional part of the product of the exposure time and the pulse rate[26]. Note that according to equation (D.19), the product of the exposure time and pulse rate is simply the numbers of spray events, Ns for which inhalation exposure is being estimated.

D.3.4 Outdoor Fogging/Misting Systems - Animal Barn Misting Systems

As with the ORMS scenario, the well-mixed box (WMB) model was used to develop exposure equation (5.30) for the animal barn misting systems post-application inhalation scenario[27]. The WMB model incorporates a number of simplifying assumptions: fresh air (having zero pesticide concentration) enters the box at a constant airflow rate (based on the number of air changes per hour), a turbulent internal airflow thoroughly mixes the fresh air with the pesticide-laden air resulting in a uniform pesticide air concentration within the box, and the perfectly mixed air exits the box at the same constant airflow rate (i.e. the inflow rate equals the outflow rate). Thus the indoor area where the aerosol is being applied (i.e. barn) is assumed to be in an enclosed box, which seems a reasonable assumption for a walled, indoor space. This scenario assumes instantaneous spray releases, that is, the total amount of aerosol released at each spray event is modeled to occur instantaneously.

The removal of the pesticide from the box depends on airflow. The WMB model developed for this scenario models the pesticide air concentrations *after* multiple instantaneous aerosol spray releases at regular time intervals[28]. Only dissipation due to airflow into and out of the box is modeled. The mass balance within the box can be described by the following differential equation:

$$V\frac{dC}{dt} = -Q \cdot C$$

$$\frac{dC}{C} = -\frac{Q}{V}dt$$

[26] For example, if the time between applications is 40 minutes or 2/3 hour (i.e. T_{BA} = 0.67) or equivalently, the pulse rate is 3 sprays over 2 hours (i.e. PR = 1.5), and the exposure time is three hours (ET = 3), then int(ET·PR) = int(3 × 1.5) = int(4.5) = 4; and frac(ET·PR) = frac(4.5) = 0.5.

[27] For the ORMS and animal barn scenarios, the WMB models describing the air concentrations over time have the same form. The parameterization of these models is the only difference. For the ORMS scenario, the decay rate constant is specified by the ratio of the airflow rate and the volume of the treated space, whereas for the animal barn scenario, the decay rate constant is specified by the air changes per hour.

[28] The regular spray applications are assumed to continue for the entire time spent inside the animal barn.

where **C** is the air concentration, **Q** is the airflow, and **V** is the volume of the box. Integrating the differential equation and simplifying and combining terms yields an equation describing the air concentration over time.

$$\int \frac{dC}{C} = -\int \frac{Q}{V} dt$$

$$\ln(C) = -\frac{Q}{V} t + a$$

$$e^{\ln(C)} = e^{-\frac{Q}{V}t+a}$$

$$C = A \cdot e^{-\frac{Q}{V}t}$$

where $A = e^a$ is a constant whose value is determined by the initial condition that at time t = 0, the pesticide air concentration is equal to initial air concentration, i.e. $C(0) = C_0$. Based on this initial constraint, A is set equal to C_0.

For an indoor scenario, the ratio of the airflow, Q to the volume of the treated space, V is defined as the number of air changes per hour, ACH (i.e. ACH = Q/V). The WMB model described above for the animal barn misting system scenario is similar to the model used for aerosol area fogger scenario. In fact, the equation for modeling pesticide air concentrations over time after the first spray event (but before the second spray) is exactly the same as equation (D.2) except for the use of an air exchange rate (ACH) for the ratio of the airflow to the volume of the treated space and the subscript on the left-hand side denoting the number of applications:

$$C_1(t) = C_0 e^{-ACH \cdot t} \qquad \text{(D.24)}$$

where **C(t)** is the air concentration at time **t**, $\mathbf{C_0}$ is the initial air concentration (i.e. concentration at time t=0), and **ACH** is the air changes per hour.

Assuming the same amount of pesticide is released at each spray event, the equation describing the air concentrations after the second spray event (but before the third spray) is:

$$C_2(t) = \left(C_0 + C_0 e^{-ACH \cdot T_{BA}}\right) e^{-ACH \cdot (t - T_{BA})} \qquad \text{(D.25)}$$

where $\mathbf{T_{BA}}$ is the time between application. The first $\mathbf{C_0}$ term represents the (entire) air concentration released at the second spray event; the $C_0 e^{-ACH \cdot T_{BA}}$ term represents the remaining air concentration from the first application at the time of the second spray event; and the $e^{-ACH \cdot (t - T_{BA})}$ term specifies that the sum of the air concentrations (from the first and second spray events) will dissipate at the same decay rate constant, **ACH**, but that the dissipation will begin at time $\mathbf{T_{BA}}$. The term $\mathbf{(t - T_{BA})}$ shifts the origin of dissipation process from zero to $\mathbf{T_{BA}}$.

The equation describing the air concentrations over time after a series of regularly-spaced spray events can be generalized for the **(n+1)th** spray event as follows:

$$C_{n+1}(t) = \left(1 + e^{-ACH \cdot T_{BA}} + e^{-ACH \cdot (2 \times T_{BA})} + e^{-ACH \cdot (3 \times T_{BA})} + \ldots + e^{-ACH \cdot ((n-1) \times T_{BA})} + e^{-ACH \cdot (n \times T_{BA})}\right) C_0 e^{-ACH \cdot (t - n \times T_{BA})} \quad \text{(D.26)}$$

when $(n \times T_{BA}) \le t < ((n+1) \times T_{BA})$, that is from the time of the (n+1)th spray event to the time just prior to the (n+2)th spray event[29]. By specifying $R = e^{-ACH \cdot T_{BA}}$, equation (D.26) can be rewritten as

$$C_{n+1}(t) = \left(1 + R + R^2 + R^3 + \ldots + R^{n-1} + R^n\right) C_0 e^{-ACH \cdot (t - n \times T_{BA})} \quad \text{(D.27)}$$

where the term **R** is the fraction of air concentration remaining from the previous spray event. Since **R** <1 by definition, the sum of the **R** terms is a geometric series, which can be written as:

$$\left(1 + R + R^2 + R^3 + \ldots + R^{n-1} + R^n\right) = \frac{1 - R^{n-1}}{1 - R} \quad \text{(D.28)}$$

By substituting equation (D.27) into (D.26), the general equation describing air concentrations after a series of **(n+1)** regularly-spaced spray events can be written as:

$$C_{n+1}(t) = \left(\frac{1 - R^{n-1}}{1 - R}\right) C_0 e^{-ACH \cdot (t - n \times T_{BA})} \quad \text{(D.29)}$$

After several spray events, the air concentration at the beginning of each dissipation period approaches a fixed value determined by the geometric series in equation (D.28). This value can be determined by allowing $n \to \infty$, which implies that $R^{n-1} \to 0$ since **R** < 1. Thus after a sufficient number of spray events, the general equation describing air concentrations after a series of **(n+1)** regularly-spaced spray events can be written as:

$$C_{n+1}(t) = \left(\frac{C_0}{1 - R}\right) e^{-ACH \cdot (t - n \times T_{BA})} \quad \text{(D.30)}$$

Since R < 1, the term $\frac{C_0}{1 - R} > C_0$. In other words, after a sufficient number of spray events, the (total) air concentration present immediately after the spray event will approach a fixed value that is larger than the (initial) concentration released during the spray event (due to the remaining air concentration from previous spray events). Therefore, it is more health protective to calculate inhalation exposure after the total air concentration approaches this larger, fixed value (i.e. after a sufficient number of spray applications have occurred).

[29] Note that the 1st spray event occurs at time t = 0 (or t = 0 × T_{BA}), the 2nd spray event at t = T_{BA} (or t = 1 × T_{BA}), the 3rd at t = 2 × T_{BA}, the nth at t = (n - 1) × T_{BA}, and the (n + 1)th at t = n × T_{BA}.

The air concentration equation (D.30) can be used to calculate the exposure, **E**, over the time period $(n \times T_{BA})$ to $((n+1) \times T_{BA})$, that is, the *entire* time period from the $(n+1)^{th}$ spray event until the time just prior to the $(n+2)^{th}$ spray event (i.e. the next spray event). The exposure equation is based on integrating equation (D.30) and multiplying by an inhalation rate, **IR**.

$$E = IR \int_{n \times T_{BA}}^{(n+1) \times T_{BA}} C_{n+1}(t)dt$$

$$E = IR \int_{n \times T_{BA}}^{(n+1) \times T_{BA}} \left(\frac{C_0}{1-R} \right) e^{-ACH \cdot (t - n \times T_{BA})} dt$$

$$E = IR \left(\frac{C_0}{1-R} \right) \left(-\frac{1}{ACH} \right) \left[e^{-ACH \cdot (t - n \times T_{BA})} \right]_{n \times T_{BA}}^{(n+1) \times T_{BA}}$$

$$E = IR \left(\frac{C_0}{1-R} \right) \left(\frac{1}{ACH} \right) \left[e^{-ACH \cdot (n \times T_{BA} - n \times T_{BA})} - e^{-ACH \cdot ((n+1) \times T_{BA} - n \times T_{BA})} \right]$$

$$E = IR \left(\frac{C_0}{1-R} \right) \left(\frac{1}{ACH} \right) \left[e^{-ACH \cdot (0)} - e^{-ACH \cdot (T_{BA})} \right]$$

$$E = IR \left(\frac{C_0}{1-R} \right) \left(\frac{1}{ACH} \right) \left[1 - R \right]$$

$$E = \frac{IR \cdot C_0}{ACH} \qquad \text{(D.31)}$$

Note that this exposure equation (D.31) is for an exposure time equal to the time between applications (T_{BA}), that is, exposure due to one spray event and is also same as Eqn. D.17 given earlier. If exposure is being calculated for an exposure time that is a whole number multiple of T_{BA}, that is, for multiple spray events, then a multiple of equation (D.30) can be used to calculate exposure over such an exposure time[30]. Thus to calculate exposure due to multiple spray events when the exposure time is a whole number multiple of the time between application [i.e. ET = 0 mod(T_{BA})], the following exposure equation can be used:

$$E = \frac{IR \cdot C_0 \cdot N_s}{ACH} \qquad \text{(D.32)}$$

[30] For example, if the time between applications is one hour (i.e. $T_{BA} = 1$) and the exposure time is exactly four hours (ET = 4), then exposure over the four-hour exposure time would be equal to four times the exposure due to one spray event as calculated by equation (3.8).

where $\mathbf{N_s}$ is the number of spray events. The number of spray events could be calculated from the exposure time, **ET** and the time between applications ($\mathbf{T_{BA}}$):

$$N_s = \frac{ET}{T_{BA}}$$

If $\mathbf{T_{BA}}$ is specified to have units hr/spray, then the inverse of this parameter could be termed the pulse rate (**PR**), which would have units spray/hr. Alternatively, N_s could be calculated from ET and PR as follows:

$$N_s = ET \cdot PR \tag{D.33}$$

Substituting equation (D.33) into equation (D.32), the exposure equation over an exposure time equal to a whole number multiple of the time between applications becomes:

$$E = \frac{IR \cdot C_0 \cdot ET \cdot PR}{ACH} \tag{D.34}$$

Now consider exposure over some exposure time *less than* the time between applications. Again, the air concentration equation (C.4.7) can be used to calculate the exposure, **E**, over the time period $(n \times T_{BA})$ to $((n+\rho) \times T_{BA})$, where $0 < \rho < 1$; that is, some *fraction* of the time period from the $(n+1)^{th}$ spray event until some time prior to the $(n+2)^{th}$ spray event (i.e. the next spray event). The exposure equation is based on integrating equation (D.30) and multiplying by an inhalation rate, **IR**.

$$E = IR \int_{n \times T_{BA}}^{(n+\rho) \times T_{BA}} C_{n+1}(t)dt$$

$$E = IR \int_{n \times T_{BA}}^{(n+\rho) \times T_{BA}} \left(\frac{C_0}{1-R}\right) e^{-ACH \cdot (t - n \times T_{BA})} dt$$

$$E = IR\left(\frac{C_0}{1-R}\right)\left(-\frac{1}{ACH}\right)\left[e^{-ACH \cdot (t - n \times T_{BA})}\right]_{n \times T_{BA}}^{(n+1) \times T_{BA}}$$

$$E = IR\left(\frac{C_0}{1-R}\right)\left(\frac{1}{ACH}\right)\left[e^{-ACH \cdot (n \times T_{BA} - n \times T_{BA})} - e^{-ACH \cdot ((n+\rho) \times T_{BA} - n \times T_{BA})}\right]$$

$$E = IR\left(\frac{C_0}{1-R}\right)\left(\frac{1}{ACH}\right)\left[e^{-ACH \cdot (0)} - e^{-ACH \cdot (\rho \times T_{BA})}\right]$$

$$E = IR\left(\frac{C_0}{1-R}\right)\left(\frac{1}{ACH}\right)\left[1-R^{\rho}\right]$$

$$E = \frac{IR \cdot C_0}{ACH} \cdot \frac{(1-R^{\rho})}{(1-R)} \qquad \text{(D.35)}$$

Note that this exposure equation (D.35) is for an exposure time equal to some fraction of the time between applications, that is, ($_{BA}$)× Combining equation (D.35) and equation (D.33), the exposure equation over an exposure time equal to a whole number multiple of T_{BA}, a general exposure equation for an exposure time of any duration can be expressed as:

$$E = \frac{IR \cdot C_0 \cdot \text{int}(ET \cdot PR)}{ACH} + \frac{IR \cdot C_0}{ACH} \cdot \frac{(1-R^{frac(ET \cdot PR)})}{(1-R)}$$

$$E = \frac{IR \cdot C_0}{ACH}\left[\text{int}(ET \cdot PR) + \frac{(1-R^{frac(ET \cdot PR)})}{(1-R)}\right] \qquad \text{(D.36)}$$

where $R = e^{-ACH \cdot T_{BA}}$, **int(ET·PR)** is the integer (i.e. whole number) part of the product of the exposure time, ET and the pulse rate, PR (i.e. number of spray events per hour) and **frac(ET·PR)** is the fractional part of the product of the exposure time and the pulse rate[31]. Note that according to equation (D.33), the product of the exposure time and pulse rate is simply the numbers of spray events, N_s for which inhalation exposure is being estimated.

[31] For example, if the time between applications is 40 minutes or 2/3 hour (i.e. T_{BA} = 0.67) or equivalently, the pulse rate is 3/2 sprays/hour (i.e. PR = 1.5); and the exposure time is three hours (ET = 3), then int(ET·PR) = int(3 × 1.5) = int(4.5) = 4; and frac(ET·PR) = frac(4.5) = 0.5.

D.3.5 Indoor Environments - Instantaneous Release/Aerosol Applications

As with the *outdoor* aerosol spray area foggers scenario, the well-mixed box (WMB) model was used to develop exposure equation (7.6) for the *indoor* instantaneous release/aerosol application post-application inhalation scenario[32]. The WMB model incorporates a number of simplifying assumptions: fresh air (having zero pesticide concentration) enters the box at a constant airflow rate (based on the number of air changes per hour), a turbulent internal airflow thoroughly mixes the fresh air with the pesticide-laden air resulting in a uniform pesticide air concentration within the box, and the perfectly mixed air exits the box at the same constant airflow rate (i.e. the inflow rate equals the outflow rate). Thus the indoor area where the aerosol is being applied (e.g., living room) is assumed to be in an enclosed box, which seems a reasonable assumption for a walled, indoor space. This scenario assumes an instantaneous spray release, that is, the total amount of aerosol released during a spray event is modeled to occur instantaneously.

The removal of the pesticide from the box depends on airflow. The WMB model developed for this scenario models the pesticide air concentrations *after* an initial, instantaneous release of an aerosol spray. Only dissipation due to airflow into and out of the box is modeled. The mass balance within the box can be described by the following differential equation:

$$V\frac{dC}{dt} = -Q \cdot C$$

$$\frac{dC}{C} = -\frac{Q}{V}dt$$

where **C** is the air concentration, **Q** is the airflow, and **V** is the volume of the box. Integrating the differential equation and simplifying and combining terms yields an equation describing the air concentration over time.

$$\int \frac{dC}{C} = -\int \frac{Q}{V}dt$$

$$\ln(C) = -\frac{Q}{V}t + a$$

$$e^{\ln(C)} = e^{-\frac{Q}{V}t+a}$$

$$C = A \cdot e^{-\frac{Q}{V}t}$$

[32] For the *outdoor* aerosol spray area foggers and the *indoor* instantaneous release/aerosol application scenarios, the WMB models describing the air concentrations over time have the same form. The parameterization of these models is the only difference. For the outdoor aerosol spray area foggers scenario, the decay rate constant is specified by the ratio of the airflow rate and the volume of the treated space; whereas for the indoor instantaneous release/aerosol application scenario, the decay rate constant is specified by the air changes per hour.

where $A = e^a$ is a constant whose value is determined by the initial condition that at time t = 0, the pesticide air concentration is equal to initial air concentration, i.e. $C(0) = C_0$. Based on this initial constraint, A is set equal to C_0. Also, for an indoor scenario, the ratio of the airflow, Q to the volume of the treated space, V is defined as the number of air changes per hour, ACH (i.e. ACH = Q/V). Based on the initial constraint that $C(0) = C_0$ and that ACH = Q/V, the WMB model described above for modeling pesticide air concentrations over time can be written as follows:

$$C(t) = C_0 e^{-ACH \cdot t} \tag{D.37}$$

where **C(t)** is the air concentration at time **t**, $\mathbf{C_0}$ is the initial air concentration (i.e. concentration at time t=0), and **ACH** is the air changes per hour. The air concentration equation (D.37) is then used to calculate the exposure, E:

$$E = IR \int_0^{ET} C(t)dt \tag{D.38}$$

The exposure, **E** is based on integrating equation (D.36) over the exposure time, **ET** which is then multiplied by an inhalation rate, **IR**. The final exposure equation is derived from equation (D.38) by performing the integration and simplifying terms.

$$E = IR \int_0^{ET} C_0 e^{-ACH \cdot t} dt$$

$$E = IR * C_O \left(\frac{-1}{ACH} \right) \left(e^{-ACH(ET)} - e^{-ACH(0)} \right)$$

$$E = \frac{IR \cdot C_0}{ACH} \left(1 - e^{-ACH(ET)} \right) \tag{D.39}$$

D.3.6 Indoor Environments - Vapor Emission for Surface Sprays

As with the *outdoor* candles, coils, torches, and mats scenario, the well-mixed box (WMB) model was used to develop exposure equation (7.11) for the *indoor* vapor emission for surface sprays post-application inhalation scenario[33]. The vapor emission for surface sprays scenario differs from the other exposure scenarios based on the WMB model because it includes a variable emission rate term and thus results in a more complicated exposure equation. The WMB was used to model pesticide air concentrations within an enclosed, fixed volume (i.e. a

[33] For the *outdoor* candles, coils, torches, and mats and the *indoor* vapor emission for surface sprays scenarios, the WMB models describing the air concentrations over time have a similar form. The parameterization of these models is one of the differences. For the outdoor candles, coils, torches, and mats scenario, the decay rate constant is specified by the ratio of the airflow rate and the volume of the treated space, whereas for the indoor vapor emission for surface sprays scenario, the decay rate constant is specified in part by the air changes per hour.

box) over time during the variable emission of a pesticide from a surface spray. The WMB model incorporates a number of simplifying assumptions: fresh air (having zero pesticide concentration) enters the box at a constant airflow rate, a turbulent internal airflow thoroughly mixes the fresh air with the pesticide-laden air resulting in a uniform pesticide air concentration within the box, and the perfectly mixed air exits the box at the same constant airflow rate (i.e. the inflow rate equals the outflow rate). Thus the indoor area where the aerosol is being applied (e.g., living room) is assumed to be in an enclosed box, which seems a reasonable assumption for a walled, indoor space.

The removal of the surface spray emission from the box depends on airflow. The WMB model developed for this scenario models the pesticide air concentrations *during* a variable emission of pesticide from a surface spray. Only emission and dissipation due to airflow into and out of the box is modeled. The mass balance within the box can be described by the following differential equation:

$$V\frac{dC}{dt} = ER - Q \cdot C + k \cdot V \cdot C$$

$$\frac{dC}{dt} = \frac{ER}{V} - \frac{Q}{V} \cdot C + k \cdot C$$

$$\frac{dC}{dt} = \frac{ER}{V} - \left(\frac{Q}{V} - k\right)C$$

where **C** is the air concentration, **ER** is the emission rate, **Q** is the airflow, **k** is the decay rate constant of the emission rate, and **V** is the volume of the box. Based on the method of undetermined coefficients, the solution to this differential equation has the form:

$$C(t) = \frac{\frac{ER}{V}}{\left(\frac{Q}{V} - k\right)} - A \cdot e^{-\left(\frac{Q}{V} - k\right)t}$$

$$C(t) = \frac{ER}{V\left(\frac{Q}{V} - k\right)} - A \cdot e^{-\left(\frac{Q}{V} - k\right)t}$$

where A is a constant whose value is determined by the initial condition that at time t = 0, the pesticide air concentration is equal to zero, i.e., C(0) = 0. Based on this initial constraint, the equation describing the air concentration over time can be written as:

$$C(t) = \frac{ER}{V\left(\frac{Q}{V} - k\right)} - \frac{ER}{V\left(\frac{Q}{V} - k\right)} e^{-\left(\frac{Q}{V} - k\right)t}$$

Based on the WMB model described above, the equation for modeling pesticide air concentrations over time is as follows:

$$C(t) = \frac{ER}{V\left(\frac{Q}{V} - k\right)}\left[1 - e^{-\left(\frac{Q}{V} - k\right)t}\right] \qquad \text{(D.40)}$$

where **C(t)** is the air concentration at time **t**, **ER** is the emission rate, **Q** is the airflow, **k** is the decay rate constant of the emission rate, and **V** is the volume of the box. For an indoor scenario, the ratio of the airflow, Q to the volume of the treated space, V is defined as the number of air changes per hour, ACH:

$$ACH = \frac{Q}{V} \qquad \text{(D.41)}$$

For the indoor vapor emission for surface sprays scenario, the decreasing emission rate, ER is based on decay rate constant, k[34] which can be calculated from various physical and chemical properties of the pesticide.

$$ER = k \cdot M \cdot e^{-k \cdot t} \qquad \text{(D.42)}$$

where **M** is the amount (i.e. mass) of the surface spray application. Substituting equations (D.41) and (D.42) into equation (D.40) and yields the equation for modeling pesticide air concentrations over time following surface spray application base on a variable emission rate:

$$C(t) = \frac{k \cdot M \cdot e^{-k \cdot t}}{V(ACH - k)}\left[1 - e^{-(ACH - k)t}\right]$$

Which can be rewritten as:

$$C(t) = \frac{k \cdot M}{V(ACH - k)}\left[e^{-k \cdot t} - e^{-ACH \cdot t}\right] \qquad \text{(D.43)}$$

The air concentration equation is then used to calculate the exposure, **E**, which is based on integrating equation (D.43) over the exposure time, **ET** which is then multiplied by an inhalation rate, **IR**:

$$E = IR \int_0^{ET} C(t)dt \qquad \text{(D.44)}$$

The final exposure equation is derived from equation (D.44) by performing the integration and simplifying terms.

$$E = IR \int_0^{ET} \frac{k \cdot M}{V(ACH - k)}\left[e^{-k \cdot t} - e^{-ACH \cdot t}\right]dt$$

[34] As discussed in Guo (2002), Evans (1994) proposed estimating the decay rate constant, k based on the 90% drying time which, in turn, is estimated by a method developed by Chinn (1981).

$$E = \frac{IR \cdot k \cdot M}{V(ACH - k)}\left[-\frac{1}{k}e^{-k \cdot t} + \frac{1}{ACH}e^{-ACH \cdot t} \right]_0^{ET}$$

$$E = \frac{IR \cdot k \cdot M}{V(ACH - k)}\left[\frac{1}{k}e^{-k \cdot t} - \frac{1}{ACH}e^{-ACH \cdot t} \right]_0^{ET}$$

$$E = \frac{IR \cdot k \cdot M}{V(ACH - k)}\left[\left(\frac{1}{k}e^{-k \cdot (0)} - \frac{1}{ACH}e^{-ACH \cdot (0)} \right) - \left(\frac{1}{k}e^{-k \cdot ET} - \frac{1}{ACH}e^{-ACH \cdot ET} \right) \right]$$

$$E = \frac{IR \cdot k \cdot M}{V(ACH - k)}\left[\left(\frac{1}{k} - \frac{1}{ACH} \right) - \left(\frac{1}{k}e^{-k \cdot ET} - \frac{1}{ACH}e^{-ACH \cdot ET} \right) \right]$$

$$E = \frac{IR \cdot k \cdot M}{V(ACH - k)}\left[\left(\frac{ACH - k}{k \cdot ACH} \right) - \left(\frac{ACH \cdot e^{-k \cdot ET} - k \cdot e^{-ACH \cdot ET}}{k \cdot ACH} \right) \right]$$

$$E = \frac{IR \cdot k \cdot M}{V \cdot k \cdot ACH}\left[\left(\frac{ACH - k}{ACH - k} \right) - \left(\frac{ACH \cdot e^{-k \cdot ET} - k \cdot e^{-ACH \cdot ET}}{ACH - k} \right) \right]$$

$$E = \frac{IR \cdot M}{V \cdot ACH}\left[1 - \left(\frac{ACH \cdot e^{-k \cdot ET} - k \cdot e^{-ACH \cdot ET}}{ACH - k} \right) \right] \qquad \text{(D.45)}$$

D.3.7 Vapor Emission for Surface-directed Sprays – Using the Saturation Concentration

If the information necessary to conduct an assessment for post-application inhalation exposure following surface-directed sprays is not available, a screening level approach can be performed using the saturation concentration of the chemical. This approach relies only on chemical properties such as molecular weight and vapor pressure to estimate an air concentration.

It should be noted that using the saturation concentration to estimate inhalation exposure is a very conservative approach. The saturation concentration is a chemical's theoretical maximum air concentration. It represents what would occur if a large amount of chemical were spilled in a non-ventilated room and allowed to evaporate until equilibrium is reached.

Exposure Algorithms

The following equation can be used to calculate the saturation concentration of a specific chemical:

$$C_{sat} = \frac{VP * CF1 * MW * CF2 * CF3}{R * T}$$

where:
C_{sat} = Saturation concentration (mg/m^3);
VP = Vapor pressure (mmHg);
MW = Molecular weight (g/mol);
R = Gas constant = 0.0821 L-atm/mol-K;
T = Temperature of the air (296 K);
CF1 = Conversion factor (atm/760 mm Hg);
CF2 = Conversion factor (10^3 mg/g); and
CF3 = Conversion factor (10^3 L/m^3).

The saturation concentration can then be used in the following exposure equation to estimate a screening level exposure:

$$E = C_{sat} * IR * ET$$

where:
C_{sat} = Saturation concentration (mg/m^3);
IR = Inhalation rate (m^3/hr); and
ET = Exposure time (hr/day).

Exposure Algorithm Inputs and Assumptions

Table D-4: Indoor Environments – Recommended Post-application Inhalation Exposure Factor Point Estimates

Algorithm Notation	Exposure Factor (units)		Point Estimate(s)
IR	Inhalation rate (m^3/hour)	Adults	0.64
		Children 1 to <2 years old	0.33
C_{sat}	Saturation concentration (mg/m^3)		Calculated
VP	Vapor pressure (mmHg)		Chemical-specific
MW	Molecular weight (g/mol)		Chemical-specific
R	Gas constant (L-atm/mol-K)		0.0821
T	Temperature of the air (kelvin, K)		296
ET	Exposure time (hr/day)	Adults	16
		Children 1 to <2 years old	18

Inhalation Rate (IR)
See *Section 2.2* for discussion of inhalation rates. **The recommended point estimates for use in post-application inhalation exposure assessments are 0.64 m^3/hr for adults and 0.33 m^3/hr for children 1 to < 2 years old**.

Saturation Concentration (C_{sat})
The saturation concentration is a chemical's theoretical maximum air concentration. It represents what would occur if a large amount of chemical were spilled in a non-ventilated room and allowed to evaporate until equilibrium is reached. Calculating post-application inhalation exposure and risk using the saturation concentration should be considered a very conservative approach.

Vapor Pressure (VP)
The vapor pressure is a chemical-specific value in units of mmHg.

Molecular weight (MW)
The molecular weight is a chemical-specific value in units of g/mol.

Gas constant (R)
A constant with units of L-atm/mol-K.

Temperature (T)
The temperature of the air in units of kelvin (K).

Exposure Time (ET)
For vapor emissions from surface-directed sprays, it is assumed that the vapors can continue to emit over time; therefore, exposure time is related to time spent in a residence. Empirical distributions for adults and children are provided in the Exposure Factors Handbook 2011 Edition (U.S. EPA, 2011; Adults -- Table 16-16 and Children -- Table 16-15). The distribution for exposure time for adults and for children 1 to < 2 years old is provided in *Table D-5*. **The recommended point estimates for use in post-application inhalation exposure assessments are 16 hours for adults and 18 hours for children 1 to < 2 years old**.

Table D-5: Exposure Time (ET, hours)

Statistic	Adults	Children 1 to < 2 years
5th percentile	9	11
25th percentile	13	15
50th percentile	15	18
75th percentile	19	21
90th percentile	23	24
95th percentile	24	24
AM (SD)	16 (5)	18

AM (SD) = arithmetic mean (standard deviation)

Exposure Characterization and Data Quality

When using the saturation concentration to estimate inhalation exposure, the assessor should note that this is a very conservative approach. The saturation concentration is a chemical's

theoretical maximum air concentration. It represents what would occur if a large amount of chemical were spilled in a non-ventilated room and allowed to evaporate until equilibrium is reached.

Combining Post-application Scenarios

Post-application inhalation exposure from surface-directed sprays can be calculated using the saturation concentration as an estimate of air concentration. As was mentioned, the saturation concentration is a highly conservative assumption of air concentration; a chemical's theoretical maximum air concentration. It represents what would occur if a large amount of chemical were spilled in a non-ventilated room and allowed to evaporate until equilibrium is reached. Therefore, the exposure value calculated for this route should not be combined with the other potential routes of exposure.

D.4 Selection of Air Velocity

Meteorological data from National Weather Service (NWS) and other appropriate meteorological monitoring stations was considered in this SOP. Such data have been widely used for dispersion modeling in the Agency's fumigant human health risk assessments. The six weather stations were located around the country and recorded wind velocity (i.e., meters/second or m/s) and other meteorological parameters. The meteorological conditions for these sites represent a broad range of situations, including inland and coastal sites in California and Florida as well as the Midwest and desert plain of the Pacific Northwest.

These types of weather stations typically use cup and vane anemometers to measure windspeed and typically do not record velocities below 1 m/s. Any meteorological monitor recording velocities less than 1 m/s are recorded as 0 m/s. *Table D-6* reports the results from each weather station considered and the percentage of hourly wind speed data that were recorded below 1 m/s and 1.5 m/s, respectively.

Both flying pest pressure and post-application inhalation exposure will likely be highest in the assessed scenarios for days when the air conditions are "calm" (>0.3 m/s) as defined on the Beaufort Wind Force Scale because less mixing will occur at lower windspeeds.

Table D-6: Wind Velocity from National Weather Stations (1999-2003)

City	Source	Percent of the hourly wind speed data below 1 m/s	Percent of the hourly wind speed data below 1.5 m/s
Bakersfield CA	ASOS or Automated Surface Observing System operated by the FAA	18%	18%
Ventura CA	CIMIS or California Irrigation Management Information System	22%	29%
Bradenton FL	FAWN or Florida Automated Weather Network	25%	42%
Tallahassee FL	NWS or National Weather Service	26%	42%

Table D-6: Wind Velocity from National Weather Stations (1999-2003)			
City	**Source**	**Percent of the hourly wind speed data below 1 m/s**	**Percent of the hourly wind speed data below 1.5 m/s**
Flint MI	NWS or National Weather Service	4%	4%
Yakima WA	NWS or National Weather Service	9%	9%

D.5 Estimates of Deposited Residue (DepR)

For indoor environments, post-application dermal exposure resulting from contact with treated indoor surfaces is dependent on three exposure factors: transferable residue (TR), transfer coefficient (TC), and exposure time (ET). 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 based on the deposited residue and the fraction of active ingredient available for transfer. The deposited residue is the residue that is deposited onto indoor surfaces following an application. It can be obtained either from (1) chemical-specific deposition data, (2) the application rate of the product, or (3) default values based on the type of application. Information on each of these methods is provided in the main body of the SOP, but more in-depth information on the analyses for calculating residue values for each option is provided below.

D.5.1 Deposited Residue Based on Chemical-specific Data

Deriving deposited residue values from chemical-specific deposition data is the preferred option for determining the residue value to use in the dermal exposure calculation. These types of data will best reflect the residue pattern and magnitude of deposition after an application. As was discussed in the Indoor SOP, chemical-specific data can be used to calculate a residue value for estimating dermal exposure based on the type of treatment performed (i.e., broadcast, perimeter, or crack and crevice). It is assumed that a chemical-specific deposition study is performed using deposition coupons, which are placed on the floor of the treated room. Coupons should be placed throughout the room so as to capture deposition both near and away from the target application site. A key point to remember in using chemical-specific data is to check the application rate used in the study against the proposed rate and adjust the data if necessary for any differences.

In the case of broadcast treatments, the product is typically applied evenly to the floor throughout the room. Therefore, the deposited residue for the room would be calculated as the average residue of all the coupons in the room.

In the case of perimeter/spot/bedbug (coarse and pinstream) treatments, the product is typically applied only to the outer edges of the room (e.g., along the baseboards). This area is considered the “treated area”, while the area in the center of the room is considered the “untreated area”. The deposited residue for the room is calculated as a weighted average of the residues in the treated area and the residues in the untreated area. Coupons placed along the outer edge of the room are considered to be representative of the “treated area” while those placed closer to the center of the room are considered to be representative of the “untreated area”. The residues

measured on the coupons in each area are averaged together to come up with an average residue for the treated area and an average residue for the untreated area. Then, the following formula is used to calculate a weighted average for the entire room:

(70% * average residue untreated area) + (30% * average residue treated area)

In the case of crack and crevice treatments, the product is typically applied only to voids and crevices in the room. For the purposes of calculating the deposited residue, the area along the outer edges of the room is considered the "treated area" (similar to perimeter treatments), while the area in the center of the room is considered the "untreated area". The deposited residue for the room is calculated similar to the perimeter treatments – a weighted average of the residues in the treated area and the residues in the untreated area. Coupons placed along the outer edge of the room are considered to be representative of the "treated area" while those placed closer to the center of the room are considered to be representative of the "untreated area". The residues measured on the coupons in each area are averaged together to come up with an average residue for the treated area and an average residue for the untreated area. Then, the following formula is used to calculate a weighted average for the entire room:

(90% * average residue untreated area) + (10% * average residue treated area)

D.5.2 Deposited Residue Based on Application Rate

If chemical-specific deposition data are not available, but the label provides an application rate in terms of mass per unit area, then residue values may be estimated using the application rate.

Broadcast Treatments:
Deposited residue = application rate

- Assumed that application evenly distributes the pesticide across the floor of a room.
- Deposited residue for the whole room is assumed to be equivalent to the application rate.

Perimeter/Spot/Bedbug (coarse and pinstream) Treatments:
Deposited residue = 50% of application rate

- Application only to outer edges of room.
- Residues will not be evenly distributed within room –higher residues near outer edges than center of room.
- Method of application and distribution of residues in room is considered when calculating the residue value for the whole room.
- Appropriate residue value to use for whole room would be a weighted average based on distribution of residues in room and likelihood of contacting higher residues found near outer edges (for perimeter/spot/bedbug treatments, assume a 70/30 ratio of untreated/treated areas).
- Deposited residue value used for the whole room in the exposure equation will be some percentage of the application rate.

It is assumed that the deposited residue for perimeter/spot/bedbug (coarse and pinstream) treatments is equivalent to 50% of the application rate. This is based on studies that have measured residues resulting from broadcast and perimeter treatments. A summary of the studies and comparisons is provided in *Table D-7* through *Table D-9*.

Considerations:

- Based on two comparisons only, one of which includes applications from different studies which had different application and sampling schemes.

Table D-7: Comparison of Perimeter and Broadcast Treatment Residues (residues from different studies				
Perimeter Treatment				
SOURCE				**RESIDUE (µg/cm^2)**
U.S. EPA (1993)	0.5% Malathion	compressed air sprayer	▪ Collection media: cotton dosimeter patches. ▪ Sampling time: 0 and 4 hours; no difference identified between 2 sampling times. ▪ Number of samples: divided floor into 16 blocks; 100 samples collected. ▪ Size of room: 12 ft x 12 ft (366 cm x 366 cm). ▪ Treated area = 0-30 cm from wall. ▪ Untreated area = >90 cm from wall. ▪ 9 ug/cm^2 = (30% of average residue from treated area) + (70% of average residue from untreated area)	9
Broadcast Treatments				
SOURCE				**RESIDUE (µg/cm^2)**
Fenske (1990)	0.5% Chlorpyrifos	manually-pressurized handwand	▪ Collection media: aluminum foil samples. ▪ 5 coupons collected immediately after application.	13.6
Gurunathan et al. (1998)	0.5% Chlorpyrifos	manually-pressurized handwand	▪ Surface wipe samples collected from surface of dressers and toys placed on floor. ▪ Value reported is max concentration measured on toys 1 week following application.	11.5
Krieger (2001)	0.5% Chlorpyrifos	manually-pressurized handwand	▪ Foil samples collected in 3 treated rooms (no information on number of samples per room). ▪ Residue value reported is average for three rooms.	15
Comparison of Residues from Perimeter and Broadcast Treatments				
Broadcast residue (µg/cm^2)		**Perimeter residue (µg/cm^2)**		**Perimeter Residue = X% of Broadcast Residues**
13.6		9		66%
11.5				78%
15				60%

Table D-8: Comparison of Perimeter and Broadcast Treatment Residues (residues from the same study)				
Perimeter Treatment				
SOURCE				**RESIDUE (µg/cm^2)**
Selim (2008)	0.1% esfenvalerate	aerosol can	▪ Collection media: alpha-cellulose coupons. ▪ Sampling time: collected 30 minutes after application. ▪ Number of samples: at each sampling time, samples were collected from 61 locations on the floor. ▪ Size of room: 15 ft 2 in x 15 ft 2 in (462 cm x 462 cm). ▪ Treated area = based on figure in study which showed which coupons were within treated area. ▪ Untreated area = based on figure in study which showed which coupons were within untreated area. ▪ 0.9 µg/cm^2 = (30% of average residue from treated area) + (70% of average residue from untreated area).	0.9
Broadcast Treatment				
SOURCE				**RESIDUE (µg/cm^2)**
Selim (2008)	0.1% esfenvalerate	aerosol can	▪ Collection media: alpha-cellulose coupons. ▪ Sampling time: collected 30 minutes after application. ▪ Number of samples: at each sampling time, samples were collected from 61 locations on the floor. ▪ Size of room: 15 ft 2 in x 15 ft 2 in (462 cm x 462 cm).	2.901
Comparison of Residues from Perimeter and Broadcast Treatments				
Broadcast residue (ug/cm^2)			**Perimeter residue (ug/cm^2)**	**Perimeter Residue = X% of Broadcast Residue**
2.901			0.9	31%

Table D-9: Summary of Perimeter Residues as a Percent of Broadcast Residues from Two Comparisons	
Minimum:	31%
Maximum:	78%
Average:	59%
Proposed in SOP:	50%

Crack and Crevice Treatment:

Deposited residue = 10% of application rate

- Application only to outer edges of room in cracks and crevices.
- Residues will not be evenly distributed within room – higher residues near outer edges than center of room.
- Method of application and distribution of residues in room is considered when calculating the residue value for the whole room.
- Appropriate residue value to use for whole room would be a weighted average based on distribution of residues in room and likelihood of contacting higher residues found near outer edges (for crack and crevice treatments, assume a 90/10 ratio of untreated/treated areas).
- Deposited residue value used for the whole room in the exposure equation will be some percentage of the application rate.

It is assumed that the deposited residue is equivalent to 10% of the application rate. This is based on studies that have measured deposited residues resulting from broadcast and crack and crevice treatments. A summary of the studies and comparisons is provided in *Table D-10* through *Table D-12*.

Considerations:

- Based on two comparisons only, one of which includes applications from different studies which had different application and sampling schemes.

Table D-10: Comparison of Crack and Crevice and Broadcast Treatment Residues (residues from different studies)				
Crack and Crevice Treatments				
SOURCE				**RESIDUE ($\mu g/cm^2$)**
Keenan (2007)	0.05% Deltamethrin	aerosol can with C/C tip	Application technique: applied directly into C/C. Collection media: chromatography paper attached to foam boards located in 3 locations in room (in corner, under window and along wall). Number of samples: Cut paper into 5 8-cm sections from the wall/floor intersection out to 40 cm. Size of room: 10 ft x 10 ft (305 cm x 305 cm). Treated area = 0-8 cm. Untreated area = 8-40 cm. 1.5 ug/cm^2 value comes from taking 10% of the residue found in the 0-8 cm area and 90% of the residue found in the 8-40 cm area.	1.5
Selim (2008)	0.1% Esfenvalerate	aerosol can with C/C tip	Application technique: applied 1-inch band along baseboard (as opposed to 18 inch band which they considered perimeter treatment). Collection media: deposition coupons. Number of samples: 61 coupons placed along wall/floor intersection (15 cm x 5 cm) and placed in pattern throughout room (5 cm x 5 cm). Size of room: 15 ft 2 in x 15 ft 2 in (462 cm x 462 cm). Treated area = based on figure in study which showed which coupons were within treated area. Untreated area = based on figure in study which showed which coupons were within untreated area. 0.2 $\mu g/cm^2$ value comes from taking 10% of residue found along edges of room (coupons picked based on diagram in study of what coupons fell in area treated) and 90% of residue found on coupons in center of room.	0.2
Stout and Mason (2003)	0.5% Chlorpyrifos	compressed air applied by certified appl w/ pin-stream spray tip	Application technique: dilute solution is systematically placed into the potential cockroach harborages such as the cracks and crevices of the cabinetry, and around and behind the stove, refrigerator and dishwasher. Collection media: deposition coupons. 12 coupons placed in rows in kitchen (application site) and den. Collected prior to, immediately following the application (the sample collection process was initiated after the application and required about 1 h to complete), and at days 3, 7, 14 and 21 days post-application. Individual coupons in kitchen ranged from 0.0015 to 0.23 $\mu g/cm^2$. Average of all coupons = 0.04 $\mu g/cm^2$. 90/10 weighted average for room = 0.01 $\mu g/cm^2$.	0.01
Wright and Jackson (1975)	0.5% Chlorpyrifos	aerosol-type sprayer with injection tube	Collection media: aluminum pie plates (22.9 cm diameter). 1 row of 6 plates centered in room starting 91 cm from wall, with each successive plate 2.5 cm from lip of preceding plate. At each sampling time, 1 plate analyzed from 3 replicate rooms. Residue values reported are average of 3 replicates. Meant to collect residues from non-target areas in room -- did not collect residues near application sites.	0.0006
		compressed air sprayer		0.0023
Byrne et. al (1998)	0.5% Chlorpyrifos	compressed air sprayer	A crack and crevice injector tip was used to apply the test material to where two surfaces met inside cabinets, pantry, vanity, and drawers (e.g., side and back, back and top, side and bottom, etc.); to the crack between the baseboard and wall; along the countertop backsplash-wall interface; under eating table(s); and around the toilet base. The fine fan tip was used to apply test material in a band approximately one-third meter wide under sinks, to the underside of shelves and tables, under large appliances such as a refrigerator, and to the underside of drawers (while drawers were removed). The pin stream tip was used only intermittently to spray behind large appliances such as a washing machine. To measure total chlorpyrifos deposition onto nontarget horizontal surfaces, 100-cm^2 denim cloth pads were placed on horizontal surfaces. Measured 10 day cumulative deposition pads -- reporting day 10 average	0.0085

Table D-10: Comparison of Crack and Crevice and Broadcast Treatment Residues (residues from different studies)				
			values for 2 rooms for each house.	
Leidy et. al (1996)	0.5% Chlorpyrifos	aerosol can w/ C&C tip (residue at floor/wall interface)	Collection media = 2.5 cm x 30.2 cm aluminum template (plate). Samples collected in 3 rooms at wall/floor interface and in center of room. Residues reported from pre-application to 84 days post application. Residues reported here are Day 0 residues.	0.008
		aerosol can w/ C&C tip (residue from center of room)		0.01
Wright and Jackson (1975)	1% Chlorpyrifos	aerosol-type sprayer with injection tube	Collection media: aluminum pie plates (22.9 cm diameter). 1 row of 6 plates centered in room starting 91 cm from wall, with each successive plate 2.5 cm from lip of preceding plate. At each sampling time, 1 plate analyzed from 3 replicate rooms. Residue values reported are average of 3 replicates. Meant to collect residues from non-target areas in room -- did not collect residues near application sites.	0.0012
		compressed air sprayer		0.011
	1% Diazinon	aerosol-type sprayer with injection tube		0.0011
		compressed air sprayer		0.0053
	2% Diazinon	aerosol-type sprayer with injection tube		0.001
		compressed air sprayer		0.016
Broadcast Treatments				
SOURCE				**RESIDUE (µg/cm^2)**
Fenske (1990)	0.5% Chlorpyrifos	manually-pressurized handwand	Collection media: aluminum foil samples. 5 coupons collected immediately after application.	15
Gurunathan et al. (1998)	0.5% Chlorpyrifos	manually-pressurized handwand	Surface wipe samples collected from surface of dressers and toys placed on floor. Value reported is max concentration measured on toys 1 week following application	
Krieger (2001)	0.5% Chlorpyrifos	manually-pressurized handwand	Foil samples collected in 3 treated rooms (no information on number of samples per room). Residue value reported is average for three rooms.	
Comparison of Residues from Crack and Crevice and Broadcast Treatments				
Broadcast residue (µg/cm^2)		**Crack and Crevice residue (µg/cm^2)**		**Crack and Crevice Residues = X% of Broadcast Residue**

Table D-10: Comparison of Crack and Crevice and Broadcast Treatment Residues (residues from different studies)		
15	1.5	10%
	0.2	1%
	0.01	0.07%
	0.0006	0.004%
	0.0023	0.02%
	0.0085	0.06%
	0.008	0.05%
	0.01	0.07%
	0.0012	0.01%
	0.011	0.07%
	0.0011	0.01%
	0.0053	0.04%
	0.001	0.01%
	0.016	0.11%

Table D-11: Comparison of Crack and Crevice and Broadcast Treatment Residues (residues from the same study)				
Crack and Crevice Treatment				
SOURCE				**RESIDUE (µg/cm^2)**
Selim (2008)	0.1% Esfenvalerate	aerosol can with C/C tip	Application technique: applied 1-inch band along baseboard (as opposed to 18 inch band which they considered perimeter treatment). Collection media: deposition coupons. Number of samples: 61 coupons placed along wall/floor intersection (15 cm x 5 cm) and placed in pattern throughout room (5 cm x 5 cm). Size of room: 15 ft 2 in x 15 ft 2 in (462 cm x 462 cm). Treated area = based on figure in study which showed which coupons were within treated area. Untreated area = based on figure in study which showed which coupons were within untreated area. 0.2 ug/cm^2 value comes from taking 10% of residue found along edges of room (coupons picked based on diagram in study of what coupons fell in area treated) and 90% of residue found on coupons in center of room.	0.2
Broadcast Treatment				
SOURCE				**RESIDUE (µg/cm^2)**
Selim (2008)	0.1% Esfenvalerate	aerosol can	Collection media: alpha-cellulose coupons. Sampling time: collected 30 minutes after application. Number of samples: at each sampling time, samples were collected from 61 locations on the floor. Size of room: 15 ft 2 in x 15 ft 2 in (462 cm x 462 cm)	2.901
Comparison of Residues from Crack and Crevice and Broadcast Treatments				
Broadcast residue (µg/cm^2)		**Crack and Crevice residue (µg/cm^2)**		**Crack and Crevice Residue = X% of Broadcast Residue**
2.901		0.2		7%

Table D-12: Summary of Crack and Crevice Residues as a Percent of Broadcast Residues from Two Comparisons	
MINIMUM:	0.004%
MAXIMUM:	10%
AVERAGE:	1%
Proposed in SOP:	10%

D.5.3 Default residue values based on type of application

If chemical-specific deposition data are not available and the label does not provide an application rate in terms of mass per unit area, then default residue values may be used based on the percent spray of the product. **These values are meant to be high-end conservative values to use when little to no other information is available to calculate a product-specific residue value.**

Broadcast Treatment (liquids and foggers):
Recommended default residue value: 15 $\mu g/cm^2$ for a 0.5% liquid spray
5.4 $\mu g/cm^2$ for a 0.5% fogger

The default residue value proposed for broadcast liquid formulation treatments is based on a review of four literature studies which measured deposition following application of 0.5% spray pesticide products to indoor residences. The maximum residue value measured was chosen as the default residue value as a conservative approach. The following table provides a summary of the studies considered and further details about each study are provided after the table. It is assumed that the more active ingredient applied (i.e., higher percent spray), the higher the measured residue value would be; therefore, it is proposed in the Indoor SOP that the residue value be adjusted depending on the percent spray.

Table D-13: Summary of Broadcast Default Residue Analysis

Active Ingredient and Percent Solution Applied	Source	Application Equipment	Residue ($\mu g/cm^2$)	Notes on Study
		Average residue:	10	
		Minimum:	2.9	
		Maximum:	15	
0.10% esfenvalerate	Selim (2008)	aerosol can	2.901	**Application technique:** The test substance was applied as a broadcast spray across an 8 ft by 8 ft area in the center of the room. Application was performed from a distance of approximately 18 inches, in one foot wide swaths, sweeping across the area in one foot wide rows, while moving backwards, to evenly cover the area, as if applying to a carpet. **Sample Collection:** Collection media: alpha-cellulose coupons. Sampling time: collected 30 minutes after application. Number of samples: at each sampling time, samples were collected from 61 locations on the floor. Size of room: 15 ft 2 in x 15 ft 2 in (462 cm x 462 cm)
0.50% chlorpyrifos	Vaccaro (1991)	manually-pressurized handwand	7.19	**Application technique:** Pesticide product diluted with water and applied as an emulsion using a manually-pressurized handwand. **Sample collection:** Collection media: gauze coupons. Placed randomly on floor in treated room. 4 coupons sampled in room w/o activity and 2 coupons sampled in rooms w/activity (3 rooms). Value reported is average coupon residue for all 4 rooms sampled.

Table D-13: Summary of Broadcast Default Residue Analysis				
Active Ingredient and Percent Solution Applied	Source	Application Equipment	Residue ($\mu g/cm^2$)	Notes on Study
0.50% chlorpyrifos	Fenske et al.(1990)	manually-pressurized handwand	13.6	**Application technique:** formulation applied approximately 40 cm above the carpet with a handheld fan broadcast nozzle attached to a CO_2 pressurized tank. **Sample collection:** Collection media: aluminum foil samples. 5 coupons collected immediately after application.
0.50% chlorpyrifos	Krieger et al.(2001)	manually-pressurized handwand	15	**Application technique:** formulation applied with a handheld pressurized tank and wand. **Sample collection:** Foil samples collected in 3 treated rooms (no information on number of samples per room). Residue value reported is average for three rooms.

The default residue value proposed for broadcast fogger treatments is based on a review of three NDETF studies which measured deposition following application of 0.2% deltamethrin (Selim, 2000c), 0.5% permethrin (Selim, 2003c) and 0.5% pyrethrin (Selim, 2000b). The average residue for each study was adjusted to account for the differences in percent spray and then averaged across the three studies. In the case of foggers, the average residue was used, rather than the maximum from the three studies, since the residues were all very close (0.5% deltamethrin: 5.6 $\mu g/cm^2$; 0.5% permethrin: 4.8 $\mu g/cm^2$; 0.5% pyrethrin: 5.8 $\mu g/cm^2$). It is assumed that the more active ingredient applied (i.e., higher percent spray), the higher the measured residue value would be; therefore, it is proposed in the Indoor SOP that the residue value be adjusted depending on the percent spray.

Perimeter/Spot/Bedbug (Coarse) Treatment:
Recommended default residue value: 4.5 $\mu g/cm^2$

For perimeter/spot/bedbug (coarse) treatments, deposition data from three studies were available for five chemicals. The table below presents the residue values obtained from the available chemical-specific studies. The available data did not seem to indicate any trend with percent spray (i.e., a higher percent spray did not necessarily result in a higher residue value for a room). Therefore, for these application methods, a weighted average was calculated for each study and an average residue value based on all the available studies was used as the default for each particular application method. These values should be used as is and should not be adjusted for percent spray.

Table D-14: Summary of Perimeter/Spot/Bedbug (Coarse) Default Residue Analysis				
Active Ingredient and Percent Solution Applied	Source	Application Equipment	Residue ($\mu g/cm^2$)	Notes on Study
		Average residue:	4.5	
		Minimum:	0.9	
		Maximum:	8.8	

Table D-14: Summary of Perimeter/Spot/Bedbug (Coarse) Default Residue Analysis				
Active Ingredient and Percent Solution Applied	Source	Application Equipment	Residue ($\mu g/cm^2$)	Notes on Study
0.50% malathion	U.S. EPA (1993)	compressed air sprayer	8.8	**Application technique:** Report states that crack and crevice application was made but defines crack and crevice as treatment "around the perimeter or baseboard area of a room". Application made with a compressed air sprayer. **Sample collection:** Collection media: cotton dosimeter patches. Sampling time: 0 and 4 hours; no difference identified between 2 sampling times. Number of samples: divided floor into 16 blocks; 100 samples collected. Size of room: 12 ft x 12 ft (366 cm x 366 cm). Treated area = 0-30 cm from wall. Untreated area = >90 cm from wall. Weighted average residue = (30% of average residue from treated area) + (70% of average residue from untreated area).
0.17% chlorpyrifos (heavy)	Keenan (2007)	compressed air sprayer	5.2	**Application technique:** perimeter application directed at the baseboards but spreading for as much as half a meter up the wall and along the floor. chlorpyrifos: **a**pplied as a "heavy" and a "light" level . PCA described the heavy application as "good coverage, what I would use in my house". PCA described the light application as a "fine spray, what I would use in somebody else's house". Study personnel could not visually distinguish between the two applications. deltamethrin and cyfluthrin: applied as "light" perimeter application. **Sample Collection:** Collection media: chromatography paper attached to foam boards located in 3 locations in room (in corner, under window and along wall). Number of samples: Cut paper into 5 8-cm sections from the wall/floor intersection out to 40 cm. Size of room: 10 ft x 10 ft (305 cm x 305 cm). Treated area = 0-8 cm. Untreated area = 8-40 cm. Weighted average residue = (30% of average residue from treated area) + (70% of average residue from untreated area).
0.17% chlorpyrifos (light)			4.9	
0.03% deltamethrin			5.5	
0.02% cyfluthrin			1.5	
0.10% esfenvalerate	Selim (2008)	aerosol can with typical nozzle	0.9	**Application technique:** The applicator applied the test substance to the entire baseboard, moving at a speed of 1 linear foot per second. The test container was held 18 inches above the baseboard to achieve an approximate one foot spray band (6 inches up the wall and six inches on the floor). **Sample Collection:** Collection media: alpha-cellulose coupons. Sampling time: collected 30 minutes after application. Number of samples: at each sampling time, samples were collected from 61 locations on the floor. Size of room: 15 ft 2 in x 15 ft 2 in (462 cm x 462 cm). Treated area and untreated area = based on information in study which indicated which coupons were within treated area. Weighted average residue = (30% of average residue from treated area) + (70% of average residue from untreated area).

Perimeter/Spot/Bedbug (Pinstream) Treatment:
Recommended default residue value: 1.1 $\mu g/cm^2$

For perimeter/spot/bedbug (pinstream) treatments, deposition data from two studies were available for four chemicals. The table below presents the residue values obtained from the available chemical-specific studies. The available data did not seem to indicate any trend with percent spray (i.e., a higher percent spray did not necessarily result in a higher residue value for a room). Therefore, for these application methods, a weighted average was calculated for each study and an average residue value based on all the available studies was used as the default for each particular application method. These values should be used as is and should not be adjusted for percent spray.

Table D-15: Summary of Perimeter/Spot/Bedbug (pinstream) Default Residue Analysis

Active Ingredient and Percent Solution Applied	Source	Application Equipment	Residue (ug/cm^2)	Notes on Study
		Average residue:	1.1	
		Minimum:	0.027	
		Maximum:	4.4	
1% propoxur	Smith (2011) – Review of unpublished study from ORD	aerosol can with C/C tip	0.0866	**Application technique:** propoxur: applied with aerosol can into simulated cracks and crevices (SCC) constructed in a test house. permethrin and cypermethrin: applied using compressed air sprayer with c/c tip. The SCCs were constructed by placing paneling on three walls in living room and affixing wood strips to the paneling to create cracks and crevices from the floor to the ceiling. Each of the six panels consisted of 1536 lineal inches (3901 lineal cm) for a total of 9216 lineal inches. **Sample collection:** Surface residues of all four chemicals were collected using deposition coupons and floor wipes in the room of application (the living room) and two other rooms in the test house (the den and master bedroom) during the application, immediately after, and 1, 2, 3, 7, 14, 21, 28, and 35 days after application. Treated area and untreated area = based on information in study which indicated which coupons were within treated area. Weighted average residue = (30% of average residue from treated area) + (70% of average residue from untreated area).
0.5% permethrin		compressed air sprayer with C/C tip	0.0552	
0.2% cypermethrin		compressed air sprayer with C/C tip	0.0273	
0.05% deltamethrin	Keenan (2007)	aerosol can with C/C tip	4.4	**Application technique:** aerosol can applied as a crack and crevice spray in the test room using an applicator wand supplied at purchase by the manufacturer. **Sample collection:** Collection media: chromatography paper attached to foam boards located in 3 locations in room (in corner, under window and along wall). Number of samples: Cut paper into 5 8-cm sections from the wall/floor intersection out to 40 cm. Size of room: 10 ft x 10 ft (305 cm x 305 cm). Treated area = 0-8 cm. Untreated area = 8-40 cm. Weighted average residue = (30% of average residue from treated area) + (70% of average residue from untreated area).

Crack and crevice Treatment*:*
Recommended default residue value: 0.3 $\mu g/cm^2$

For crack and crevice treatments, deposition data from two studies were available for four chemicals. The table below presents the residue values obtained from the available chemical-specific studies. The available data did not seem to indicate any trend with percent spray (i.e., a higher percent spray did not necessarily result in a higher residue value for a room). Therefore, for these application methods, a weighted average was calculated for each study and an average residue value based on all the available studies was used as the default for each particular application method. These values should be used as is and should not be adjusted for percent spray.

Table D-16: Summary of Crack and Crevice Default Residue Analysis

Active Ingredient and Percent Solution Applied	Source	Application Equipment	Residue ($\mu g/cm^2$)	Notes on Study
		Average residue:	0.3	
		Minimum:	0.00956	
		Maximum:	1.5	
1% propoxur	Smith (2011) – Review of unpublished study from ORD	aerosol can with C/C tip	0.0319	**Application technique:** propoxur: applied with aerosol can into simulated cracks and crevices (SCC) constructed in a test house. permethrin and cypermethrin: applied using compressed air sprayer with c/c tip. The SCCs were constructed by placing paneling on three walls in living room and affixing wood strips to the paneling to create cracks and crevices from the floor to the ceiling. Each of the six panels consisted of 1536 lineal inches (3901 lineal cm) for a total of 9216 lineal inches. **Sample collection:** Surface residues of all four chemicals were collected using deposition coupons and floor wipes in the room of application (the living room) and two other rooms in the test house (the den and master bedroom) during the application, immediately after, and 1, 2, 3, 7, 14, 21, 28, and 35 days after application. Treated area and untreated area = based on information in study which indicated which coupons were within treated area. Weighted average residue = (10% of average residue from treated area) + (90% of average residue from untreated area).
0.5% permethrin		compressed air sprayer with C/C tip	0.019	
0.2% cypermethrin		compressed air sprayer with C/C tip	0.00956	
0.5% chlorpyrifos	Stout and Mason (2003)	compressed air applied by certified appl w/ pin-stream spray tip	0.01	**Application technique:** dilute solution is systematically placed into the potential cockroach harborages such as the cracks and crevices of the cabinetry, and around and behind the stove, refrigerator and dishwasher. **Sample collection:** Collection media: deposition coupons. 12 coupons placed in rows in kitchen (application site) and den. Collected prior to, immediately following the application (the sample collection process was initiated after the application and required about 1 h to complete), and at days 3, 7, 14 and 21 days post-application. Individual coupons in kitchen ranged from 0.0015 to 0.23 ug/cm2. Weighted average residue = (10% of average residue from treated area) + (90% of average residue from untreated area).

Table D-16: Summary of Crack and Crevice Default Residue Analysis				
Active Ingredient and Percent Solution Applied	Source	Application Equipment	Residue ($\mu g/cm^2$)	Notes on Study
0.1% esfenvalerate	Selim (2008)	aerosol can with C/C tip	0.2	**Application technique:** The applicator applied the test substance to the entire baseboard (corner), moving at a speed of 1 linear foot per second. The test container was held 12 to 18 inches above the baseboard to achieve an approximate one inch spray band at the floor/wall interface. **Sample Collection:** Collection media: deposition coupons. Number of samples: 61 coupons placed along wall/floor intersection (15 cm x 5 cm) and placed in pattern throughout room (5 cm x 5 cm). Size of room: 15 ft 2 in x 15 ft 2 in (462 cm x 462 cm). Treated area = based on figure in study which showed which coupons were within treated area. Untreated area = based on figure in study which showed which coupons were within untreated area. Weighted average residue = (10% of average residue from treated area) + (90% of average residue from untreated area)
0.05% deltamethrin	Keenan (2007)	aerosol can with C/C tip	1.5	**Application technique:** applied directly into C/C. **Sample collection:** Collection media: chromatography paper attached to foam boards located in 3 locations in room (in corner, under window and along wall). Number of samples: Cut paper into 5 8-cm sections from the wall/floor intersection out to 40 cm. Size of room: 10 ft x 10 ft (305 cm x 305 cm). Treated area = 0-8 cm. Untreated area = 8-40 cm. Weighted average residue = (10% of average residue from treated area) + (90% of average residue from untreated area)

D.6 Generic Estimates of Transferable Residue

Following an application, pesticide residue that remains on target surfaces (e.g., carpets, leaves, turf, etc.) and thus available for surface-to-skin transfer is referred to as transferable residue. Examples of non-transferable residue would be residue that evaporates, adheres to carpet fibers, or absorbs into plant surfaces. Typically, chemical-specific studies are submitted quantifying transferable residue using standardized and replicable methodologies on the day of application (i.e., "day 0") and subsequent days (i.e., 1, 3, 5, 7 days) following application. This data can then be directly used in mathematical models to estimate daily residue.

When a chemical-specific study is unavailable, however, transferable residue on the day of application (i.e., "day 0") can be estimated as a fraction of the application rate (e.g., 10% of the application rate as transferable residue on the day of application) and transferable residue on subsequent days can be calculated using a daily dissipation rate (e.g., 15% of the transferable residue on the day of application is present on the day after application).

Existing transferable residue studies for a variety of chemicals can provide a basis for generic approximations of the "day 0" transferable residue and daily dissipation when chemical-specific studies are unavailable to assess post-application exposure in outdoor and indoor residential settings. "Day 0" transferable residue, as a fraction of the application rate, is derived as the ratio

of the application rate as a mass per area target surface concentration (e.g., lbs active ingredient per acre) to the measured mass per area "day 0" concentration. Converting each value to the same units provides a unitless ratio which can also be considered as a percentage (i.e., 10% of the application is transferable residue on the day of application). Daily residue dissipation is typically derived using a first-order exponential decay model. Each day's measured transferable residue is log-transformed and regressed against the day of application using ordinary least squares (OLS). The resulting slope represents a constant fraction, or percentage, of residue that dissipates per day. The following sections present analyses of existing studies for various residential settings.

D.6.1 Turf

Transferable residue on turf has historically been referred to as transferable turf residue (TTR), and can be measured using a number of different techniques. The industry-based Occupational and Residential Exposure Task Force (ORETF) tested five techniques in 1996: the California roller method, the shoe method, the polyurethane foam (PUF) roller method, the drag sled method, and the foliar wash method. A follow-up study was conducted on a turf farm in 1997 using three modified techniques: the modified California roller method, the modified shoe method, and the ORETF roller method. The data from both of these studies is summarized and analyzed in a 1999 ORETF report (Cowell, J., and Johnson, D., 1999). Ultimately – based on the information provided by ORETF and working in conjunction with the California Department of Pesticide Regulation (DPR) and Canada's Pest Management Regulatory Agency (PMRA) – a TTR collection method (the Modified California Roller Method) was agreed upon for all future TTR studies. The Modified California Roller was selected because it produced the most consistent results across individuals, active ingredients, formulation types, and time than the other techniques. It also was sensitive enough to detect low levels of residues and was one of the easier techniques to use.

In a typical TTR study, triplicate samples are collected using the Modified California Roller Method before the day of application, on the day of application, and for several days following the application (e.g., 1, 3, 5, 7 days after application). Each sample is then extracted in solution to yield a mass of chemical which can be expressed as a turf residue concentration (e.g., [X] μg per [X] cm^2). This data can then be directly used in mathematical models to estimate daily residue.

TTR studies can also be used as surrogates in the event chemical-specific information is unavailable for a particular pesticide. The Agency analyzed 36 TTR studies using liquid formulations, 11 TTR studies using wettable powders/water dispersible granular (WP/WDG) formulations, and 12 studies using granular formulations for the purposes of establishing generic transferable residue factors. Since they are applied as sprays, residue data resulting from applications with the liquid/wettable powder/water dispersible granular formulation were combined while residues from applications of granular formulations were treated separately. *Table D-17* and *Table D-18* present the "day 0" transferable residue as a fraction of the application rate (F) for each of the 47 liquid/wettable powder/water dispersible granular studies and each of the 12 granular studies, respectively.

Table D-17: Residential Turf – Liquid/WP/WDG Transferable Residue Data				
MRID Number	**Active Ingredient**	**Site**	**Formulation**	**Fraction of Application Rate Available for Transfer (F)**
45040701	Isoxaban	CA	DF	0.015
		IN	DF	0.011
		MS	DF	0.0070
44901001	Chlorothalonil	GA	DF	0.010
		NY	DF	0.0042
		OR	DF	0.006
44955501	Permethrin	GA	EC	0.0064
		CA	EC	0.0085
		PA	EC	0.0061
45288601	Propiconazole	IN	EC	0.0016
		CA	EC	0.0097
		PA	EC	0.0045
45361602	Fluroxypyr	CA	EC	0.0043
		MS	EC	0.0035
		PA	EC	0.0074
45118725	Pyraclostrobin	NC	EC	0.0018
		CA	EC	0.0062
		PA	EC	0.0022
46684102	Pendimethalin	PA	EC	0.0019
		GA	EC	0.0016
		CA	EC	0.0021
45260201	Trinexapac-methyl	GA	EC	0.0047
		CA	EC	0.0031
		IN	EC	0.0069
44958501	Mancozeb	NC	F	0.00077
		PA	F	0.00041
		CA	F	0.00097
44958701	Simazine	CA	L	0.0027
		FL	L	0.0032
44958901	Monosodium Methanearsonate	NY	L	0.0029
		NC	L	0.0014
		CA	L	0.015
45067201	Trichlorfon	GA	L	0.00015
		MO	L	0.000033
		NY	L	0.0000050
44687101	Pentachloronitrobenzene	CA	L	0.011
		OR	L	0.0081
		MO	L	0.0067
45251501	Propamocarb	CA	L	0.0043
		MO	L	0.0035
		VA	L	0.0090
45894314	Propamocarb hydrochloride	CA	L	0.013
		PA	L	0.011

Table D-17: Residential Turf – Liquid/WP/WDG Transferable Residue Data				
MRID Number	**Active Ingredient**	**Site**	**Formulation**	**Fraction of Application Rate Available for Transfer (F)**
45249601	Triclopyr (Amine)	CA	L	0.0050
		IN	L	0.0046
		MS	L	0.0036
	Triclopyr (Ester)	CA	L	0.0031
		IN	L	0.0037
		MS	L	0.0050
45250001	Fenarimol	CA	L	0.061
		IN	L	0.0084
		MS	L	0.0058
45214201	Paclobutrazol	CA	L	0.010
		NY	L	0.0029
		NC	L	0.0053
45114301	Carbaryl	CA	L	0.030
		GA	L	0.015
		PA	L	0.011
44799001	Bensulide	NY	L	0.0040
44828401	Spinosad	CA	L	0.013
		MS	L	0.023
		PA	L	0.0087
44951901	Siduron	NY	L	0.0051
44959101	Diazinon	GA	L	0.00012
		CA	L	0.00050
		PA	L	0.00035
44968001	Iprodion	GA	L	0.0068
		CA	L	0.0094
		NY	L	0.0073
45111501	Cypermethrin	CA	L	0.0053
		MO	L	0.0014
		PA	L	0.0051
	Chlorothalonil	CA	L	0.013
		GA	L	0.0081
		NY	L	0.014
45033101	2,4-D	CA	L	0.013
		WI	L	0.011
45251401	Glufosinate-Ammonium	NY	LC	0.0040
		CA	LC	0.0070
		GA	LC	0.0028
4507150	Oryzalin	CA	SC	0.0049
		IN	SC	0.0046
		MS	SC	0.010
44959001	Dicamba	FL	SC	0.0078
		CA	SC	0.012
		PA	SC	0.010
46571104	Cyanzofamid	NC	SC	0.0037

Table D-17: Residential Turf – Liquid/WP/WDG Transferable Residue Data				
MRID Number	**Active Ingredient**	**Site**	**Formulation**	**Fraction of Application Rate Available for Transfer (F)**
45576801	Triticonazole	GA	SC	0.0060
		CA	SC	0.0032
		NY	SC	0.0017
46703508	Penoxsulam	GA	SC	0.043
		FL	SC	0.0068
47172301	Mesotrione	NY	SC	0.00096
		CA	SC	0.0032
		GA	SC	0.0017
45251201	Deltamethrin	NY	SC	0.0058
		GA	SC	0.0086
		CA	SC	0.014
	Oryzalin	CA	SC	0.061
		IN	SC	0.011
		MS	SC	0.013
45640010	Dinotefuran	CA	SG	0.0061
		PA	SG	0.0066
		GA	SG	0.0047
44969901	Pendimethalin	CA	WDG	0.030
45071501	Chlorothalonil (Daconil, Ultrex)	CA	WDG	0.0049
		GA	WDG	0.0046
		NY	WDG	0.010
45405301	Nicotinamide	PA	WDG	0.011
		GA	WDG	0.0044
		CA	WDG	0.0090
45102911	methyl 2,4-[o-(methylphenoxymethyl)phenyl]-2-methoxyimino) acetamide	NC	WDG	0.0043
		CA	WDG	0.014
		PA	WDG	0.017
45260401	Prodimaine	GA	WDG	0.0098
		CA	WDG	0.0012
		PA	WDG	0.00091
45149001	Cyfluthrin	GA	WP	0.011
		MS	WP	0.015
		NY	WP	0.0034
		CA	WP	0.012
		MO	WP	0.0069
		PA	WP	0.017
44952501	Pronamide	NC	WP	0.027
44952901	Myclobutanil	NC	WP	0.012
		CA	WP	0.024
44806401	Acephate	Fl	WSP	0.0052
44995502	Oxadiazon	GA	WSP	0.026
F = Fraction of residue available on day 0 Range of Data = 0.000005 – 0.061 (n = 131)				

Table D-18: Residential Turf – Granular Transferable Residue Data				
MRID Number	**Active Ingredient**	**Site**	**Formulation**	**Fraction of Application Rate Available for Transfer (F)**
44958801	Atrazine	GA	G	0.0021
		FL	G	0.0069
45260401	Prodimaine	GA	G	0.00021
		CA	G	0.00022
		PA	G	0.00039
44829601	Chlorpyrifos	CA	G	0.0013
		IN	G	0.00075
		MS	G	0.00075
44959101	Diazinon	GA	G	0.000039
		CA	G	0.000012
		PA	G	0.000028
45067201	Trichlorfon	GA	G	0.000006
		MO	G	0.000032
44998301	Benefin	CA	G	0.000109
		IN	G	0.000087
		MS	G	0.000047
	Trifluralin	CA	G	0.00012
		IN	G	0.000094
		MS	G	0.000067
46673901	Carbaryl	FL	G	0.0062
		KS	G	0.0019
		CA	G	0.0051
47172301	Mesotrione	NY	G	0.00077
		CA	G	0.0016
		GA	G	0.0017
45249601	Triclopyr, Clopyralid	CA	G	0.0051
		IN	G	0.0025
		MS	G	0.0023
45040701	Isoxaben (Gallery)	CA	G	0.00080
		IN	G	0.0020
		MS	G	0.00030
	Isoxaben (Gallery plus Surflan)	CA	G	0.0059
		IN	G	0.0027
		MS	G	0.00030
	Oryzalin (Gallery plus Surflan)	CA	G	0.0060
		IN	G	0.0030
		MS	G	0.00020
F = Fraction of residue available on day 0 Range of Data = 0.0000064 – 0.0069 (n = 37)				

D.6.2 Gardens, Trees, and "Pick-your-own" Farms

Transferable residue in vegetable, fruit, and flower gardens, trees, shrubs, bushes, and "pick-your-own" farms has historically been referred to as dislodgeable foliar residue (DFR). In chemical-specific studies, DFR is measured using a "leaf-punch" technique. Three (3) samples, each containing 40 leaf punches equal to approximately 400 square centimeters (cm^2) of 2-sided foliar surface area, are collected on the day of application and for several days following the application (e.g., 1, 3, 5, 7 days after application). Each of the 3 samples is then "dislodged" in solution to yield a mass of chemical which can be expressed as a foliar concentration (e.g., [X] μg per 400 cm^2).

DFR studies can also be used as surrogates in the event chemical-specific information is unavailable for a particular pesticide. Nineteen (19) studies conducted by the Agricultural Reentry Task Force (ARTF) were analyzed for the purposes of establishing generic transferable residue factors. *Table D-19* below presents the "day 0" transferable residue as a fraction of the application rate (F_{AR}) and the fraction per day daily dissipation (F_D) for each of the 19 studies.

Table D-19: Gardens, Trees, and "Pick-your-own" Farms – Transferable Residue Data

Study Reference		Crop	Chemical	Application Rate (lb ai/acre)	Day 0 DFR (measured; μg ai/cm^2)	Transferable Residue as fraction of Application Rate (F_{AR})	Fraction per Day Daily Dissipation (F_D)
ARTF #	MRID						
ARF025	45138202	Apple	Malathion	1.25	2.45	0.17	0.09
					2.18	0.16	
					2.33	0.17	
ARF028	45175101	Orange	Cyfluthrin	0.10	0.03	0.02	0.03
					0.04	0.04	
					0.04	0.03	
ARF044	45469502	Nursery Citrus	Malathion	1.20	1.38	0.10	0.47
					1.77	0.13	
					1.26	0.09	
ARF009	45005904	Sweet Corn	Chlorothalonil	1.40	1.82	0.12	0.19
					4.43	0.28	
					4.80	0.31	
ARF021	45005908	Dry Bean/Pea	Chlorothalonil	1.40	1.78	0.11	0.07
					1.57	0.10	
					1.45	0.09	
ARF041	45432301	Orange	Carbaryl	7.07	24.20	0.31	0.04
					24.60	0.31	
					30.00	0.38	
ARF010	45005905	Sweet Corn	Chlorothalonil	1.40	3.83	0.24	0.32
					2.31	0.15	
					2.27	0.14	
ARF022	45005909	Sunflower	Carbaryl	1.50	4.93	0.29	0.13
					6.05	0.36	
					4.78	0.28	
ARF048	45491901	Wine Grapes	Malathion	0.93	0.44	0.04	0.32
					0.69	0.07	
					0.78	0.07	
ARF023	45005910	Raisin Grapes	Malathion	0.94	1.37	0.13	0.10

Table D-19: Gardens, Trees, and "Pick-your-own" Farms – Transferable Residue Data							
Study Reference		Crop	Chemical	Application Rate (lb ai/acre)	Day 0 DFR (measured; μg ai/cm^2)	Transferable Residue as fraction of Application Rate (F_{AR})	Fraction per Day Daily Dissipation (F_D)
ARTF #	MRID						
					1.24	0.12	
					1.37	0.13	
ARF042	45432302	Grapefruit	Carbaryl	7.70	24.20	0.31	0.34
					24.60	0.31	
					30.00	0.38	
ARF012	45005907	Cauliflower	Chlorothalonil	1.10	0.94	0.08	0.19
					0.99	0.08	
					0.93	0.08	
ARF011	45005906	Cauliflower	Chlorothalonil	1.12	4.38	0.35	0.12
					4.43	0.35	
					4.70	0.37	
ARF024	45005911	Tobacco	Carbaryl	2.00	4.83	0.22	0.24
					4.68	0.21	
					5.45	0.24	
ARF037	45191701	Cabbage	Carbaryl	2.00	3.95	0.18	0.17
					1.27	0.06	
					1.74	0.08	
ARF051	45530103	Tomato	Chlorothalonil	2.70	5.58	0.18	0.40
					5.65	0.19	
					4.88	0.16	
ARF049	45491902	Squash	Malathion	0.95	3.28	0.31	0.10
					5.05	0.47	
					3.55	0.33	
ARF039	45344501	Chrysanthemum	Diazinon	0.66	5.63	0.76	0.45
					6.58	0.89	
					3.60	0.49	
					5.90	0.80	
					4.95	0.67	
					3.40	0.46	
ARF043	45469501	Nursery Citrus	Malathion	1.30	2.46	0.17	0.11
					2.89	0.20	
					2.55	0.18	
F_{AR} = "Day 0" DFR, expressed as a fraction of Application Rate F_D = daily dissipation, expressed as a fraction per day							

Though F_{AR} values are intended to be applied when chemical-specific data are unavailable, there may be systematic differences such that different F_{AR} values could be used for specific circumstances. For example, if it were the case that apples typically demonstrated higher F_{AR} values than other crops, one would want to utilize apple-specific F_{AR} values in order not to underestimate potential exposure while conducting activities associated with apples. The same could apply for chemical class (i.e., insecticides, fungicides, etc.). To investigate such trends, F_{AR} data from *Table D-19* are plotted separately against crop and chemicals in *Figure D-2* and *Figure D-3*, respectively. A lognormal probability plot of the composite dataset coded for crop-chemical combination is also presented in *Figure D-4*.

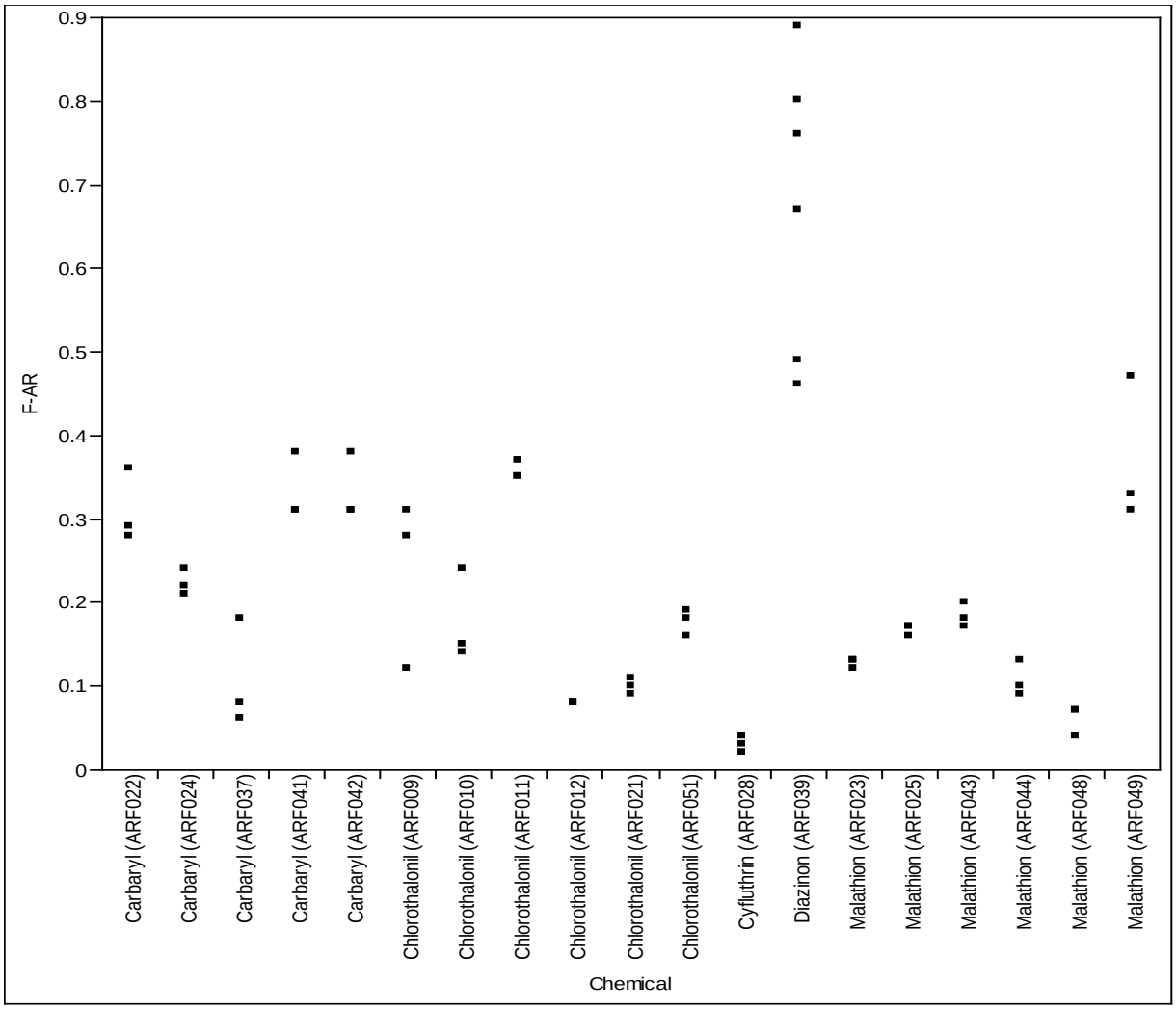


Figure D-2: Fraction of Transferable Residue, By Chemical

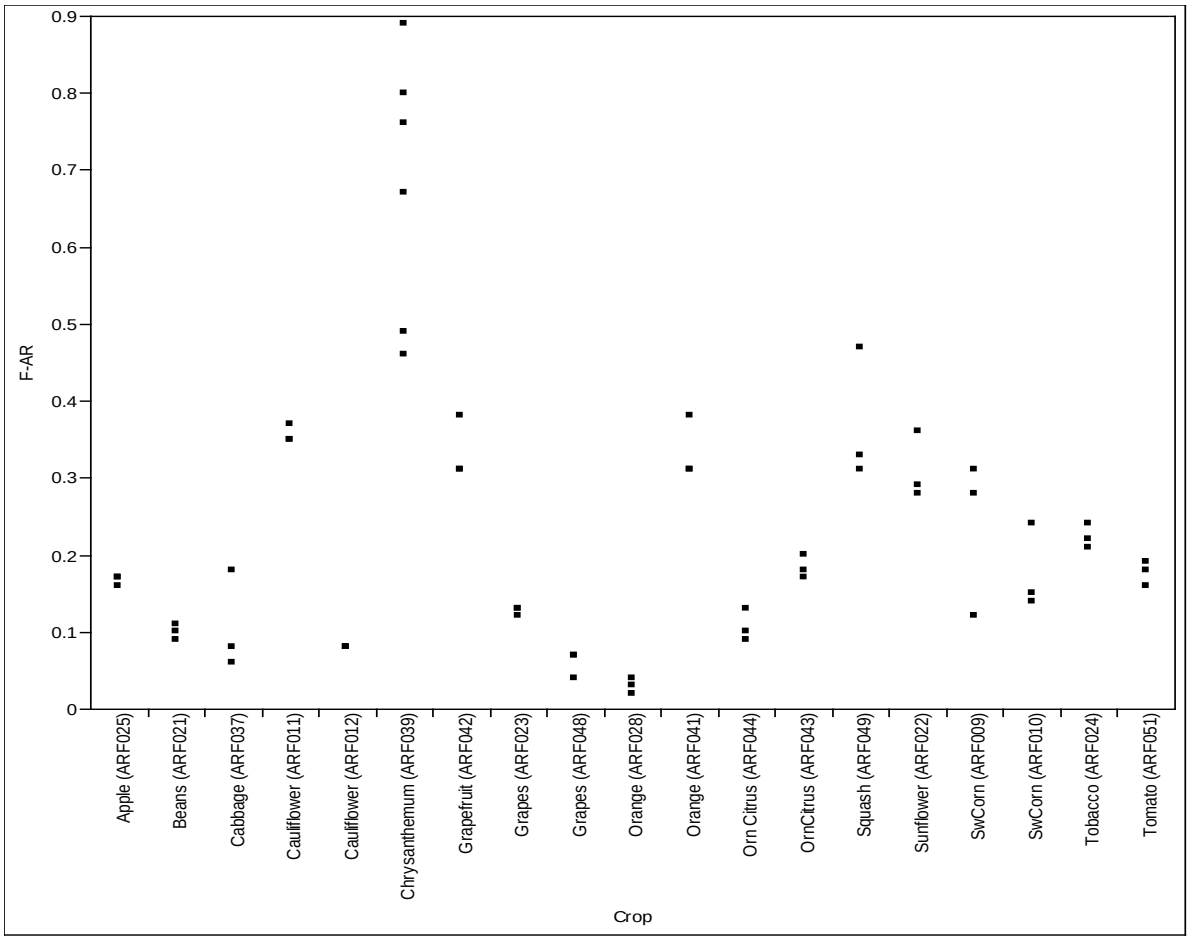


Figure D-3: Fraction of Transferable Residue, By Crop Type

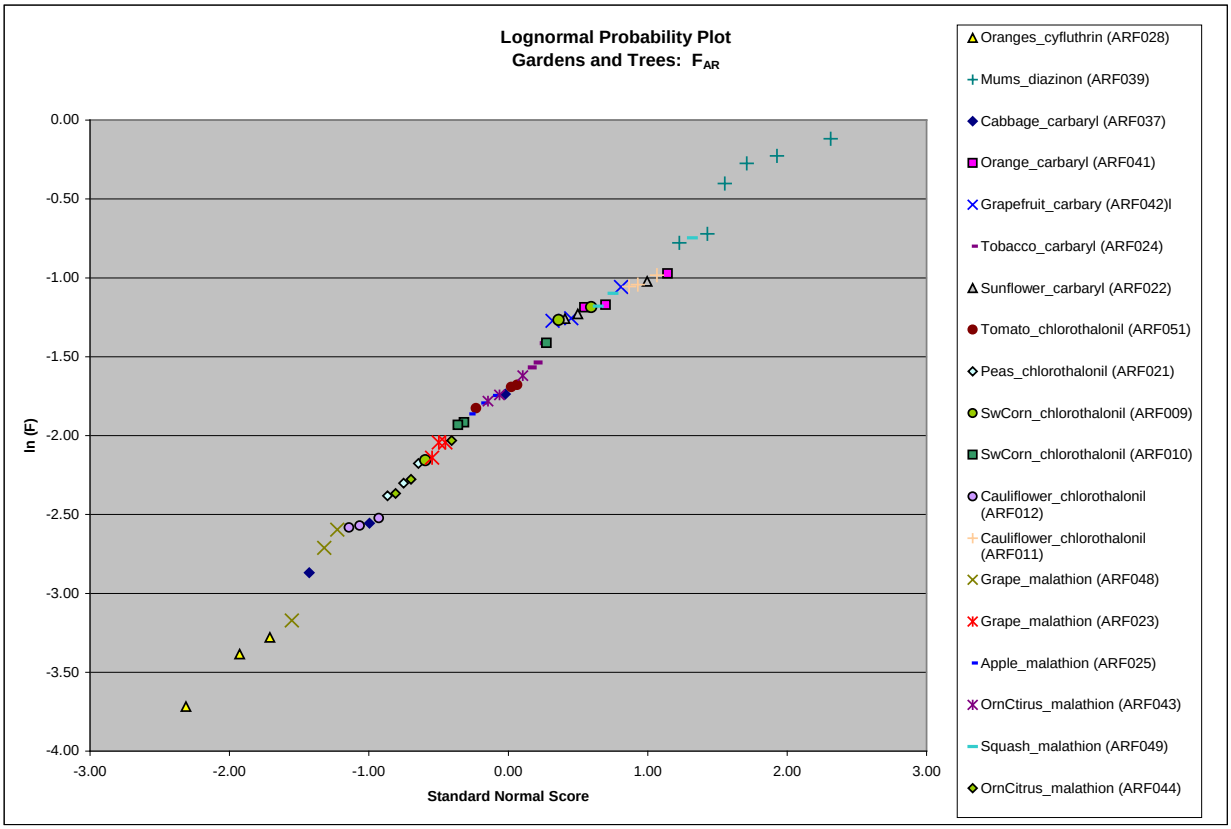


Figure D-4: Gardens and Trees – Fraction of Available Residue Lognormal Probability Plot

It is not clear from the data whether any broad categories can be defined for F_{AR} values. For example, *Figure D-4* shows that while malathion demonstrates relatively high F_{AR} values (0.31 – 0.47; ARF049) it also demonstrates some of the lowest (0.04 – 0.07; ARF048). The same appears to be the case for specific crops with oranges, as one example, demonstrating fairly high F_{AR} values (0.31 – 0.38; ARF041) and low F_{AR} values (0.02 – 0.04; ARF028).

Due to the the lack of meaningful trends or patterns in these datasets, the F_{AR} values (as well as residue dissipation values) are pooled into composite datasets for the purposes of providing generic transferable residue factors for exposure assessment. Lognormal probability plots for these composite datasets are presented below in *Figure D-5* and *Figure D-6*.

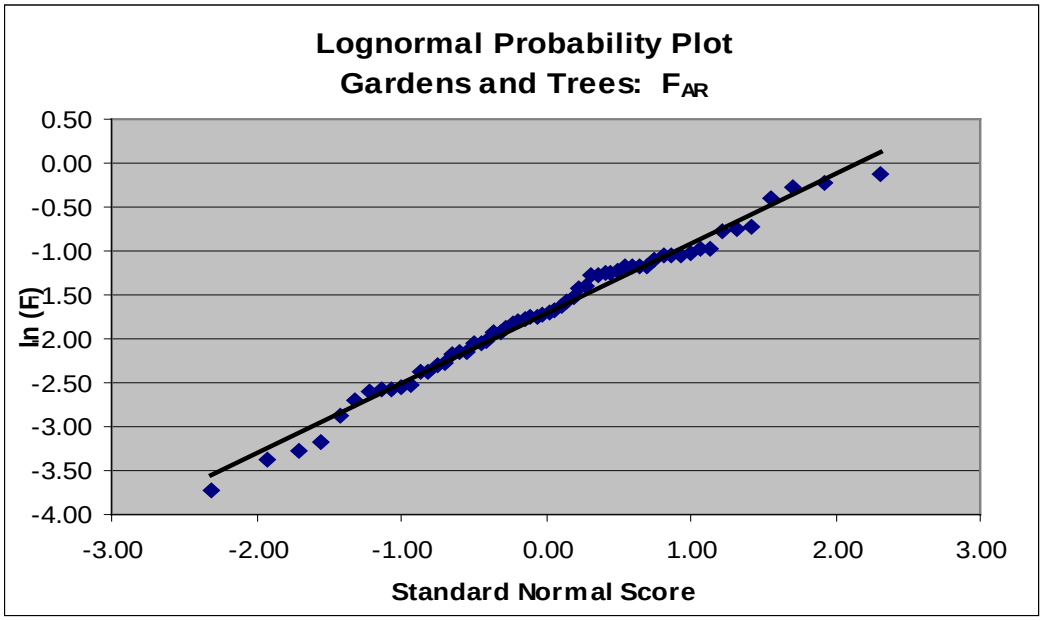


Figure D-5: Gardens and Trees – Fraction of Available Residue Lognormal Probability Plot

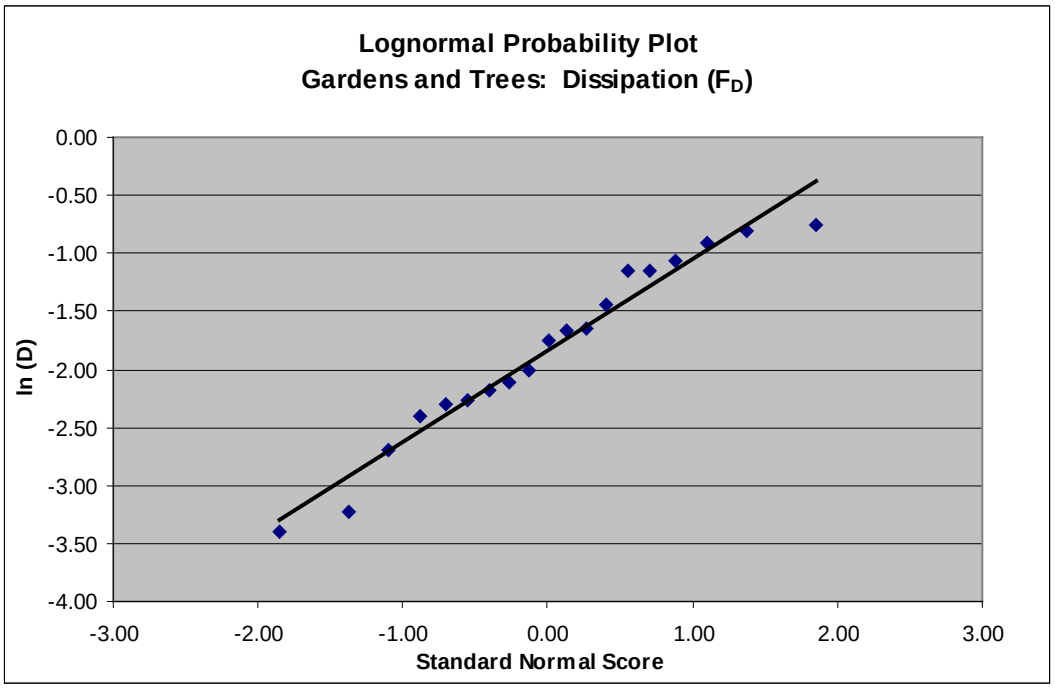


Figure D-6: Gardens and Trees – Residue Dissipation Lognormal Probability Plot

Because both datasets reasonably fit lognormal distributions, statistics, such as standard deviations and percentiles can be estimated based on characteristics of the lognormal distribution. *Table D-20* and *Table D-21* below present select summary statistics for each factor. [Note: it is recognized that treating each data point independently is technically incorrect due to the "nested" structure of the data set (i.e., F_{AR} values within crops, which are within chemicals,

etc.); however, resulting statistics are nonetheless reasonable and useful for exposure assessment purposes.]

Table D-20: Gardens, Trees, and "Pick-your-own" Farms Statistical Summary	
Statistic	**Transferable Residue as Fraction of Application Rate (F_{AR})**
50th percentile	0.18
75th percentile	0.31
90th percentile	0.50
95th percentile	0.66
99th percentile	> 1.0
99.9th percentile	> 1.0
AM (SD)	0.25 (0.23)
GM (GSD)	0.18 (2.2)
Range	0.02 – 0.89
N	60
Statistics based on a lognormal distribution. AM (SD) = arithmetic mean (standard deviation) GM (GSD) = geometric mean (geometric standard deviation)	

Table D-21: Gardens, Trees, and "Pick-your-own" Farms Statistical Summary	
Statistic	**Fraction per Day Daily Dissipation (F_D)**
50th percentile	0.16
25th percentile	0.09
5th percentile	0.04
1st percentile	0.03
0.1st percentile	0.01
AM (SD)	0.22 (0.20)
GM (GSD)	0.16 (2.2)
Range	0.03 – 0.47
N	19
Statistics based on a lognormal distribution. AM (SD) = arithmetic mean (standard deviation) GM (GSD) = geometric mean (geometric standard deviation)	

D.6.3 Indoor Surfaces

The values for fraction transferred are based on information from two sources which examined transferability of chemicals from carpets and hard surfaces. For the purposes of the residential indoor SOP, data obtained from studies included in the analysis by Beamer et. al (2009) and data from the NDETF studies were combined for the two types of surfaces (carpet and vinyl/hard surfaces).

1) Beamer, P; Canales, R; and Leckie, J. (2009) Developing probability distributions for transfer efficiencies for dermal exposure. Journal of Exposure Science and Environmental Epidemiology. 19: 274-283.

Beamer *et. al* (2009) analyzed numerous transfer efficiency studies, which covered various methods including the cloth roller, drag sled, PUF roller, and bare hand press. A literature search was conducted, which identified 35 studies and included 25 different sampling methods, 25 chemicals, and 10 surface types. According to Beamer *et al*., the majority of these studies only reported mean values and were not included in the analysis. Thirteen studies provided full data sets, but four of those provided little data on four different chemicals and were excluded from the analysis. Therefore, out of a total of 35 studies identified, only nine studies were used to fit transfer efficiency distributions for three chemicals (chlorpyrifos, pyrethrins and piperonyl butoxide) on 4 different surfaces with 8

different methods. Most of the transfer efficiencies were measured relatively soon after application (i.e., within 24 hours). Data sets were compared using a non-parametric analysis of variance method and the Kruskal-Wallis test to determine whether different combinations of data sets arise from the same distribution. The data sets were initially separated by chemical and surface type. The Kruskall-Wallis test was used to determine whether data sets from different sampling methods, but for the same chemical and surface could be combined. All data sets for a specific chemical and surface type were evaluated and data sets were eliminated one by one, with the attempt being to maximize the number of data points until the *p*-value was greater than 0.05. The experimental methods of the combined data sets were assessed to determine whether there were any consistent trends related to the inclusion/exclusion of data sets. No consistent trends were observed with respect to different transfer efficiency methods, dry versus wet hand presses, different application concentrations and formulations and different sampling time points after application. The combined data set was assessed to determine which distribution was a best fit and it was determined to be the lognormal distribution. The Kruskal-Wallis *p*-value for all surface and chemical combinations was less than 0.0001, indicating that distributions are statistically different. A trend for pesticide transfer was observed for surface type with transfer from vinyl being higher than from carpet.

Full data sets were provided for 5 studies which were utilized for this SOP and included the following studies:

Camann, D.; Harding, H.; Geno, P.; and Agrawl S. (1996). Comparison of Methods to Determine Dislodgeable Residue Transfer from Floors (EPA/600/R96/089) United States Environmental Protection Agency, Research Triangle Park, NC.

> Three methods were evaluated for measurement of freshly-applied pesticide residues on carpeted and vinyl floors. Tests were conducted to determine the relative performance of the three methods for removal of dislodgeable residues and to compare them with human skin. The Dow drag sled and the Southwest Research Institute polyurethane foam (PUF) roller performed better than the California cloth roller. Moistening the sampling media increased the transfer by the drag sled and the PUF roller, but substantially increased measurement variability. An isopropanol handwipe method efficiently removed dried pesticide residues from the hands of volunteers (104% of chlorpyrifos, 92% of pyrethrin I). Both the drag sled and the PUF roller were found to be acceptable dislodgeable residue methods on the basis of these studies. The transfer efficiency of the drag sled consistently exceeded the transfer efficiency of the PUF roller, which consistently exceeded the transfer efficiency of human hand presses. This relationship was observed for a variety of pesticides, loadings, application methods, and surfaces. The pliable polyurethane foam sampling surface of the PUF roller with its rolling action is likely to better simulate human skin in its transfer via contact with surfaces than is the denim cloth of the Dow sled with its drag action. Either memanical method can be used to estimate dermal transfer of pesticide residues from recently treated floors. Round-robin testing of the drag sled and PUF roller by potential registrants under strict QA/QC guidance from EPA is recommended.

Fortune, C. (1997). Round-Robin Testing of Methods for Collecting Dislodgeable Residues from Carpets. (EPA/600/R97/107). United States Environmental Protection Agency, Research Triangle Park, NC.

> A round-robin test was conducted using six volunteers to evaluate three dislodgeable residue methods sampling new carpets treated with a commercial pesticide formulation. Seven separate tests were performed, each using a formulation containing three target pesticides (chlorpyrifos, pyrethrin I, and piperonyl butoxide). Strict QA/QC guidelines were followed as each participant collected three replicate samples each with the polyurethane foam (PUF) roller, the California roller, and the Dow drag sled methods. Sampling precision was high for all three methods for measurements of this type. The overall results (mean % RSD, relative standard deviation, N=21) show the Dow sled with the best sampling precision (25.4% RSD), followed by the California roller (30.7%), and then the PUF roller (37.9%). Mean transfer efficiency, the ratio of the method transfer rate to the pesticide deposition rate, was highest for the California roller (5.0%), followed by the Dow sled (2.1%) and the PUF roller (1.7%). The mean transfer efficiency rates in this study were substantially higher than those reported in earlier studies of this type. Information relating to ease of use, simplicity, time requirements, and other criteria for each of the test methods was obtained from written subjective evaluation and critique by each volunteer. A compilation of that information revealed that both the Dow sled and PUF roller methods were rated highly and equal to

one another, while the California roller was rated lower. Further testing is recommended to determine the effect on transfer efficiency rates due to carpet age, type and prior cleaning or chemical treatment.

Krieger, R. I., C. E. Bernard, T. M. Dinoff, L. Fell, T. Osimitz, J. H. Ross, and T. Thongsinthusak. (2000). Biomonitoring and whole body cotton dosimetry to estimate potential human dermal exposure to semivolatile chemicals. J. Exposure Analysis & Environ. Epidemiol. 10: 50-57.

Current methods of estimating absorbed dosage (AD) of chemicals were evaluated to determine residue transfer from a carpet treated with chlorpyrifos (CP) to humans who performed a structured exercise routine. To determine the dislodgeability of residue, a California Department of Food and Agriculture (CDFA) roller was applied to a flat cotton cloth upon a treated carpet. Levels ranged from 0.06 to 0.99 μg CP/cm^2. Cotton whole body dosimeters (WBD) were also used to assess residue transfer. The dosimeters retained 1.5 to 38 mg CP/person. Urine biomonitoring (3 days) for 3,5,6-trichloro-2-pyridinol(TCP) of persons who wore only swimsuits revealed a mean AD of 176 μg CP equivalents/person. The results show that the AD depends on the extent of contact transfer and dermal absorption of the residue. Default exposure assessments based upon environmental levels of chemicals and hypothetical transport pathways predict excessive exposure. The cotton WBD retains chemical residues and may be effectively used to predict dermal dose under experimental conditions.

Ross, J; Fong, HR; Thongsinthusak, T; Margetich, S; Krieger, R. (1991). Measuring potential dermal transfer of surface pesticide residue generated from indoor fogger use: using the CDFA roller methods. Chemosphere 22: 975 – 984.

A standardized, reproducible method of surrogate dermal monitoring was devised to supplement knowledge of the potential transfer of pesticide residues from floor surfaces to persons in contact with the floor. This device was a 12 kg foam-covered rolling cylinder equipped with stationary handles. The device was rolled over a cotton cloth (the actual collection media) placed over carpet to be sampled. This method transfers between 1 and 3 percent of the potential available pesticide material from nylon carpeting to the collection media. Transfer from carpet to cotton cloth correlates highly with transfer to cotton clothing worn by persons exercising on the carpet.

Clothier, J. (2000). Dermal Transfer Efficiency of Pesticides from New Vinyl Sheet Flooring to Dry and Wetted Palms. (EPA/600/R00/029). United States Environmental Protection Agency, Research Triangle Park, NC.

This report presents results of a study to determine the transfer efficiencies from carpet to human skin of four pesticides commonly used for residential indoor insect control. Formulations of the insecticides chlorpyrifos, pyrethrin I and piperonyl butoxide were applied to new, cut-pile nylon carpeting by broadcast spray and allowed to dry for 4 hours. Deposition coupons were used to estimate initial surface loadings and the PUF Roller was to measure dislodgeable residues. After the 4-hour drying period, adult volunteers performed hand presses (left and right hands, palm only) with either dry or wetted skin. Water, an aqueous dioctylsulfosuccinate (DSS) surfactant solution, and the participant's own saliva were used as wetting agents. Transfer efficiencies for wetted palms were two to six higher than those for dry palms. The mean (six presses) transfer efficiencies for chlorpyrifos were 1.64% for water-wetted (W), 0.90% for saliva-wetted (S), 1.21% for DSS-wetted, and 0.48% for dry skin (D). Transfer efficiencies for the other two freshly-applied pesticides were higher in most cases (W = 2.50%, S = 1.87%, DSS = 1.39%, and D = 0.32% for pyrethrin I and W = 2.58%, S = 2.03%, DSS = 1.72%, and D = 0.44% for piperonyl butoxide). Transfer efficiencies for aged permethrin residues in used carpet of similar composition were on the same order as those observed for freshly-applied residues: 2.45% for palms moistened with water, 2.3% with saliva, and 0.6% for dry palms.

2) An analysis of data provided by the Non-Dietary Exposure Task Force (NDETF) was conducted. This analysis included data for bare hand presses on carpets and vinyl surfaces for deltamethrin, permethrin, piperonyl butoxide and pyrethrin.

2a) MRID 46188605: Measurement of Transfer of Pyrethrin and Piperonyl Butoxide Residues from Vinyl Flooring Treated with a Fogger Formulation.

The purpose of the study was to determine the degree of transfer of pyrethrin (PY) and piperonyl butoxide (PBO) residue from treated vinyl flooring to dry bare hands after a single application of a fogger formulation containing 0.778% PY and 1.55% PBO. A total release aerosol fogger product was applied using a sprayboom apparatus in the center of four 16 ft. x 16 ft. x 8 ft. test rooms. Additionally, the study compared residue transfer from bare hands using alternate methods (indoor roller and drag sled) for measuring residue transfer from the application of an indoor aerosol fogger. Total deposition was measured using coupons, collected after the product application and drying period, respectively. During the application, and for three hours thereafter, the ventilation system in the room was turned off with the dampers closed to allow for deposition of the spray onto the test surfaces. After the three hours, the dampers were opened for a 30 minute drying period and then the flooring sections were transferred to a hand press test room. Residues remaining on bare and gloved hands, percale from indoor roller, and denium from a drag sled following contact with treated vinyl surfaces were determined. The analysis of the alpha cellulose deposition coupons for the roller, drag samples and first and second hand presses (bare and gloved) show that the mean deposition rate of PY and PBO is consistent from application to application and is reproducible. A comparison of the percent transfer of PY and PBO residues from the roller, drag sled, bare and gloved hands shows that for all procedures the percent transferability of PY is higher than that of PBO.

2b) MRID 46188614: Determination of Pyrethrin (PY) and Piperonyl Butoxide (PBO) Residue on the Hand from Treated Vinyl Flooring Sections Following Hand Press on Untreated Surfaces.

The purpose of the study was to determine the amount of residue left on a hand exposed to vinyl flooring treated with a formulation containing pyrethrin (PY) and piperonyl butoxide (PBO) following hand contact with untreated vinyl flooring surfaces. In this study, three test rooms were used, with one containing the application equipment (the sprayboom). Sixty-six vinyl flooring sections were pinned onto a sheet of plastic-covered plywood attached to the top of six 40 in x 40 in wooden platforms. Total deposition was measured using deposition coupons, which were collected after application of the test material, followed by a drying period. After collection of the deposition coupons, four vinyl flooring sections were removed and moved to a hand press room. Two male test subjects performed one hand press on the treated surface and 4 separate hand presses on untreated pieces of vinyl flooring. Each subject performed hand presses with each hand, for a total of four replicates. The subjects' hands were then cleaned with isopropyl alcohol dressing sponges to remove any remaining residues. Hand residues averaged 34.3 ng/cm^2 for PY and 38.4 ng/cm^2 for PBO. Corrected deposition coupon residues averaged 5.91 ± 1.68 µg/cm^2 for PY and 14.52 ± 3.54 µg/cm^2 for PBO. PY and PBO residues on the hand were estimated to be 0.58% and 0.26% of the PY and PBO applied to the vinyl flooring, as determined from the deposition coupons.

2c) MRID 46297602: Measurement of Transfer of Deltamethrin Residue from Vinyl and Carpet Flooring Treated with a Fogger Formulation Following a Single Hand Press.

The purpose of the study was two-fold. The first objective was to determine the amount of deltamethrin residue transferred from treated vinyl and carpet flooring to dry hands using both a hand press and roller technique. The second objective was to compare the degree of residue transferred for each collection methodology: isopropyl alcohol (IPA) hand wipes and cotton gloves used for the hand press technique and cotton percale cloth used for the modified California indoor roller technique. The test formulation contained a target weight percentage of 0.15% deltamethrin (DTM) (wt/wt). It was applied via a sprayboom that was meant to simulate a fogger spray. Total deposition was monitored using alpha cellulose deposition coupons placed at various randomly selected locations on the platforms. Residues resulting from a single, dry hand press approximately 3.5 hours following application were measured on vinyl and carpet flooring using the following sampling techniques and collection methodologies: IPA hand wipes and cotton gloves for the hand press, and percale cloth for the indoor modified California roller. Calculation of the percent transferability is a function of the measured hand residue and the DTM deposition on the corresponding flooring. Residue transfer using the modified indoor California roller appears to be higher for carpets than vinyl (2.8% to 1.5%, respectively). Residue transfer using cotton gloves appears to be higher for carpets than vinyl (2.7% to 1.9%, respectively). Residue transfer using IPA wipes appears to be higher for vinyl flooring than carpet (4.7% to 1.4%, respectively). Overall, after

combining % transferability across residue collection methodologies, transfer from vinyl flooring appears to be higher than carpet (2.6% to 2.1%, respectively). It should be noted that this is likely because of the relatively high % transferability from vinyl measured using IPA wipes (4.7%) compared with all the other methodologies (range of 1.4% to 2.8%).

2d) MRID 46188625: Measurement of Transfer of Permethrin and Piperonyl Butoxide Residues from Vinyl and Carpet Flooring Treated with a Fogger Formulation Following a Single Hand Press.

The purpose of the study was twofold. The first objective was to determine the amount of permethrin (PER) and piperonyl butoxide (PBO) residue transferred from treated vinyl and carpet flooring to bare and gloved adult hands utilizing a single hand press collection technique. The second objective was to compare the degree of residue transferred via two sampling strategies, i.e., (1) transfer from the single hand press technique versus (2) transfer to cotton percale cloth using the modified California indoor roller method. The test formulation contained a target weight percentage of 0.77% permethrin (PER) (wt/wt) and 0.77% piperonyl butoxide (PBO) (wt/wt). It was applied via a sprayboom that was meant to simulate the use of a ready-to-use fogger. Total deposition was monitored using alpha cellulose deposition coupons placed at various randomly selected locations on the platforms. Residues resulting from a single, dry hand press approximately 3.5 hours following application were measured on vinyl and carpet flooring using the following sampling techniques and collection methodologies: IPA hand wipes and cotton gloves for the hand press, and percale cloth for the indoor modified California roller. Calculation of the percent transferability is a function of the measured hand residue and the DTM deposition on the corresponding flooring. For the indoor California roller, the findings illustrate that the percentage of PBO and PER residue transferred from carpet flooring sections to percale was higher than the percentage transferred from vinyl flooring sections. Also, the percentage of PBO transferred from vinyl to percale was less than half the percentage of PER transferred, while for carpet flooring surfaces, the percentage of PBO and PER transferred was similar. For treated vinyl surfaces, the percent of PER transferred to the percale, gloved or bare hands, was always higher than the percent of PBO transferred. For carpet treated samples, the percent of PER and PBO residues transferred onto bare or gloved hands, are similar.

2e) MRID 46188628: Determination of Permethrin (PER) and Piperonyl Butoxide (PBO) Residue on the Hand Following Hand Press on Treated and Untreated Vinyl and Carpet.

The purpose of the study was to determine residue concentrations of permethrin (PER) and piperonyl butoxide (PBO) on bare hands following: 1) contact with either a treated vinyl tile or carpet swatch and then 2) contact with respective untreated vinyl tiles or carpet swatches. The study was conducted in two climate controlled test rooms. One room was outfitted with a fixed overhead sprayboom system. The carpet swatches and vinyl tiles were arranged beneath the spray boom for treatment in the first room while the hand procedures were performed in the second room. The formulation applied was meant to simulate a single application of a total release fogger product containing 0.77% PER and 0.77% PBO. During the spray application, and for three hours thereafter, the ventilation system in the room was turned off with the dampers closed to allow for deposition of the spray onto the test surfaces. After the three hours, the dampers were opened for a 30 minute drying period and then the carpet swatches and vinyl tiles were transferred to the second room to perform the hand press procedures. For the bare hand presses, two subjects were recruited to press their hands on a single treated swatch or vinyl tile followed by four separate presses (one each) on untreated carpet swatches or vinyl tiles respectively. Four samples were collected (two subjects times two hands). The residues remaining on the hands following this procedure were collected via isopropanol moistened dressing sponges. The mean percent of the application rate (deposition) collected from the hands was 0.83% (PER) and 0.48% (PBO) for the vinyl tiles and 1.55% (PER) and 1.49% (PBO) for the carpet swatches.

2f) MRID 46188620: Determination of Pyrethrin (PY) and Piperonyl Butoxide (PBO) Residue on the Hand Following Hand Press on Treated and Untreated Carpet.

The purpose of the study was to determine residue concentrations of pyrethrin (PY) and piperonyl butoxide (PBO) on bare hands following: 1) contact with a treated carpet swatch and then 2) contact with untreated carpet swatches. The study was conducted in two climate controlled test rooms. One room was outfitted

with a fixed overhead sprayboom system. The carpet swatches were arranged beneath the spray boom for treatment in the first room while the hand procedures were performed in the second room. The formulation applied was meant to simulate a single application of a total release fogger product containing 0.77% PY and 1.55% PBO. During the spray application, and for three hours thereafter, the ventilation system in the room was turned off with the dampers closed to allow for deposition of the spray onto the test surfaces. After the three hours, the dampers were opened for a 30 minute drying period and then the carpet swatches were transferred to the second room to perform the hand press procedures. For the bare hand presses, two subjects were recruited to press their hands on a single treated swatch and then to make an additional four separate presses (one each) on untreated carpet swatches. Four samples were collected (two subjects times two hands). The residues remaining on the hands following this procedure were collected via isopropanol moistened dressing sponges. The mean percent of the application rate (deposition) collected from the hands was 4.43% (PY) and 4.57% (PBO).

Carpets

Table D-22: Indoor Environments – Fraction Transferred Data for Carpets (Fai)

Chemical	Information Source	Study	Method	Transferable Residue as Fraction of Application Rate
Deltamethrin	NDETF	46297602	handpress	0.0204
Deltamethrin	NDETF	46297602	handpress	0.0167
Deltamethrin	NDETF	46297602	handpress	0.0204
Deltamethrin	NDETF	46297602	handpress	0.0185
Deltamethrin	NDETF	46297602	handpress	0.0130
Deltamethrin	NDETF	46297602	handpress	0.0139
Deltamethrin	NDETF	46297602	handpress	0.0130
Deltamethrin	NDETF	46297602	handpress	0.0046
Deltamethrin	NDETF	46297602	handpress	0.0093
Deltamethrin	NDETF	46297602	handpress	0.0157
Permethrin	NDETF	46188625	handpress	0.0170
Permethrin	NDETF	46188625	handpress	0.0312
Permethrin	NDETF	46188625	handpress	0.0188
Permethrin	NDETF	46188625	handpress	0.0098
Permethrin	NDETF	46188625	handpress	0.0186
Permethrin	NDETF	46188625	handpress	0.0146
Permethrin	NDETF	46188625	handpress	0.0158
Permethrin	NDETF	46188625	handpress	0.0172
Permethrin	NDETF	46188625	handpress	0.0230
Permethrin	NDETF	46188625	handpress	0.0324
Permethrin	NDETF	46188628	handpress	0.0188
Permethrin	NDETF	46188628	handpress	0.0137
Permethrin	NDETF	46188628	handpress	0.0167
Permethrin	NDETF	46188628	handpress	0.0128
Pyrethrin	NDETF	46188620	handpress	0.0591
Pyrethrin	NDETF	46188620	handpress	0.0615
Pyrethrin	NDETF	46188620	handpress	0.0568
Pyrethrin	NDETF	46188620	handpress	0.0418
PBO	NDETF	46188625	handpress	0.0192
PBO	NDETF	46188625	handpress	0.0359
PBO	NDETF	46188625	handpress	0.0205
PBO	NDETF	46188625	handpress	0.0107
PBO	NDETF	46188625	handpress	0.0214
PBO	NDETF	46188625	handpress	0.0178

Table D-22: Indoor Environments – Fraction Transferred Data for Carpets (Fai)				
Chemical	**Information Source**	**Study**	**Method**	**Transferable Residue as Fraction of Application Rate**
PBO	NDETF	46188625	handpress	0.0180
PBO	NDETF	46188625	handpress	0.0234
PBO	NDETF	46188625	handpress	0.0285
PBO	NDETF	46188625	handpress	0.0432
PBO	NDETF	46188628	handpress	0.0188
PBO	NDETF	46188628	handpress	0.0128
PBO	NDETF	46188628	handpress	0.0154
PBO	NDETF	46188628	handpress	0.0124
PBO	NDETF	46188620	handpress	0.0569
PBO	NDETF	46188620	handpress	0.0606
PBO	NDETF	46188620	handpress	0.0509
PBO	NDETF	46188620	handpress	0.0368
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.032
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.028
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.070
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.059
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.008
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.014
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.003
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.001
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.0006
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.001
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.005
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.003
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.0003
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.0006
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.0004
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.0003
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.0007
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.0008
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.009
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.011
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.014
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.021
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.022
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.017
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	PUF roller	0.017
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	PUF roller	0.017
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	PUF roller	0.011
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	PUF roller	0.006
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	PUF roller	0.006
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	PUF roller	0.014
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	PUF roller	0.010
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	PUF roller	0.023
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	PUF roller	0.014
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	PUF roller	0.016
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	PUF roller	0.014
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	PUF roller	0.032

Table D-22: Indoor Environments – Fraction Transferred Data for Carpets (Fai)				
Chemical	**Information Source**	**Study**	**Method**	**Transferable Residue as Fraction of Application Rate**
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	PUF roller	0.012
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	PUF roller	0.024
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	PUF roller	0.023
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	PUF roller	0.017
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	PUF roller	0.015
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	PUF roller	0.086
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	PUF roller	0.012
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	PUF roller	0.039
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	PUF roller	0.034
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	CA roller	0.073
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	CA roller	0.059
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	CA roller	0.041
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	CA roller	0.017
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	CA roller	0.023
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	CA roller	0.024
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	CA roller	0.030
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	CA roller	0.072
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	CA roller	0.021
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	CA roller	0.038
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	CA roller	0.035
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	CA roller	0.039
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	CA roller	0.035
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	CA roller	0.064
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	CA roller	0.034
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	CA roller	0.071
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	CA roller	0.047
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	CA roller	0.033
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	CA roller	0.013
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	CA roller	0.095
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	CA roller	0.052
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	drag sled	0.029
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	drag sled	0.016
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	drag sled	0.010
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	drag sled	0.009
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	drag sled	0.010
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	drag sled	0.014
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	drag sled	0.010
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	drag sled	0.031
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	drag sled	0.008
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	drag sled	0.014
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	drag sled	0.028
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	drag sled	0.021
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	drag sled	0.012
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	drag sled	0.053
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	drag sled	0.016
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	drag sled	0.022
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	drag sled	0.083
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	drag sled	0.063

Table D-22: Indoor Environments – Fraction Transferred Data for Carpets (Fai)				
Chemical	**Information Source**	**Study**	**Method**	**Transferable Residue as Fraction of Application Rate**
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	drag sled	0.012
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	drag sled	0.065
Pyrethrin	Beamer et al. (2009)	Fortune (1997a)	drag sled	0.023
PBO	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.013
PBO	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.013
PBO	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.014
PBO	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.019
PBO	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.015
PBO	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.013
PBO	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.002
PBO	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.001
PBO	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.0005
PBO	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.001
PBO	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.002
PBO	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.001
PBO	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.034
PBO	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.031
PBO	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.056
PBO	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.047
PBO	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.026
PBO	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.010
PBO	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.0004
PBO	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.0009
PBO	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.0003
PBO	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.0002
PBO	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.0002
PBO	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.0005
PBO	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.013
PBO	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.039
PBO	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.007
PBO	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.008
PBO	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.007
PBO	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.012
PBO	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.011
PBO	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.017
PBO	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.014
PBO	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.016
PBO	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.009
PBO	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.033
PBO	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.015
PBO	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.027
PBO	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.024
PBO	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.017
PBO	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.017
PBO	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.021
PBO	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.014
PBO	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.036
PBO	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.034

Table D-22: Indoor Environments – Fraction Transferred Data for Carpets (Fai)				
Chemical	**Information Source**	**Study**	**Method**	**Transferable Residue as Fraction of Application Rate**
PBO	Beamer et al. (2009)	Fortune (1997)	CA roller	0.196
PBO	Beamer et al. (2009)	Fortune (1997)	CA roller	0.110
PBO	Beamer et al. (2009)	Fortune (1997)	CA roller	0.104
PBO	Beamer et al. (2009)	Fortune (1997)	CA roller	0.020
PBO	Beamer et al. (2009)	Fortune (1997)	CA roller	0.033
PBO	Beamer et al. (2009)	Fortune (1997)	CA roller	0.099
PBO	Beamer et al. (2009)	Fortune (1997)	CA roller	0.046
PBO	Beamer et al. (2009)	Fortune (1997)	CA roller	0.070
PBO	Beamer et al. (2009)	Fortune (1997)	CA roller	0.042
PBO	Beamer et al. (2009)	Fortune (1997)	CA roller	0.044
PBO	Beamer et al. (2009)	Fortune (1997)	CA roller	0.043
PBO	Beamer et al. (2009)	Fortune (1997)	CA roller	0.057
PBO	Beamer et al. (2009)	Fortune (1997)	CA roller	0.054
PBO	Beamer et al. (2009)	Fortune (1997)	CA roller	0.113
PBO	Beamer et al. (2009)	Fortune (1997)	CA roller	0.069
PBO	Beamer et al. (2009)	Fortune (1997)	CA roller	0.055
PBO	Beamer et al. (2009)	Fortune (1997)	CA roller	0.028
PBO	Beamer et al. (2009)	Fortune (1997)	CA roller	0.041
PBO	Beamer et al. (2009)	Fortune (1997)	CA roller	0.057
PBO	Beamer et al. (2009)	Fortune (1997)	CA roller	0.102
PBO	Beamer et al. (2009)	Fortune (1997)	CA roller	0.058
PBO	Beamer et al. (2009)	Fortune (1997)	drag sled	0.027
PBO	Beamer et al. (2009)	Fortune (1997)	drag sled	0.018
PBO	Beamer et al. (2009)	Fortune (1997)	drag sled	0.013
PBO	Beamer et al. (2009)	Fortune (1997)	drag sled	0.014
PBO	Beamer et al. (2009)	Fortune (1997)	drag sled	0.008
PBO	Beamer et al. (2009)	Fortune (1997)	drag sled	0.014
PBO	Beamer et al. (2009)	Fortune (1997)	drag sled	0.016
PBO	Beamer et al. (2009)	Fortune (1997)	drag sled	0.024
PBO	Beamer et al. (2009)	Fortune (1997)	drag sled	0.009
PBO	Beamer et al. (2009)	Fortune (1997)	drag sled	0.020
PBO	Beamer et al. (2009)	Fortune (1997)	drag sled	0.027
PBO	Beamer et al. (2009)	Fortune (1997)	drag sled	0.023
PBO	Beamer et al. (2009)	Fortune (1997)	drag sled	0.021
PBO	Beamer et al. (2009)	Fortune (1997)	drag sled	0.052
PBO	Beamer et al. (2009)	Fortune (1997)	drag sled	0.023
PBO	Beamer et al. (2009)	Fortune (1997)	drag sled	0.020
PBO	Beamer et al. (2009)	Fortune (1997)	drag sled	0.060
PBO	Beamer et al. (2009)	Fortune (1997)	drag sled	0.026
PBO	Beamer et al. (2009)	Fortune (1997)	drag sled	0.018
PBO	Beamer et al. (2009)	Fortune (1997)	drag sled	0.065
PBO	Beamer et al. (2009)	Fortune (1997)	drag sled	0.024
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.007
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.023
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.024
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.011
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.017
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.018

Table D-22: Indoor Environments – Fraction Transferred Data for Carpets (Fai)				
Chemical	**Information Source**	**Study**	**Method**	**Transferable Residue as Fraction of Application Rate**
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.010
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.013
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.013
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.019
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.031
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.015
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.002
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.004
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.004
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.007
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.002
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.002
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.0003
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.001
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.001
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.001
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.005
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.016
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.015
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.008
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.007
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.018
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.017
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.013
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.015
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.009
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.011
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.029
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.002
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.003
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.003
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.003
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.0003
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.0007
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.0002
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.0001
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.0002
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.0003
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	cloth roller	0.021
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	cloth roller	0.121
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	cloth roller	0.058
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	cloth roller	0.029
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	cloth roller	0.058
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	cloth roller	0.100
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	cloth roller	0.035
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	cloth roller	0.024
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	cloth roller	0.041
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	cloth roller	0.025

Table D-22: Indoor Environments – Fraction Transferred Data for Carpets (Fai)				
Chemical	**Information Source**	**Study**	**Method**	**Transferable Residue as Fraction of Application Rate**
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	cloth roller	0.016
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	cloth roller	0.020
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.012
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.018
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.007
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.007
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.008
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.004
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.011
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.012
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.012
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.022
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.010
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.022
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.013
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.022
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.018
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.011
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.017
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.016
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.015
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.025
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	PUF roller	0.029
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	CA roller	0.079
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	CA roller	0.099
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	CA roller	0.029
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	CA roller	0.013
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	CA roller	0.059
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	CA roller	0.016
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	CA roller	0.040
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	CA roller	0.038
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	CA roller	0.036
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	CA roller	0.034
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	CA roller	0.025
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	CA roller	0.047
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	CA roller	0.035
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	CA roller	0.044
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	CA roller	0.035
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	CA roller	0.043
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	CA roller	0.039
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	CA roller	0.035
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	CA roller	0.058
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	CA roller	0.074
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	CA roller	0.047
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	drag sled	0.029
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	drag sled	0.030
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	drag sled	0.019
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	drag sled	0.005

Table D-22: Indoor Environments – Fraction Transferred Data for Carpets (Fai)				
Chemical	**Information Source**	**Study**	**Method**	**Transferable Residue as Fraction of Application Rate**
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	drag sled	0.015
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	drag sled	0.008
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	drag sled	0.018
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	drag sled	0.017
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	drag sled	0.012
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	drag sled	0.014
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	drag sled	0.014
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	drag sled	0.016
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	drag sled	0.012
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	drag sled	0.042
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	drag sled	0.017
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	drag sled	0.024
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	drag sled	0.036
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	drag sled	0.022
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	drag sled	0.015
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	drag sled	0.042
Chlorpyrifos	Beamer et al. (2009)	Fortune (1997)	drag sled	0.019
Chlorpyrifos	Beamer et al. (2009)	Krieger et al. (2000)	cloth roller	0.032
Chlorpyrifos	Beamer et al. (2009)	Krieger et al. (2000)	cloth roller	0.018
Chlorpyrifos	Beamer et al. (2009)	Krieger et al. (2000)	cloth roller	0.118
Chlorpyrifos	Beamer et al. (2009)	Krieger et al. (2000)	cloth roller	0.171
Chlorpyrifos	Beamer et al. (2009)	Krieger et al. (2000)	cloth roller	0.179
Chlorpyrifos	Beamer et al. (2009)	Krieger et al. (2000)	cloth roller	0.063
Chlorpyrifos	Beamer et al. (2009)	Krieger et al. (2000)	cloth roller	0.209
Chlorpyrifos	Beamer et al. (2009)	Krieger et al. (2000)	cloth roller	0.015
Chlorpyrifos	Beamer et al. (2009)	Krieger et al. (2000)	cloth roller	0.006
Chlorpyrifos	Beamer et al. (2009)	Krieger et al. (2000)	cloth roller	0.113
Chlorpyrifos	Beamer et al. (2009)	Krieger et al. (2000)	cloth roller	0.019
Chlorpyrifos	Beamer et al. (2009)	Krieger et al. (2000)	cloth roller	0.064
Chlorpyrifos	Beamer et al. (2009)	Ross et al. (1991)	cloth roller	0.030
Chlorpyrifos	Beamer et al. (2009)	Ross et al. (1991)	cloth roller	0.081
Chlorpyrifos	Beamer et al. (2009)	Ross et al. (1991)	cloth roller	0.258
Chlorpyrifos	Beamer et al. (2009)	Ross et al. (1991)	cloth roller	0.059
Chlorpyrifos	Beamer et al. (2009)	Ross et al. (1991)	cloth roller	0.047
Chlorpyrifos	Beamer et al. (2009)	Ross et al. (1991)	cloth roller	0.034
Chlorpyrifos	Beamer et al. (2009)	Ross et al. (1991)	cloth roller	0.025
Chlorpyrifos	Beamer et al. (2009)	Ross et al. (1991)	cloth roller	0.055
Chlorpyrifos	Beamer et al. (2009)	Ross et al. (1991)	cloth roller	0.051
Chlorpyrifos	Beamer et al. (2009)	Ross et al. (1991)	cloth roller	0.034
Chlorpyrifos	Beamer et al. (2009)	Ross et al. (1991)	cloth roller	0.025
Chlorpyrifos	Beamer et al. (2009)	Ross et al. (1991)	cloth roller	0.034
Chlorpyrifos	Beamer et al. (2009)	Ross et al. (1991)	cloth roller	0.020
Chlorpyrifos	Beamer et al. (2009)	Ross et al. (1991)	cloth roller	0.045
Chlorpyrifos	Beamer et al. (2009)	Ross et al. (1991)	cloth roller	0.017
Chlorpyrifos	Beamer et al. (2009)	Ross et al. (1991)	cloth roller	0.011
Chlorpyrifos	Beamer et al. (2009)	Ross et al. (1991)	cloth roller	0.025
Chlorpyrifos	Beamer et al. (2009)	Ross et al. (1991)	cloth roller	0.010
Chlorpyrifos	Beamer et al. (2009)	Ross et al. (1991)	cloth roller	0.006

Table D-22: Indoor Environments – Fraction Transferred Data for Carpets (Fai)				
Chemical	**Information Source**	**Study**	**Method**	**Transferable Residue as Fraction of Application Rate**
Chlorpyrifos	Beamer et al. (2009)	Ross et al. (1991)	cloth roller	0.011
Chlorpyrifos	Beamer et al. (2009)	Ross et al. (1991)	cloth roller	0.024
Chlorpyrifos	Beamer et al. (2009)	Ross et al. (1991)	cloth roller	0.008
Chlorpyrifos	Beamer et al. (2009)	Ross et al. (1991)	cloth roller	0.006
Chlorpyrifos	Beamer et al. (2009)	Ross et al. (1991)	cloth roller	0.007

Table D-23: Indoor Environments Summary of Fraction Transferred (Fai) for Carpets	
Statistic	**Fraction Transferred**
Arithmetic Mean	0.04
Standard Deviation	0.58
Range	0.0001 – 0.258
N	375

Hard Surfaces

Table D-24: Indoor Environments – Fraction Transferred Data for Hard Surfaces (Fai)				
Chemical	**Information Source**	**Study**	**Method**	**Transferable Residue as Fraction of Application Rate**
Pyrethrin	NDETF	46188605	handpress	0.0140
Pyrethrin	NDETF	46188605	handpress	0.0316
Pyrethrin	NDETF	46188605	handpress	0.0365
Pyrethrin	NDETF	46188605	handpress	0.0411
Pyrethrin	NDETF	46188605	handpress	0.0134
Pyrethrin	NDETF	46188605	handpress	0.0776
Pyrethrin	NDETF	46188605	handpress	0.1509
Pyrethrin	NDETF	46188605	handpress	0.0657
Pyrethrin	NDETF	46188605	handpress	0.0640
Pyrethrin	NDETF	46188605	handpress	0.0684
Pyrethrin	NDETF	46188605	handpress	0.0186
Pyrethrin	NDETF	46188605	handpress	0.0258
Pyrethrin	NDETF	46188605	handpress	0.0664
Pyrethrin	NDETF	46188605	handpress	0.1610
Pyrethrin	NDETF	46188605	handpress	0.0597
Pyrethrin	NDETF	46188605	handpress	0.0496
Pyrethrin	NDETF	46188605	handpress	0.0739
Pyrethrin	NDETF	46188605	handpress	0.0336
Pyrethrin	NDETF	46188605	handpress	0.0336
Pyrethrin	NDETF	46188605	handpress	0.0217
Pyrethrin	NDETF	46188605	handpress	0.0453
Pyrethrin	NDETF	46188605	handpress	0.0313
Pyrethrin	NDETF	46188605	handpress	0.0623
Pyrethrin	NDETF	46188605	handpress	0.0306
Pyrethrin	NDETF	46188605	handpress	0.0080
Pyrethrin	NDETF	46188605	handpress	0.0109
Pyrethrin	NDETF	46188605	handpress	0.0386
Pyrethrin	NDETF	46188605	handpress	0.0440
Pyrethrin	NDETF	46188605	handpress	0.0526

Table D-24: Indoor Environments – Fraction Transferred Data for Hard Surfaces (Fai)				
Chemical	**Information Source**	**Study**	**Method**	**Transferable Residue as Fraction of Application Rate**
Pyrethrin	NDETF	46188605	handpress	0.0526
Pyrethrin	NDETF	46188605	handpress	0.0351
Pyrethrin	NDETF	46188605	handpress	0.0912
Pyrethrin	NDETF	46188614	handpress	0.0075
Pyrethrin	NDETF	46188614	handpress	0.0097
Pyrethrin	NDETF	46188614	handpress	0.0092
Pyrethrin	NDETF	46188614	handpress	0.0067
PBO	NDETF	46188625	handpress	0.0175
PBO	NDETF	46188625	handpress	0.0196
PBO	NDETF	46188625	handpress	0.0331
PBO	NDETF	46188625	handpress	0.0255
PBO	NDETF	46188625	handpress	0.0208
PBO	NDETF	46188625	handpress	0.0086
PBO	NDETF	46188625	handpress	0.0139
PBO	NDETF	46188625	handpress	0.0269
PBO	NDETF	46188625	handpress	0.0259
PBO	NDETF	46188625	handpress	0.0291
PBO	NDETF	46188605	handpress	0.0078
PBO	NDETF	46188605	handpress	0.0185
PBO	NDETF	46188605	handpress	0.0183
PBO	NDETF	46188605	handpress	0.0206
PBO	NDETF	46188605	handpress	0.0083
PBO	NDETF	46188605	handpress	0.0411
PBO	NDETF	46188605	handpress	0.0800
PBO	NDETF	46188605	handpress	0.0368
PBO	NDETF	46188605	handpress	0.0330
PBO	NDETF	46188605	handpress	0.0348
PBO	NDETF	46188605	handpress	0.0116
PBO	NDETF	46188605	handpress	0.0128
PBO	NDETF	46188605	handpress	0.0346
PBO	NDETF	46188605	handpress	0.0881
PBO	NDETF	46188605	handpress	0.0369
PBO	NDETF	46188605	handpress	0.0297
PBO	NDETF	46188605	handpress	0.0372
PBO	NDETF	46188605	handpress	0.0174
PBO	NDETF	46188605	handpress	0.0153
PBO	NDETF	46188605	handpress	0.0108
PBO	NDETF	46188605	handpress	0.0327
PBO	NDETF	46188605	handpress	0.0184
PBO	NDETF	46188605	handpress	0.0373
PBO	NDETF	46188605	handpress	0.0192
PBO	NDETF	46188605	handpress	0.0094
PBO	NDETF	46188605	handpress	0.0069
PBO	NDETF	46188605	handpress	0.0240
PBO	NDETF	46188605	handpress	0.0269
PBO	NDETF	46188605	handpress	0.0290
PBO	NDETF	46188605	handpress	0.0277

Table D-24: Indoor Environments – Fraction Transferred Data for Hard Surfaces (Fai)				
Chemical	**Information Source**	**Study**	**Method**	**Transferable Residue as Fraction of Application Rate**
PBO	NDETF	46188605	handpress	0.0180
PBO	NDETF	46188605	handpress	0.0522
PBO	NDETF	46188628	handpress	0.0043
PBO	NDETF	46188628	handpress	0.0051
PBO	NDETF	46188628	handpress	0.0064
PBO	NDETF	46188628	handpress	0.0043
PBO	NDETF	46188614	handpress	0.0037
PBO	NDETF	46188614	handpress	0.0047
PBO	NDETF	46188614	handpress	0.0046
PBO	NDETF	46188614	handpress	0.0039
Deltamethrin	NDETF	46297602	handpress	0.0673
Deltamethrin	NDETF	46297602	handpress	0.1242
Deltamethrin	NDETF	46297602	handpress	0.0445
Deltamethrin	NDETF	46297602	handpress	0.0352
Deltamethrin	NDETF	46297602	handpress	0.0280
Deltamethrin	NDETF	46297602	handpress	0.0331
Deltamethrin	NDETF	46297602	handpress	0.0611
Deltamethrin	NDETF	46297602	handpress	0.0228
Deltamethrin	NDETF	46297602	handpress	0.0311
Deltamethrin	NDETF	46297602	handpress	0.0166
Permethrin	NDETF	46188625	handpress	0.0259
Permethrin	NDETF	46188625	handpress	0.0320
Permethrin	NDETF	46188625	handpress	0.0491
Permethrin	NDETF	46188625	handpress	0.0368
Permethrin	NDETF	46188625	handpress	0.0304
Permethrin	NDETF	46188625	handpress	0.0123
Permethrin	NDETF	46188625	handpress	0.0177
Permethrin	NDETF	46188625	handpress	0.0382
Permethrin	NDETF	46188625	handpress	0.0390
Permethrin	NDETF	46188625	handpress	0.0452
Permethrin	NDETF	46188628	handpress	0.0071
Permethrin	NDETF	46188628	handpress	0.0089
Permethrin	NDETF	46188628	handpress	0.0112
Permethrin	NDETF	46188628	handpress	0.0064
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.096
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.159
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.126
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.111
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.449
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.189
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	PUF Roller	0.065
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	PUF Roller	0.107
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	PUF Roller	0.077
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	PUF Roller	0.040
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	PUF Roller	0.107
Pyrethrin	Beamer et al. (2009)	Camann et al. (1996)	PUF Roller	0.216
Pyrethrin	Beamer et al. (2009)	Clothier (2000)	dry handpress	0.060

Table D-24: Indoor Environments – Fraction Transferred Data for Hard Surfaces (Fai)				
Chemical	**Information Source**	**Study**	**Method**	**Transferable Residue as Fraction of Application Rate**
Pyrethrin	Beamer et al. (2009)	Clothier (2000)	dry handpress	0.050
Pyrethrin	Beamer et al. (2009)	Clothier (2000)	dry handpress	0.018
Pyrethrin	Beamer et al. (2009)	Clothier (2000)	dry handpress	0.022
Pyrethrin	Beamer et al. (2009)	Clothier (2000)	dry handpress	0.058
Pyrethrin	Beamer et al. (2009)	Clothier (2000)	dry handpress	0.010
Pyrethrin	Beamer et al. (2009)	Clothier (2000)	PUF Roller	0.044
Pyrethrin	Beamer et al. (2009)	Clothier (2000)	PUF Roller	0.106
Pyrethrin	Beamer et al. (2009)	Clothier (2000)	PUF Roller	0.019
Pyrethrin	Beamer et al. (2009)	Clothier (2000)	PUF Roller	0.066
Pyrethrin	Beamer et al. (2009)	Clothier (2000)	PUF Roller	0.087
Pyrethrin	Beamer et al. (2009)	Clothier (2000)	PUF Roller	0.019
PBO	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.118
PBO	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.571
PBO	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.149
PBO	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.087
PBO	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.436
PBO	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.271
PBO	Beamer et al. (2009)	Camann et al. (1996)	PUF Roller	0.039
PBO	Beamer et al. (2009)	Camann et al. (1996)	PUF Roller	0.129
PBO	Beamer et al. (2009)	Camann et al. (1996)	PUF Roller	0.068
PBO	Beamer et al. (2009)	Camann et al. (1996)	PUF Roller	0.024
PBO	Beamer et al. (2009)	Camann et al. (1996)	PUF Roller	0.105
PBO	Beamer et al. (2009)	Camann et al. (1996)	PUF Roller	0.278
PBO	Beamer et al. (2009)	Clothier (2000)	dry handpress	0.018
PBO	Beamer et al. (2009)	Clothier (2000)	dry handpress	0.016
PBO	Beamer et al. (2009)	Clothier (2000)	dry handpress	0.007
PBO	Beamer et al. (2009)	Clothier (2000)	dry handpress	0.012
PBO	Beamer et al. (2009)	Clothier (2000)	dry handpress	0.025
PBO	Beamer et al. (2009)	Clothier (2000)	dry handpress	0.006
PBO	Beamer et al. (2009)	Clothier (2000)	PUF Roller	0.023
PBO	Beamer et al. (2009)	Clothier (2000)	PUF Roller	0.085
PBO	Beamer et al. (2009)	Clothier (2000)	PUF Roller	0.009
PBO	Beamer et al. (2009)	Clothier (2000)	PUF Roller	0.052
PBO	Beamer et al. (2009)	Clothier (2000)	PUF Roller	0.077
PBO	Beamer et al. (2009)	Clothier (2000)	PUF Roller	0.011
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.051
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.159
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.076
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.030
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.161
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	PUF roller	0.242
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.140
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.601
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.136
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.103
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.507
Chlorpyrifos	Beamer et al. (2009)	Camann et al. (1996)	drag sled	0.218

Table D-24: Indoor Environments – Fraction Transferred Data for Hard Surfaces (Fai)				
Chemical	**Information Source**	**Study**	**Method**	**Transferable Residue as Fraction of Application Rate**
Chlorpyrifos	Beamer et al. (2009)	Clothier (2000)	dry handpress	0.020
Chlorpyrifos	Beamer et al. (2009)	Clothier (2000)	dry handpress	0.017
Chlorpyrifos	Beamer et al. (2009)	Clothier (2000)	dry handpress	0.008
Chlorpyrifos	Beamer et al. (2009)	Clothier (2000)	dry handpress	0.014
Chlorpyrifos	Beamer et al. (2009)	Clothier (2000)	dry handpress	0.026
Chlorpyrifos	Beamer et al. (2009)	Clothier (2000)	dry handpress	0.007
Chlorpyrifos	Beamer et al. (2009)	Clothier (2000)	PUF Roller	0.024
Chlorpyrifos	Beamer et al. (2009)	Clothier (2000)	PUF Roller	0.071
Chlorpyrifos	Beamer et al. (2009)	Clothier (2000)	PUF Roller	0.012
Chlorpyrifos	Beamer et al. (2009)	Clothier (2000)	PUF Roller	0.054
Chlorpyrifos	Beamer et al. (2009)	Clothier (2000)	PUF Roller	0.076
Chlorpyrifos	Beamer et al. (2009)	Clothier (2000)	PUF Roller	0.015

Table D-25: Indoor Environments Statistical Summary – Fraction Transferred (Fai) for Hard Surfaces	
Statistic	Fraction Transferred
Arithmetic Mean	0.06
Standard Deviation	0.51
Range	0.004 – 0.601
N	182

D.6.4 Treated Pets

If chemical specific transferable residue (TR) measurements are not available, then a standard value for the fraction of active ingredient available for transfer (F_{AR}) is used. A screening level F_{AR} was recommended based on the review of 8 pet residue transfer studies (9 data sets total) submitted to the Agency. Measurements of residue transfer were derived by taking the ratio of the amount of active ingredient on a bare or gloved hand (on the day of application) to the amount of active ingredient applied. Five residue transfer studies were performed by means of volunteers "petting" or "stroking" animals treated with a known amount of active ingredient. Three additional petting studies were conducted using a gloved mannequin hand. For each study the amount of residue transferred to the hands was determined. F_{AR} studies varied in the number, location and intensity of petting/stroking actions. All 8 pet residue transfer studies were reviewed for ethical conduct and no barriers were identified in law or regulation for their being relied upon by the Agency.

All but one of the petting studies used in the selection of F_{AR} were conducted with a liquid formulation application method (i.e., aerosol and pump sprays, dip, shampoo and spot-on). The study, "Determination of the Dislodgeability of Tetrachlorvinphos (TCVP) from the Fur of Dogs Following the Application of an Insecticide Powder, Pump Spray or Aerosol (MRID 45485501)" includes a segment which was conducted to analyze a solid formulation application method, powder. While these data are the only identified by the Agency which are specific to solid formulations, several issues preclude its use. The data resulting from the powder dislodgeability study segment consist of a sample size of 5 (N = 5). In contrast, the data available for all liquid

formulation application methods combined consist of a sample size of 171 (N = 171). Furthermore, the average F_{AR} values resulting for the solid and combined liquid formulations are 0.00031 and 0.0096, respectively. The Agency recognizes that the physical differences between the solid and liquid formulations may account for the observed comparison; however, the small sample size of the solid formulation data and the large difference observed in anticipated F_{AR} (order of magnitude), limit the reliability of the data set. Therefore, the Agency has identified the liquid formulation F_{AR} data set as the most reliable for the assessment of post-application exposure from treated pets for all formulations assessed.

Based on the available studies, the recommended screening level F_{AR} point estimate for use in post-application dermal exposure assessment is 0.02 (equivalent to 2%).

Description of Available Studies Used for Dermal Exposure Fraction of Application Rate (F_{AR})

Below is a description of the available studies used to determine the input values for $F_{AR.}$

Table D-26: Available Exposure Study Identification Information	
Citation	Hughes, D.L. (1997a). Dislodgeable Residues of Fipronil Following Application of Frontline® Spray Treatment to Dogs
EPA MRID	44433306
EPA Review	Contractor (Versar, Inc.) review 4/30/98
MRID = Master Record Identification ORETF = Outdoor Residential Exposure Task Force	

Table D-27: Available Exposure Study Identification Information	
Citation	Hughes, D.L. (1997b). Dislodgeable Residues of Fipronil Following Application of Frontline® Spray Treatment to Cats
EPA MRID	44433307
EPA Review	Contractor (Versar, Inc.) review 4/30/98
MRID = Master Record Identification	

Two post-application studies, the "Dislodgeable Residues of Fipronil Following Application of Frontline Spray Treatment to Dogs" (MRID 44433306), and the "Dislodgeable Residues of Fipronil Following Application of Frontline Spray Treatment to Cats" (MRID 44433307) were conducted to examine dislodgeable residues of fipronil, the active ingredient of Frontline®, on the hair coats of dogs and cats, respectively, following their treatment with the pesticide.

The dislodgeability residues of fipronil was studied in 10 female dogs (5 short-haired dogs and 5 long-haired dogs) weighing 9.5 to 19.2 kg and 5 female cats (varying hair lengths) weighing 2.8 to 3.5 kg after a topical application of Frontline® Spray Treatment. Dogs and cats were topically treated with the Frontline® spray treatment. Each animal received one treatment on Day 1 with the maximum label rate of 6 mL of product per kg of body weight.

Dye free 100 percent cotton gloves were used for collecting residues at the following sampling time intervals: before dosing; 2, 4, and 12 hours after dosing; and 2, 3, 5, 8, 15, 22, and 29 days after dosing. A total of five strokes were applied which uniform medium pressure to each dog

and a total of four strokes were applied to each cat to cover the whole body surface at each sampling interval. One glove was used for each test animal at each of the sampling intervals.

The residue levels of fipronil in each glove were reported and used for calculating the percent of dislodgeable residues. The percent of dislodgeable residues was calculated based on the total residues levels divided by the actual amount of fipronil sprayed for each treatment. Most of the laboratory recoveries for both studies fell within the range of 70 -120%.

Table D-28: Available Exposure Study Identification Information	
Citation	McKeown, K. (2001). Determination of the Dislodgeability of Tetrachlorvinphos (TCVP) from the Fur of Dogs Following the Application of an Insecticide Powder, Pump Spray or Aerosol
EPA MRID	45485501
EPA Review	D277543
	Contractor (Versar, Inc.) review 11/19/2001
MRID = Master Record Identification	

The study, "Determination of the Dislodgeability of Tetrachlorvinphos (TCVP) from the Fur of Dogs Following the Application of an Insecticide Powder, Pump Spray or Aerosol," was conducted to determine the potential for TCVP to become dislodged from an animal and be available for human exposure. This study provides data on the amount of TCVP dislodged by the human hand when stroking a dog following the application onto the dog of an aerosol, spray, or powder product.

The study determined the total amount of TCVP on the fur of 5 dogs after a single treatment by one of three types of product (aerosol, powder and pump spray) applied according to label direction. The study concurrently determined the amount of TCVP which was dislodged onto the hand from 5 strokes of the full length of the animals' body. Both of these parameters were measured at baseline and at 4 hours, 1 day, 2 days, 4 days, 8 days, 16 days and 32 days after treatment (DAT). The study used three types of products, each with different delivery systems, the application by 5 different applicators, and the use of 5 different dogs.

The study used a "split-back" methodology. In this methodology, one side of the dog's back is stroked by a human hand to determine dislodgeability residues of TCVP, and samples of fur are taken from the opposite side of the dog's back to determine total residues of TCVP. This study uses the bare human hand to model the dislodgeability rather than a cotton glove. Fortified sample recoveries were in an acceptable range and no significant QA/QC problems were identified. The study results are similar or lower to the findings found in the earlier study where a cotton glove was used.

Table D-29: Available Exposure Study Identification Information	
Citation	Brickel, P. et al. (1997). Dislodgeable Residues of Fipronil Following Topical Application of Frontline® Spot-on Treatment to Dogs
EPA MRID	44531203
EPA Review	Contractor (Versar, Inc.) review 1/9/2008
MRID = Master Record Identification	

The study, "Dislodgeable Residues of Fipronil Following Topical Application of Frontline® Spot-on Treatment to Dogs, was conducted to measure the dislodgeability of the test substance, Frontline®", over time from the hair coat of dogs treated with a spot-on formulation containing fipronil as the active ingredient. The test substance was administered to six Beagle dogs by topical application to the back (between the shoulders) using ready-to-use pipettes intended for commercial application. Each dog received a maximum label specified application dose of 1.34 mL (131,722 µg ai) of the test product on Day 0. The subsequent field sampling consisted of stroking the entire body surface of the dog by taking 5 strokes along the body of the dog using the palmar surface of one hand, while wearing cotton gloves to collect the residues. Glove samples were collected from each dog prior to treatment and at 10 intervals following treatment (1 hr to 28 days).

The cotton gloves were analyzed for fipronil and the results were reported as µg/glove fipronil per glove. None of the residues were corrected since average recoveries of fipronil were greater than 90%. In addition, the Registrant reported the percent of the applied dose that was dislodgeable at each sampling period after application.

Table D-30: Available Exposure Study Identification Information	
Citation	Bach, T. (2002). Stroking Test in Dogs After Topical Application of Imidacloprid 10% (w/v) + Permethrin 50% (w/v) Spot-On
EPA MRID	46594103
EPA Review	Contractor (Versar, Inc.) review 9/12/2005
MRID = Master Record Identification	

The purpose of this study was to measure the dislodgeability of the test substance (imidacloprid and permethrin) from the hair coat of dogs treated with a spot-on formulation. The substance was applied to beagle dogs by topical application to the back (spine) using pipettes intended for commercial application. The test substance was applied in a quantity of 2.5 ml to each animal in the study, with each receiving a dose equivalent to 250 mg imidacloprid and 1250 mg permethrin. Residues were collected to assess post-application exposure to the treated dogs by stroking the dogs 3 times from head to tail over the application areas while wearing absorbent cotton gloves. "Medium" pressure was applied for each stroking procedure. Samples were collected at intervals of 30 minutes, 2 hours, 12 hours, and 24 hours after application. Four groups of 5 beagle dogs were established, and each group was sampled for one of the 4 sampling intervals only. Dog weights ranged between 10 and 25 kg. The limit of quantitation (LOQ) for imidacloprid was determined to be 0.25 mg/glove and 1.25 mg/glove for permethrin. If individual sample results were below the LOQ, 1/2 the LOQ for the chemical was used for quantitative purposes.

Table D-31: Available Exposure Study Identification Information	
Citation	Wrzesinski, C. (2009). Dislodgeable Residue Study of SCH 783460 from Spot-On Treated Beagle Dogs
EPA MRID	47834502
EPA Review	Contractor (Versar, Inc.) review 2/22/2010
MRID = Master Record Identification	

Table D-32: Available Exposure Study Identification Information	
Citation	Wrzesinski, C. (2010). One-Month Dislodgeable Residue Study of SCH 783460 from Spot-On Treated Cats
EPA MRID	48010801
EPA Review	Contractor (Versar, Inc.) review 4/09/2010
MRID = Master Record Identification	

Two post-application pre-registration studies, the "Dislodgeable Residue Study of SCH 783460 from Spot-On Treated Beagle Dogs" (MRID 47834502), and the "One-Month Dislodgeable Residue Study of SCH 783460 from Spot-On Treated Cats" (MRID 48010801) were conducted to measure the transferability of the test substance SCH 783460, a spot-on formulation of indoxacarb, over time from the hair coat of treated pets to a gloved mannequin hand.

The dislodgeability residues of indoxacarb were studied in 10 beagle dogs (5 female and 5 male), weighing 10.7 to 19.08 kg at dose administration, and 10 cats (5 female and 5 male) weighing 3.24 to 7.7 kg after a topical application of an indoxacarb spot-on treatment. Dogs and cats were topically treated with the indoxacarb spot-on formulation by parting the hair at the base of the skull and applying the test substance directly onto the skin. Each animal received one treatment on Day 0 with the maximum label rate of 1.5 mL of product per kg of body weight for dogs and 1.0 mL of product per kg for cats.

On each study the test substance, SCH 783460, was administered to 10 pets (10 beagle dogs for the dog study and 10 cats for the cat study), by topical application to the back using plastic syringes. Indoxacarb residues were measured on treated pets after stroking the pets three times per simulation, for 10 simulations (30 strokes total) with a mannequin hand fitted with two cotton gloves over top of a nitrile glove. Residues were extracted from the nitrile and cotton gloves. Samples were collected from each pet at the following intervals: prior to treatment, at 4, and 8 hours after treatment and at 1, 2, 4, 7, 14, 21, and 28 days after treatment. The cotton and nitrile glove samples were analyzed for indoxacarb (SCH 783460) and the active metabolite JT333. No detectable residues of the metabolite, JT333, were determined in the inner glove or nitrile glove samples, on either study, therefore only outer glove results were presented.

The residue levels of indoxacarb in each glove were reported and used for calculating the percent of dislodgeable residues. Residues were calculated in µg/glove, µg/cm^2 of dog/cat surface area, and percent of applied dose transferred.

For the dog study, indoxacarb average residues from all three gloves combined increased from 4,037 µg/glove (1.78% of applied dose and 0.65 µg/cm^2) at 4 hours after application to a maximum of 5,690 µg/glove (2.55% of applied dose and 0.926 µg/cm^2) at 1 day after application. Residues then declined to 177 µg/glove (0.078% of applied dose and 0.028 µg/cm^2) by Day 28 after application.

For the cat study, indoxacarb average residues from all three gloves combined decreased from 1,941 µg/glove (1.24% of applied dose and 0.56 µg/cm^2) at 4 hours after application to 227 µg/glove (0.141% of applied dose and 0.064 µg/cm^2) by Day 28 after application.

Table D-33: Available Exposure Study Identification Information	
Citation	Wrzesinski, C., (2010). One-Month Dislodgeable Residue Study of Indoxacarb and Permethrin from Spot-On Treated Beagle Dogs
EPA MRID	48135326
EPA Review	Contractor (Versar, Inc.) review 12/14/2010
MRID = Master Record Identification	

A post-application pre-registration study, "One-Month Dislodgeable Residue Study of Indoxacarb and Permethrin from Spot-On Treated Beagle Dogs" (MRID 48135326), was conducted to measure the transferability of the test substance SCH 900560, a spot-on formulation of indoxacarb and permethrin, over time from the hair coat of treated dogs to a gloved mannequin hand.

The dislodgeability residues of indoxacarb and permethrin were studied in 10 beagle dogs (5 female and 5 male), weighing 9.54 to 13.62 kg at dose administration. Dogs were topically treated with the indoxacarb-permethrin spot-on formulation by parting the hair at the base of the skull and applying the test substance directly onto the skin. Each animal received one treatment and actual doses ranged from 1.0 to 1.4 mL formulated product/dog (150 to 210 mg indoxacarb/dog and 480 to 672 permethrin/dog).

The test substance, SCH 900560, was administered to 10 beagle dogs by topical application to the skin on the back shoulder blade area using plastic syringes in a spot-on procedure. Indoxacarb and permethrin residues were measured on treated dogs after 25 petting simulations, with each simulation consisting of three strokes (75 strokes total). The strokes were conducted using a mannequin hand fitted with two cotton gloves over top of a nitrile glove. Residues were extracted from the nitrile and cotton gloves. Samples were collected from each dog at the following intervals: prior to treatment, at 4, and 8 hours after treatment and at 1, 2, 4, 7, 14, 21, and 28 days after treatment. The cotton and nitrile glove samples were analyzed for indoxacarb (SCH 783460) and for permethrin (SCH 169937). The *cis* and *trans* isomers of permethrin were analyzed separately and the results summed to provide total permethrin values.

The residue levels of indoxacarb and permethrin in each glove were reported and used for calculating the percent of dislodgeable residues. Residues were calculated in µg/glove, µg/cm^2 of dog surface area, and percent of applied dose transferred.

For indoxacarb, average residues from all three gloves combined increased from 2,842 µg/gloves (1.56% of applied dose and 0.87 µg/cm^2) at 4 hours after application to a maximum of 3,212 µg/gloves (1.77% of applied dose and 0.99 µg/cm^2) at 8 hours after application. Residues then declined to 247 µg/gloves (0.14% of applied dose and 0.078 µg/cm^2) by Day 28 after application.

For total permethrin, average residues from all three gloves combined increased from 9,686 µg/gloves (1.67% of applied dose and 2.98 µg/cm^2) at 4 hours after application to a maximum of 11,125 µg/gloves (1.93% of applied dose and 3.43 µg/cm^2) at 8 hours after application. Residues then declined to 821 µg/gloves (0.15% of applied dose and 0.26 µg/cm^2) by Day 28 after application.

Data Summary for Available Studies for F_{AR}

Summary: *Table D-34* summarizes pertinent exposure information from the above referenced petting/transfer study data sets identified for use in development of the F_{AR} input presented individually and combined, respectively.

Table D-34: Fraction Application Rate (FAR) Transferred			
Study	**MRID**	**N**	**Fraction Application Rate Transferred**
Dislodgeable Residues of Fipronil Following Application of Frontline® Spray Treatment to Dogs	44433306	30	0.0041
			0.0052
			0.0053
			0.0088
			0.011
			0.012
			0.0067
			0.0076
			0.0081
			0.0043
			0.0049
			0.0047
			0.0076
			0.0099
			0.015
			0.0061
			0.0069
			0.0047
			0.0070
			0.0072
			0.0058
			0.0045
			0.0038
			0.0045
			0.0055
			0.0077
			0.0071
			0.0056
			0.0088
			0.0076
Average			**0.0069**
Dislodgeable Residues of Fipronil Following Application of Frontline® Spray Treatment to Cats	44433307	15	0.0021
			0.0036
			0.0030
			0.0034
			0.0047
			0.0021
			0.0046
			0.0055
			0.0044
			0.0056
			0.0020
			0.0036
			0.0049

Table D-34: Fraction Application Rate (FAR) Transferred			
			0.0028
			0.0059
Average			**0.0039**
Determination of the Dislodgeability of Tetrachlorvinphos (TCVP) from the Fur of Dogs Following the Application of an Insecticide Powder, Pump Spray or Aerosol	45485501	10	Aerosol/ Pump Spray
			0.0056
			0.0029
			0.0035
			0.0084
			0.0035
			0.0034
			0.0038
			0.0028
			0.0025
			0.0022
Average			**0.0030**
Dislodgeable Residues of Fipronil Following Topical Application of Frontline® Spot-on Treatment to Dogs	44531203	18	0.0018
			0.0068
			0.0044
			0.0021
			0.0061
			0.0047
			0.0010
			0.0039
			0.0022
			0.031
			0.021
			0.0069
			0.0092
			0.011
			0.0046
			0.0032
			0.013
			0.0043
Average			**0.0076**
Stroking Test in Dogs After Topical Application of Imidacloprid 10% (w/v) + Permethrin 50% (w/v) Spot-On	46594103	18	0.0016
			0.0016
			0.0010
			0.0062
			0.0010
			0.0018
			0.0040
			0.0033
			0.0024
			0.0042
			0.0013
			0.0015
			0.0070
			0.0016
			0.0032
			0.0023
			0.0024
			0.0026

Table D-34: Fraction Application Rate (FAR) Transferred			
Average			**0.0027**
Dislodgeable Residue Study of SCH 783460 (Indoxacarb) from Spot-On Treated Beagle Dogs	47834502	20	0.015
			0.018
			0.014
			0.014
			0.028
			0.011
			0.018
			0.019
			0.013
			0.027
			0.016
			0.019
			0.019
			0.031
			0.043
			0.01
			0.026
			0.023
			0.015
			0.037
Average			**0.0208**
One-Month Dislodgeable Residue Study of SCH 783460 (Indoxacarb) from Spot-On Treated Cats	48010801	20	0.0072
			0.0370
			0.0035
			0.0140
			0.019
			0.0072
			0.01
			0.0061
			0.0053
			0.015
			0.0047
			0.014
			0.0016
			0.0051
			0.01
			0.0065
			0.0059
			0.013
			0.0056
			0.0084
Average			**0.0100**
			0.0085
			0.0053
			0.0032
			0.0088

Table D-34: Fraction Application Rate (FAR) Transferred			
One-Month Dislodgeable Residue Study of Indoxacarb from Spot-On Treated Beagle Dogs	48135326	20	0.0076
			0.011
			0.0144
			0.0147
			0.0049
			0.0094
			0.0113
			0.0063
			0.0056
			0.0079
			0.0092
			0.01
			0.016
			0.0149
			0.0081
			0.0099
Average			**0.0094**
One-Month Dislodgeable Residue Study of Permethrin from Spot-On Treated Beagle Dogs	48135326	20	0.0155
			0.0106
			0.0051
			0.0174
			0.017
			0.0197
			0.0268
			0.0285
			0.0096
			0.0169
			0.0119
			0.0119
			0.0119
			0.0164
			0.0199
			0.0196
			0.0294
			0.0271
			0.0166
			0.0197
Average			**0.0176**
Combined Average of All Studies			**0.0096**

Accounting for Transferable Residue Dissipation (Treated Pets)

Short-term post-application exposure is typically assessed on the same day the pesticide is applied (day 0) since it is assumed that individuals could be exposed to pets immediately after application; however, exposure is also likely to occur for longer (intermediate-/long-term) durations. Post-application exposure estimates can be refined/characterized to reflect a multi-day exposure profile by accounting for the various factors outlined in *Sections 1.3.2* and *1.3.4* such as dissipation, product-specific re-treatment intervals (i.e., monthly, bi-monthly), and activity patterns.

A pesticide dissipation rate (d) can be used to estimate a range of anticipated risk for the treatment period. If no chemical-specific dissipation data are available, a default value should be used. A default of 13% (0.13) dissipation per day was determined for all liquid pet product formulations based upon the review of the same dermal post-application exposure studies identified to determine F_{AR}.

The study, "Stroking Test in Dogs After Topical Application of Imidacloprid 10% (w/v) + Permethrin 50% (w/v) Spot-On (MRID 46594103)" was not included, however, since the sampling period did not exceed one day and, therefore, is not an adequate period of time to fully analyze dissipation. All other studies measured pesticide residues from 16 to 32 days after application. A description of each study is included in the previous section, Fraction of Application Rate (F_{AR}).

No studies were identified for collars for which dissipation data could be derived. Unlike the other pet product formulations which have shorter treatment intervals and dissipate rapidly, collars are intended to be effective for longer intervals and, likewise, are believed to emit at slower, more constant rate. Due to the lack of formulation specific data, no dissipation is assumed for pet collars and should not be accounted for when assessing longer term durations of exposure.

In order to estimate the daily dissipation rate for residue values resulting from each study, an average value was derived from all data points for each time point sampled. *Table D-35* provides a summary of daily dissipation values resulting from all post-application exposure studies reviewed.

Table D-35: Daily Dissipation Rate (d) – Pet Products

Study	MRID	Time (days)	Average Residue (mg)	Daily Dissipation Rate
Dislodgeable Residues of Fipronil Following Application of Frontline® Spray Treatment to Dogs	44433306	0.083	1.2	0.11
		0.167	1.4	
		0.5	1.4	
		2	1.1	
		3	0.79	
		5	0.55	
		8	0.33	
		15	0.21	
		22	0.084	

Table D-35: Daily Dissipation Rate (d) – Pet Products				
Study	**MRID**	**Time (days)**	**Average Residue (mg)**	**Daily Dissipation Rate**
		29	0.044	
Dislodgeable Residues of Fipronil Following Application of Frontline® Spray Treatment to Cats	44433307	0.083	0.17	0.13
		0.167	0.23	
		0.5	0.20	
		2	0.19	
		3	0.082	
		5	0.030	
		8	0.010	
		15	0.0057	
		22	0.0057	
		29	0.0057	
Determination of the Dislodgeability of Tetrachlorvinphos (TCVP) from the Fur of Dogs Following the Application of an Insecticide Powder, Pump Spray or Aerosol – Pump Spray	45485501	0.17	1.7	0.19
		1	0.87	
		2	0.32	
		4	0.071	
		8	0.019	
		16	0.002	
		32	0.002	
Determination of the Dislodgeability of Tetrachlorvinphos (TCVP) from the Fur of Dogs Following the Application of an Insecticide Powder, Pump Spray or Aerosol – Aerosol	45485501	0.17	1.3	0.18
		1	0.83	
		2	0.70	
		4	0.19	
		8	0.026	
		16	0.038	
		32	0.033	
Dislodgeable Residues of Fipronil Following Topical Application of Frontline® Spot-on Treatment to Dogs	44531203	0.04	1.1	0.17
		1.17	1.4	
		0.33	0.60	
		1	0.63	
		2	0.59	
		4	0.29	
		7	0.21	
		14	0.047	
		21	0.021	
		28	0.0047	
Dislodgeable Residue Study of SCH 783460 (Indoxacarb) from Spot-On Treated Beagle Dogs	47834502	0.17	4.04	0.12
		0.33	5.29	
		1	5.69	
		2	4.39	
		4	3.46	
		7	2.24	
		14	0.71	
		28	0.18	
One-Month Dislodgeable Residue Study of SCH 783460 (Indoxacarb) from Spot-On Treated Cats	48010801	0.17	1.94	0.056
		0.33	1.21	
		1	0.87	
		2	0.93	
		4	1.0	

Table D-35: Daily Dissipation Rate (d) – Pet Products				
Study	**MRID**	**Time (days)**	**Average Residue (mg)**	**Daily Dissipation Rate**
		7	0.85	
		14	0.75	
		28	0.23	
One-Month Dislodgeable Residue Study of Indoxacarb from Spot-On Treated Beagle Dogs	48135326	0.17	2.8	0.090
		0.33	3.2	
		1	3.2	
		2	2.8	
		4	2.1	
		7	1.4	
		14	0.70	
		28	0.25	
One-Month Dislodgeable Residue Study of Permethrin from Spot-On Treated Beagle Dogs	48135326	0.17	9.7	0.090
		0.33	11	
		1	11	
		2	9.2	
		4	7.0	
		7	4.5	
		14	2.7	
		28	0.82	
Average				**0.13**

The following algorithm should be used for the purpose of refining/characterizing estimated post-application dermal exposures attributable to an adult or child 1 < 2 years old contacting a treated companion pet [Note: When d=0 (i.e., when one assumes no dissipation), the integration equation used to derive the exposure equation below reduces to Equation 8.3.]:

$$E = \frac{TC * TR}{n * K} * \frac{(1 - e^{-ET * K}) * (1 - (1 - d)^{n})}{d}$$

where:

E = exposure (mg/day);
TC = transfer coefficient (cm^2/hr);
TR = transferable residue (mg/cm^2);
d = daily dissipation rate (unitless);
ET = exposure time (hours/day);
n = number of days of exposure; and
K = decay constant.

and

$$K = \frac{\ln (1 - d)}{-24}$$

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

where:

TR = transferable residue (mg/cm^2);
AR = application rate or amount applied to animal (mg);
F_{AR} = fraction of the application rate available as transferable residue; and
SA = surface area of the pet (cm^2).

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).

D.7 Generic Estimates of Residential Transfer Coefficients

A transfer coefficient is a measure of surface-to-skin residue transfer dependent on factors such as surface type and contact intensity. It is derived from concurrent measurements of exposure and foliar residue, and is the ratio of exposure, measured in mass of chemical per time (e.g., μg/hr), to residue, measured in mass of chemical per foliar surface area (e.g., $\mu g/cm^2$), with resulting units cm^2/hr. It follows that the use of this ratio precludes the necessity to measure exposure because it can be reasonably predicted from measured residue using a scenario-specific transfer coefficient. Additionally, based on analysis of various studies, it is apparent that transfer coefficients differ based on different activities and scenarios. For example, the transfer of residues while harvesting apples is different than while weeding cabbage; or a child playing on a treated carpet experiences a different level of residue transfer than a child playing on a treated lawn.

Chemical- and scenario-specific exposure measurements are preferable to predicting exposure using residue and transfer coefficients. However, in the event chemical- and scenario-specific exposure data are unavailable, generic transfer coefficients have been derived for use in specific residential situations.

D.7.1 Turf

Residential Turf Exposure

Data to adequately characterize exposure for individuals who contact previously treated residential turf are scarce. However, a residential re-entry exposure study is available to establish reliable transfer coefficients for representative activities in residential settings. This study (D. Klonne and D. Johnson, MRID 47292001) was conducted by the Outdoor Residential Exposure Task Force (ORETF) to determine dermal exposure to residents re-entering a treated turf plot after granular and liquid applications.

Two types of re-entry activities were monitored in the study. The first activity was an approximate 20-minute Jazzercise routine (represented by JAZZ) and the second activity was an approximate 2-hour composite routine consisting of many typical children's activities (represented by CHAPS). The Jazzercise routine is a highly choreographed routine of exercises performed to music. The CHAPS routine is a series of 12 sequential activities that simulated activities in which children routinely engage on residential turf. The activities were selected from activities listed in the National Human Activity Pattern Survey (NHAPS) for children aged 1 to 12 years (Klepeis, et. al., 2001). *Table D-36* summarizes the activities and the time allotted for each activity.

Table D-36: Summary of the Activities and the Duration for Each Activity

Activity Group	Activity	Duration (minutes)
Passive	Walking/Jogging	12
	Playing catch	12
	Crawling	12
	Picnicking	12
	Resting	12
Active	Playing with toys	8
	Playing Frisbee	8
	Playing soccer	8
	Playing games (spud)	8
	Playing tag (steal the bacon)	8
Hard Direct	Football	10
	Tumbling	10

A total of 40 participants were used in this study. For each formulation, 20 participants (10 participants each during a morning and afternoon session) performed the JAZZ routine and 20 participants (10 participants each during a morning and afternoon session) performed the CHAPS routine. A two hour duration was chosen for the CHAPS routine because the NHAPS indicated that the upper-bound estimate of time children spend playing on turf is two hours per day. The potential dermal exposure during re-entry was assessed by using whole-body dosimetry (inner and outer dosimeters), socks (JAZZ only), foot washes (CHAPS only), hand washes, and face/neck wipes.

Dermal transfer coefficients in cm^2/hr were calculated by dividing the corrected residue value (µg) by the replicate duration (hr) and by the formulation-specific turf transferable residue value (µg/cm^2). Within a given activity, total dermal dose (µg) was always lower for the granular formulation than the liquid formulation. Across each formulation, the normalized transfer coefficients (µg/hr) for the CHAPS routine were consistently higher than the JAZZ routine. *Table D-37* presents the raw transfer coefficient data for both the liquid and granular formulation.

Table D-37: Liquid and Granular Formulation TC Data Used for Dermal Scenarios (shoes)

Lifestage	Formulation	TC Values (cm^2/hr)	Formulation	TC Values (cm^2/hr)
Adult	Liquid	195,858	Granular	199,490
		139,625		114,286
		138,525		272,194
		220,767		163,520

Table D-37: Liquid and Granular Formulation TC Data Used for Dermal Scenarios (shoes)				
Lifestage	Formulation	TC Values (cm^2/hr)	Formulation	TC Values (cm^2/hr)
		148,625		218,367
		224,417		180,867
		174,375		157,398
		219,742		154,337
		112,133		186,735
		261,175		139,541
		184,262		298,457
		137,342		182,099
		230,253		196,296
		124,241		239,506
		198,882		190,741
		219,873		230,556
		195,802		240,432
		174,156		211,111
		160,802		166,049
		198,819		231,173

All transfer coefficient values are expressed as square centimeters per hour (cm^2/hr). Each adult transfer coefficient was log-transformed and plotted to evaluate its fit to a lognormal distribution. The data appears to reasonably fit a lognormal distribution as shown in the figure below. This analysis also allowed for the assessment of the statistical differences between the transfer coefficients calculated using the liquid data vs. the granular data. It was determined that these two distributions should not be combined because the upper percentile values were 25% higher for the granular transfer coefficients vs. the liquid transfer coefficients even though the central tendency values of the two distributions were similar.

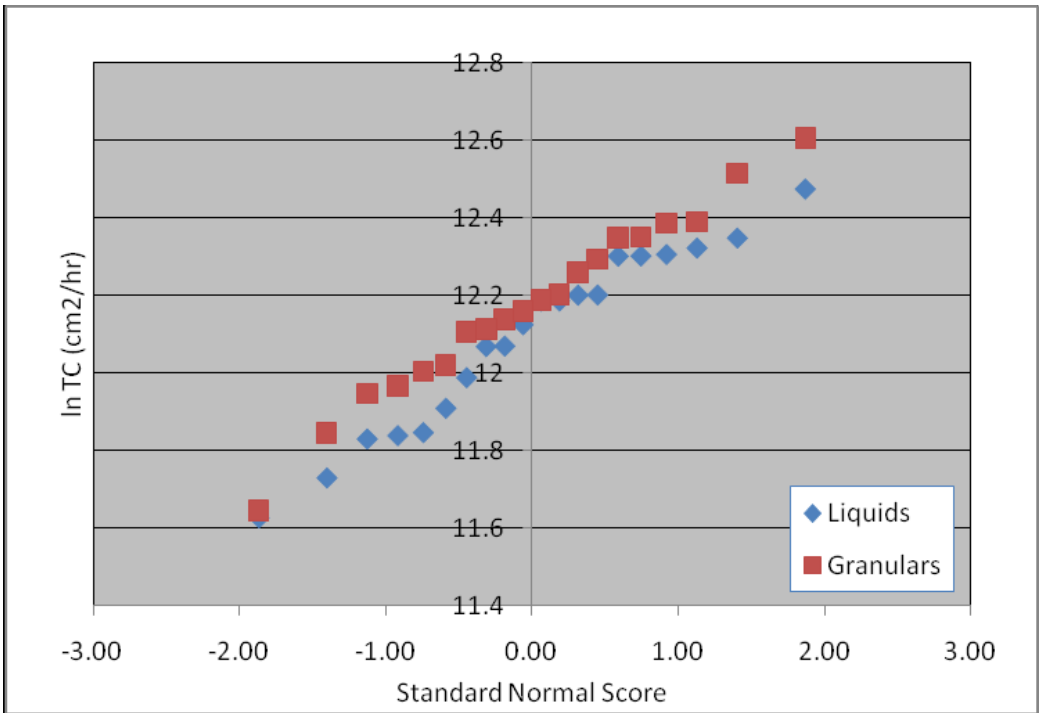


Figure D-7: Residential Turf Transfer Coefficient Lognormal Probability Plot

Statistics such as standard deviations and select percentiles are presented in *Table D-38* below. The transfer coefficients presented above represent adults only. For children, the Agency adjusted the transfer coefficient for body surface area. A 73% reduction in the adult transfer coefficient is recommended because of the differences of body surface areas between adults and children 1 < 2 years old. *Table D-38* provides some summary statistical information about the turf dermal transfer coefficients for both adults and children.

Table D-38: Dermal Exposure Transfer Coefficients (T-shirt and Shorts) for Individuals Performing CHAPS Activities

Statistic	Liquid Transfer Coefficient (cm^2/hr)		Granular Transfer Coefficient (cm^2/hr)	
	Children 1 < 2 years old [1]	Adult	Children 1 < 2 years old [1]	Adult
50th percentile	48,000	180,000	52,000	190,000
75th percentile	56,000	210,000	61,000	230,000
95th percentile	71,000	260,000	77,000	290,000
99th percentile	83,000	310,0002	91,000	340,000
AM (SD)	49,000 (NA)	180,000 (41,000)	54,000 (NA)	200,000 (45,000)
GM (GSD)	48,000 (NA)	1890,000 (1.26)	52,000 (NA)	190,000 (1.26)
Range	NA	110,000–260,000	NA	110,000–300,000
N	NA	20	NA	20

[1]A 73% reduction in the adult transfer coefficient is recommended because of the differences of body surface areas between adults and children 1 < 2 years old.
AM (SD) = arithmetic mean (standard deviation)
GM (GSD) = geometric mean (geometric standard deviation)

Golf Course Exposure

Data to adequately characterize exposure for individuals who contact previously treated turf while golfing are unavailable. However, an occupational re-entry exposure study is available to establish reliable transfer coefficients for representative golfing activities. This study (D. Klonne and E. Bruce, MRID 46734001) was conducted by the Agricultural Reentry Task Force (ARTF) to determine dermal exposure to golf course maintenance workers re-entering a treated turf plot after liquid applications. The cup changing component of this study was used to represent dermal exposure to previously treated turf while golfing.

The cup changing activity consisted of using a hand operated cup cutter to make a new hole, taking the plastic cup liner from the old hole and putting it into the new hole, and filling the old hole with sand and the plug from the new hole. A total of 6 participants were used in this study. Most workers performed the cup changing while bending over and not contacting the turf with anything, but their shoes and hands; however, one worker routinely kneeled on one knee and two other workers kneeled for a few holes. Some cup changers also repaired ball marks on the greens with a hand tool similar to those used by golfers but only one individual performed significant ball mark repair (79 instances). Cup changing occurred first thing in the morning and

a monitoring event consisted of changing 18 cups. This task took approximately 1.5 to 2.5 hours, including 33 to 110 minutes changing the cups, 43 to 52 minutes traveling between holes, and 0 to 20 minutes spent resting, talking to other workers, or performing tasks other than cup changing.

Dermal transfer coefficients in cm^2/hr were calculated by dividing the corrected residue value (µg) by the replicate duration (hr) and by the worker-specific turf transferable residue value (µg/cm^2). Total dermal transfer coefficients were calculated for three clothing scenarios: (1) wearing long pants and a long sleeved shirt, (2) wearing long pants and a t-shirt, and (3) wearing shorts and a t-shirt. *Table D-39* presents the transfer coefficient data for the shorts and t-shirt clothing scenario.

Table D-39: Dermal Exposure Transfer Coefficients (T-shirt and Shorts) for Individuals Golfing

Lifestage	TC Values (cm^2/hr)
Adult	988
	1,097
	1,253
	2,667
	7,165
	18,863

All transfer coefficient values are expressed as square centimeters per hour (cm^2/hr). Each adult transfer coefficient was log-transformed and plotted to evaluate its fit to a lognormal distribution. The data appears to reasonably fit a lognormal distribution as shown in the figure below.

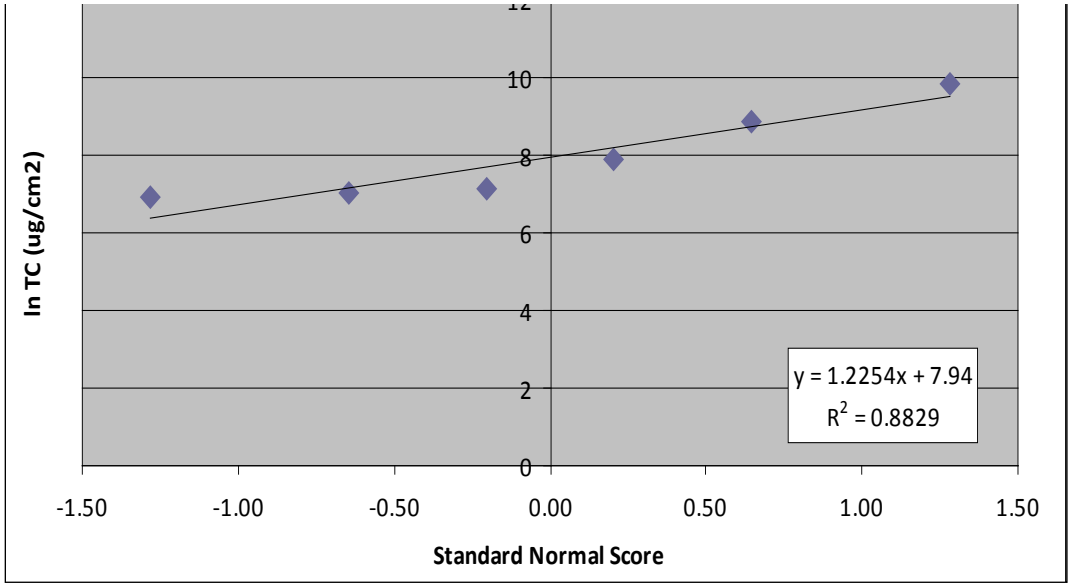


Figure D-8: Golfing Turf Transfer Coefficient Lognormal Probability Plot

The transfer coefficients presented above represent adults only. For children 11 < 16 years old, the transfer coefficient is adjusted for body surface area using a factor of 0.87 (i.e., a 13% reduction in the TC) as outlined in *Section 2.3*. For children 6 < 11 years old, the transfer coefficient is adjusted for body surface area using a factor of 0.59 (i.e., a 41% reduction in the TC) as outlined in *Section 2.3*. *Table D-40* provides some summary statistical information about the turf dermal transfer coefficients for both adults and children.

Table D-40: Dermal Exposure Transfer Coefficients (T-shirt and Shorts) for Individuals Golfing

Statistic	Adult Transfer Coefficient (cm^2/hr)	Children 11 < 16 years old Transfer Coefficient (cm^2/hr) [1]	Children 6 < 11 years old Transfer Coefficient (cm^2/hr) [2]
50th percentile	2,800	2,300	1,500
75th percentile	6,400	5,300	3,500
95th percentile	21,000	17,000	12,000
99th percentile	49,000	40,000	27,000
AM (SD)	5,300 (7,000)	4,400 (NA)	2,900 (NA)
GM (GSD)	2,800 (3.3)	2,300 (NA)	1,500 (NA)
Range	988–18,863	NA	NA
N	6	NA	NA

[1] An 18% reduction in the adult transfer coefficient is recommended to account for the differences of body surface areas between adults and children 11 < 16 years old.
[2] An 45% reduction in the adult transfer coefficient is recommended to account for the differences of body surface areas between adults and children 6 < 11 years old.
AM (SD) = arithmetic mean (standard deviation)
GM (GSD) = geometric mean (geometric standard deviation)

Lawn Mowers Exposure

Data to adequately characterize exposure for individuals who contact previously treated turf while mowing are unavailable. However, an occupational re-entry exposure study is available to establish reliable transfer coefficients for representative mowing activities. This study (D. Klonne and E. Bruce, MRID 46734001) was conducted by the Agricultural Reentry Task Force (ARTF) to determine dermal exposure to golf course maintenance workers re-entering a treated turf plot after liquid applications. The mowing component of this study was used to represent dermal exposure to previously treated turf while mowing a residential lawn. The mowing activity consisted of two distinct types of mowing: mowing greens and mowing fairways.

The mowing greens activity consisted of using a walk-behind reel mower with a grass catcher to make two perpendicular passes to cut the green to 7/32-inch height. A total of 8 participants performed this activity in the study. This activity included emptying the grass catchers and spreading clippings in the rough areas around the golf course as well as hosing off the mower with water at the conclusion of mowing. Greens mowing occurred in the morning (after cups had been changed) and a monitoring event consisted of mowing 4 to 5 greens. This task took approximately 2 to 3 hours, including 89 to 140 minutes mowing or emptying baskets, 23 to 43 minutes traveling between holes, and 0 to 29 minutes spent resting, talking to other workers, or performing tasks other than mowing. When the mower was engaged, the workers walked briskly behind the mower to keep up. At the end of each pass, the worker pushed down on the mower handle to the lift the reel off the ground and quickly turned the mower around to make the next

pass adjacent to the previous pass. Workers generally mowed in one direction, then the other, and then made a pass around the perimeter of the green to finish off the mowing process.

The mowing fairways activity consisted of using either a 5-reel riding mower to mow fairways to ¾ inch height or a 3-reel riding mower to mow tee boxes and surrounds (areas around the greens) to ½-inch height. A total of 8 participants performed these activities in the study. This activity included emptying the grass catchers of the mower and spreading clippings in the rough areas around the golf course as well as hosing off the mower with water at the conclusion of mowing. Fairway mowing occurred in the morning and a monitoring event consisted of mowing either 5 to 6 fairways or surrounds for 9 holes. This task took approximately 2 to 4.5 hours, including 96 to 253 minutes mowing fairway or surrounds, 11 to 30 minutes traveling, and 0 to 4 minutes talking to other workers or repairing motor. The workers generally mowed the fairways and surrounds in one of two patterns: 1) mow the perimeter, then back-and-forth or 2) in a "spiral" pattern, from the outside to inside. The mowers were operated at a low speed (3.5 miles per hour) since it was found that moist grass clippings were not efficiently "thrown" into the grass catchers if the speed was higher. When the grass was wet, the 5-reel mower would frequently get clumps of turf caught in the reel mechanisms, which would require the operator to lift the reels, stop the mower, get off, and clear the clipping from the reels with his hands and/or a stick. The workers would also occasionally dismount to remove debris or to move 150-yard markers.

Dermal transfer coefficients in cm^2/hr were calculated by dividing the corrected residue value (µg) by the replicate duration (hr) and by the worker-specific turf transferable residue value (µg/cm^2). Total dermal transfer coefficients were calculated for three clothing scenarios: (1) wearing long pants and a long sleeved shirt, (2) wearing long pants and a t-shirt, and (3) wearing shorts and a t-shirt. *Table D-41* presents the transfer coefficient data for the shorts and t-shirt clothing scenario.

Table D-41: Dermal Exposure Transfer Coefficients (T-shirt and Shorts) for Individuals Mowing

Lifestage	Activity	TC Values (cm^2/hr)
Adult	Mowing Greens	661
		1,035
		2,245
		6,913
		1,982
		319
		25,860
		18,875
	Mowing Fairways	648
		6,616
		1,874
		2,369
		2,951
		1,109
		11,387
		3,031

All transfer coefficient values are expressed as square centimeters per hour (cm^2/hr). Each adult transfer coefficient was log-transformed and plotted to evaluate its fit to a lognormal distribution.

The data appears to reasonably fit a lognormal distribution as shown in the figure below. This analysis also allowed for the assessment of the statistical differences between the transfer coefficients calculated using the mowing greens data vs. the mowing fairways data. Based on this analysis, it was determined that there was no statistical difference between these datasets and thus, in calculating the adult dermal mowing transfer coefficient the data were combined.

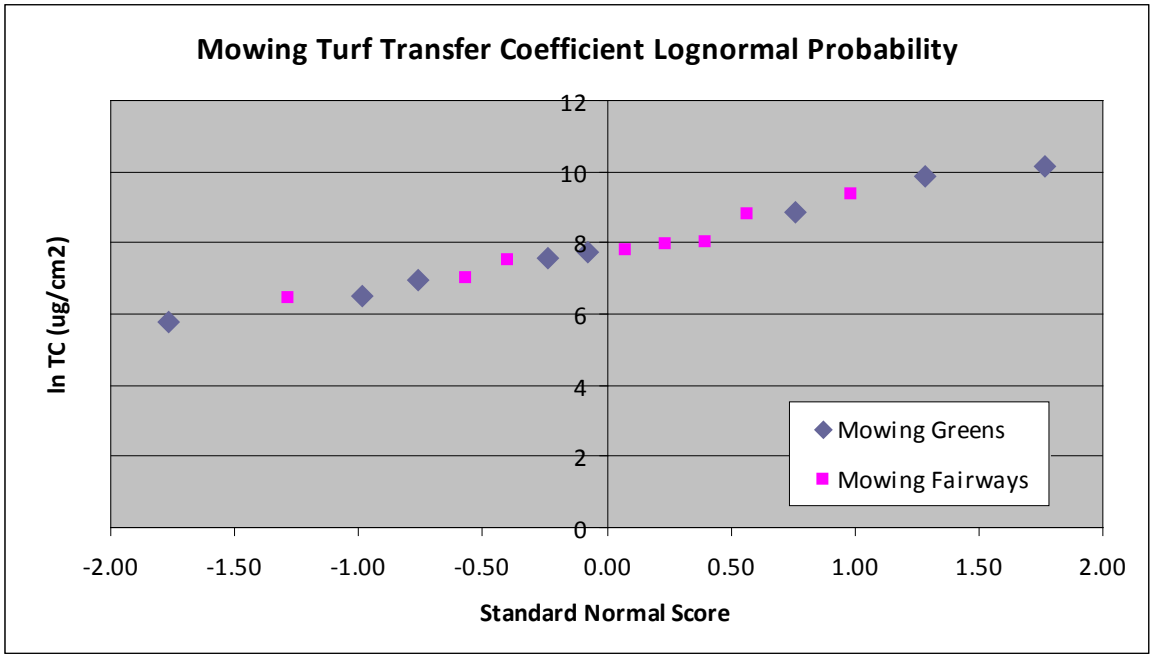


Figure D-9: Mowing Turf Transfer Coefficient Lognormal Probability Plot

The transfer coefficients presented above represent adults only. For youths/teens, the transfer coefficient is adjusted for body surface area by a factor of 0.82 (i.e., an 18% TC reduction) as outlined in *Section 2.3*. *Table D-42* provides some summary statistical information about the turf dermal transfer coefficients for both adults and children.

Table D-42: Dermal Exposure Transfer Coefficients (T-shirt and Shorts) for Individuals Performing Mowing Activities

Statistic	Adult Transfer Coefficient (cm^2/hr) [1]	Youth/Teen Transfer Coefficient (cm^2/hr) [2]
50th percentile	2,700	2,200
75th percentile	6,300	5,200
95th percentile	22,000	18,000
99th percentile	54,000	44,000
99.9th percentile	140,000	4,500 (NA)
Arithmetic Mean	5,500	2,200 (NA)
Arithmetic Standard Deviation	7,300	NA
Geometric Mean	2,700	NA
Geometric Mean Standard Deviation	3.5	NA
Range	319–25,860	NA

D.7.2 Gardens, Trees, and "Pick-your-own" Farms

Data to adequately characterize exposure for individuals who contact previously treated residential gardens and trees and in "pick-your-own" farms is unavailable. Therefore, occupational re-entry exposure studies, all conducted by the Agricultural Reentry Task Force (ARTF), were used to establish transfer coefficients for representative crops and activities in residential settings.

Unlike occupational settings where individuals generally perform one task (or, at most a few tasks) on a single crop throughout the day (e.g., harvesting apples), individuals in residential settings are likely to conduct various activities. Therefore, transfer coefficients from occupational reentry studies were used to establish composite transfer coefficients for distinct activities likely to occur in residential settings. Additionally, also unlike occupational settings, the transfer coefficients represent individuals wearing shorts and short-sleeve shirts, a standard assumption in residential exposure assessment.

Activities are divided between those that would occur in gardens (vegetables, fruit, and flowers), those that would occur with trees (fruit and nut trees and ornamental shrubs and bushes), and those that would occur for indoor plants. Transfer coefficients for each category are then derived from select occupational reentry exposure studies considered to be representative of "residential-like" activities. *Table D-43* below lists the occupational field reentry studies used to derive transfer coefficients for each of these scenarios.

Table D-43: Gardens, Trees, and "Pick-your-own" Farms – Transfer Coefficient Studies

Residential Post-application Activity	Representative Crop/Activity Combinations	Study Code	
		MRID	ARTF #
Gardens (vegetables and flowers)	Cabbage weeding	45191701	ARF037
	Tomato tying	45530103	ARF051
	Squash harvesting	45491902	ARF049
	Chrysanthemum pinching	45344501	ARF039
Trees and Retail Plants (fruits, nuts, ornamentals, shrubs, bushes)	Ornamental citrus tree pruning	45469501	ARF043
	Apple harvesting	45138202	ARF025
	Orange harvesting	45432302	ARF041
	Grapefruit harvesting	45432302	ARF042
Indoor Plants	Ornamental citrus tree pruning	45469501	ARF043

Despite the uncertainty of using occupational reentry monitoring studies, where workers likely conduct activities in a much different fashion than those in residential settings, the transfer coefficients outlined are considered reasonable for use in risk assessment. Note that use of these transfer coefficients for youths should be used in combination with an adjustment factor of 0.55 for body surface area.

Vegetable, Fruit, and Flower Gardening Activities at Home and at "Pick-your-own" Farms

Transfer coefficients for residential gardening and picking vegetables, fruits, and flowers at "pick-your-own" farms were derived using studies considered adequately representative of activities in these settings such as weeding and picking vegetables and flowers. The studies used

measured exposure for workers during four different studies: cabbage weeding, tomato tying, squash harvesting, and chrysanthemum pinching. *Table D-44* below presents the raw data for these studies.

Table D-44: Gardening at Home and at "Pick-your-own" Vegetable Farms: Transfer Coefficient Data

Study Reference		Crop	Activity	Person ID	DAA	Transfer Coefficient
ARTF #	MRID					
ARF037	45191701	Cabbage	Weeding	A	1	29,612
					2	41,329
					3	31,947
				B	1	19,910
					2	28,428
					3	24,226
				C	1	21,134
				D	1	24,149
					2	28,601
				E	2	16,482
					3	23,976
				F	2	29,683
					3	20,604
ARF051	45530103	Tomato	Tying	A	2	1,812
					3	3,999
				B	2	2,807
					3	5,040
					4	3,161
				C	2	2,349
					3	4,425
					4	2,292
				D	2	3,236
					3	6,810
					4	4,506
				E	2	2,448
					3	6,132
					4	3,479
				F	4	4,431
ARF049	45491902	Squash	Harvesting	A	2	1,395
					3	4,747
					4	3,043
				B	2	1,426
					3	6,800
					4	3,178
				C	2	1,121
					3	5,130
					4	3,195
				D	2	1,546
					3	5,042
					4	3,897
				E	2	887
					3	3,846
					4	2,550
				F	2	1,163
					3	7,411
					4	2,667

Table D-44: Gardening at Home and at "Pick-your-own" Vegetable Farms: Transfer Coefficient Data						
Study Reference		Crop	Activity	Person ID	DAA	Transfer Coefficient
ARTF #	MRID					
				G	2	1,326
					3	4,686
					4	3,642
				H	2	1,298
					3	5,466
					4	3,864
				D	2	424
					3	214
					4	177
				E	2	328
					3	299
					4	134
ARF039	45344501	Chrysanthemum	Pinching	A	1	164
					2	253
					3	223
				B	1	264
					2	422
					3	314
				C	1	250
					2	218
					3	241
				D	1	321
					2	492
					3	301
				E	1	218
					2	436
					3	201

Tree Activities at Home and at "Pick-your-own" Farms

Transfer coefficients for activities associated with fruit and nut trees and ornamental shrubs and bushes (including potential exposure from those purchased at retail locations) were derived using exposure studies for workers during four different studies: apple harvesting, orange harvesting, grapefruit harvesting, and ornamental citrus tree pruning. *Table D-45* below presents the raw data for these studies.

Table D-45: Tree Activities at Home and at "Pick-your-own" Farms: Transfer Coefficient Data						
Study Reference		Crop	Activity	Person ID	DAA	Transfer Coefficient
ARTF #	MRID					
ARF025	45138202	Apple	Harvesting	A	1	3132
					2	3207
					3	3033
				B	1	2596
					2	2741
					3	1931
				C	1	2547
					2	3323
					3	1927
				D	1	2865
					2	3161

Table D-45: Tree Activities at Home and at "Pick-your-own" Farms: Transfer Coefficient Data						
Study Reference		Crop	Activity	Person ID	DAA	Transfer Coefficient
ARTF #	MRID					
					3	1873
				E	1	2343
					2	3078
					3	1905
ARF041	45432301	Orange	Harvesting	A	5	1143
					6	1189
					7	1228
				B	5	1087
					6	1545
					7	1430
				C	5	1192
					6	1691
					7	1873
				D	5	1010
					6	2091
					7	1883
				E	5	978
					6	1983
					7	2026
ARF043	45469501	Nursery Citrus	Pruning	A	2	181
					3	146
					4	144
				B	2	505
					3	222
					4	113
				C	2	205
					3	150
					4	85
				D	2	424
					3	214
					4	177
				E	2	328
					3	299
					4	134
ARF042	45432302	Grapefruit	Harvesting	A	5	1960
					6	2008
					7	2177
				B	5	2044
					6	1822
					7	2530
				C	5	2832
					6	3188
					7	2609
				D	5	2690
					6	2579
					7	3312
				E	5	2706
					6	3358
					7	2539

Indoor Plant Activities

Transfer coefficients from the study measuring exposure while pruning ornamental citrus trees are recommended for use for activities associated with indoor plants. The data for this study is presented above in *Table D-45*.

Transfer Coefficient Data Analysis

Each transfer coefficient was log-transformed and plotted to evaluate its fit to a lognormal distribution. Each study appears to reasonably fit a lognormal distribution as shown in the figure below.

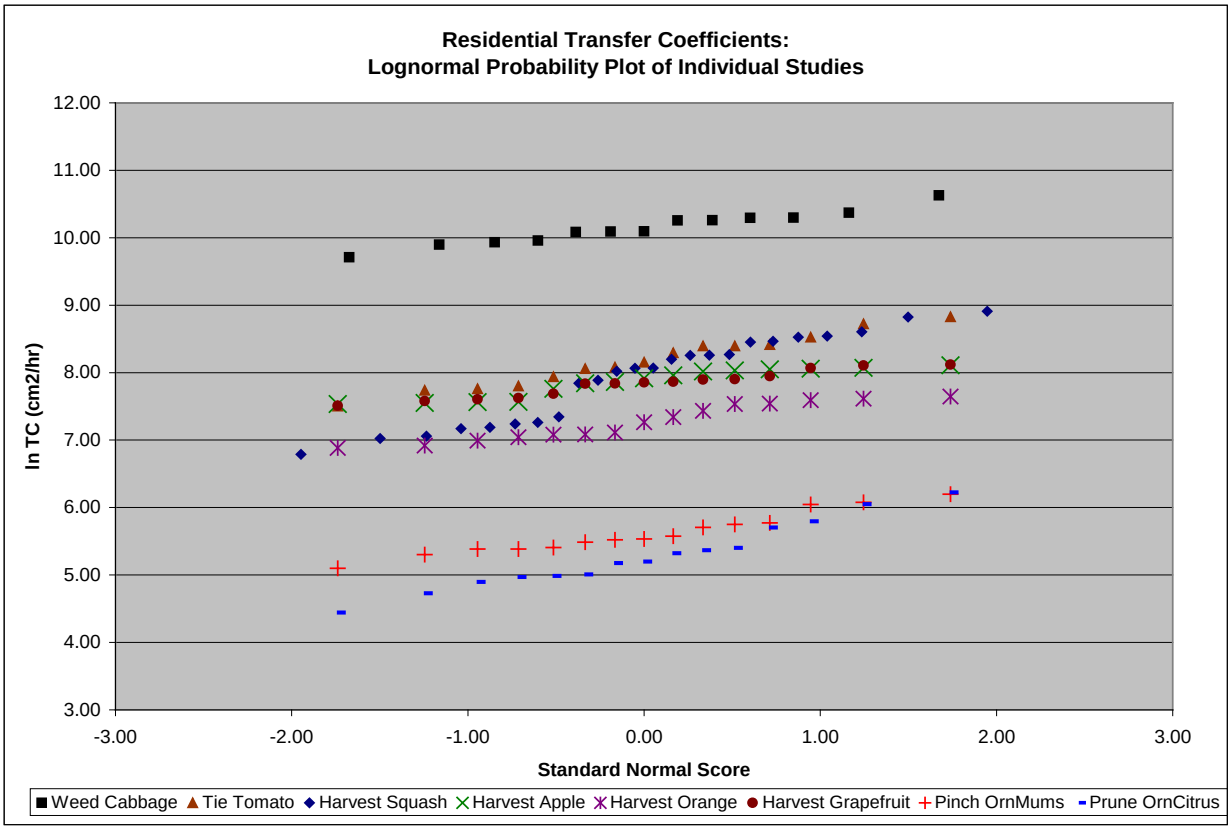


Figure D-10: Residential Transfer Coefficients: Lognormal Probability Plot of Individual Studies

As previously stated, unlike these occupational studies where workers conducted a single activity for the duration of their workday, homeowners tending to their outdoor gardens and trees and individuals attending "pick-your-own" are likely to conduct various activities. For example, it is likely that individuals would weed both their gardens on the same day or trim their bushes and apple trees on the same day. In fact, it is likely that individuals would conduct some configuration of all outdoor activities on the same day. Note that in the case of indoor plants these activities are reasonably represented by ornamental citrus tree pruning alone.

For the purposes of pesticide assessment, however, for which certain chemicals may only be used on gardens and trees composite transfer coefficient distributions have been developed to represent activities in gardens and trees. These were derived by constructing, via a 5000 trial

Monte Carlo simulation using Crystal Ball 4.0 (Microsoft Excel add-on), custom distributions using the lognormal distributions for each individual activity (*See Figure D-10*), but assigning equal probabilities of 25% for each activity. Essentially just a weighting mechanism, it assumes, for example that an individual while gardening conducts "cabbage weeding-like," "squash harvesting-like," "tomato tying-like," and "chrysanthemum pinching-like" activities in equal proportions (i.e., 25% of the time spent conducting each). Additional data on specific gardening activities (or an exposure study representing actual homeowner gardening work) could confirm this assumption or inform a more accurate weight to each activity. Thus, absent exposure studies specific for activities in residential settings (e.g., a study in which individuals perform various activities following pesticides applications in various locations on their property), the approach outlined is considered reasonable.

Parameters for each lognormal distribution are outlined in *Table D-46* below.

Table D-46: Gardens, Trees, and "Pick-your-own" Farms – Transfer Coefficient Studies

Residential Post-application Activity	Representative Crop/Activity Combinations	Lognormal TC Distribution Parameters	
		GM	GSD
Gardening (vegetables, fruits, and flowers)	Cabbage weeding	25,463	1.27
	Tomato tying	3,547	1.47
	Squash harvesting	2,774	1.89
	Chrysanthemum pinching	275	1.36
Tree maintenance (fruits, nuts, shrubs, bushes)	Ornamental citrus tree pruning	197	1.63
	Apple harvesting	2,591	1.24
	Orange harvesting	1,440	1.31
	Grapefruit harvesting	2,513	1.21

As previously stated, a composite distribution for activities in gardens and trees was simulated by assigning equal probabilities (i.e., 25% for each representative activity) to each single activity's distribution. The figures below present probability and cumulative density function for each of the resulting simulated distributions.

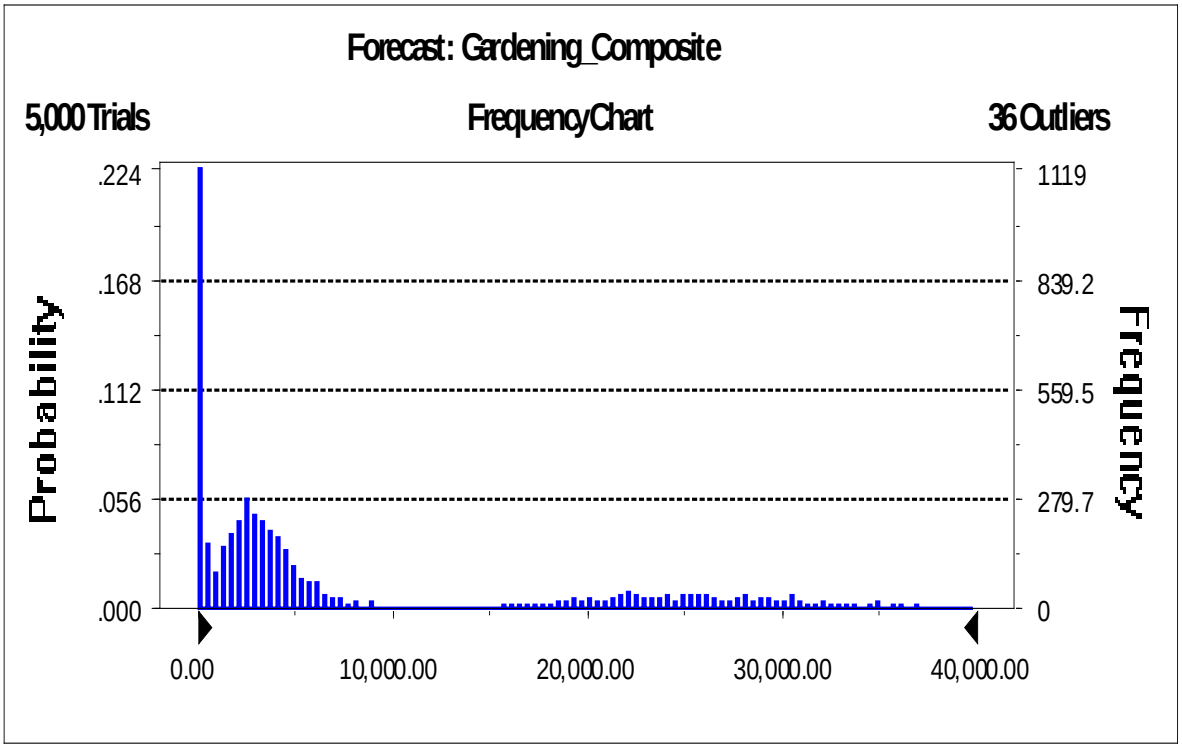


Figure D-11: Gardening Transfer Coefficient– Composite Probability Density Function Simulation

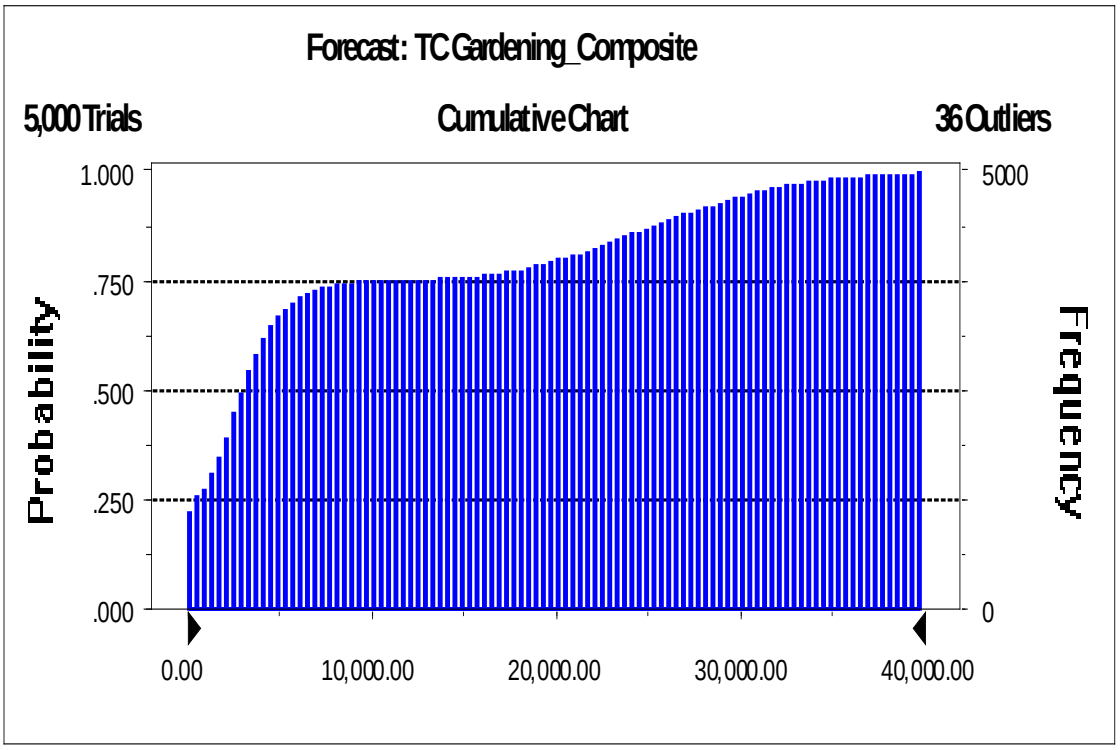


Figure D-12: Gardening Transfer Coefficient – Composite Cumulative Distribution Function Simulation

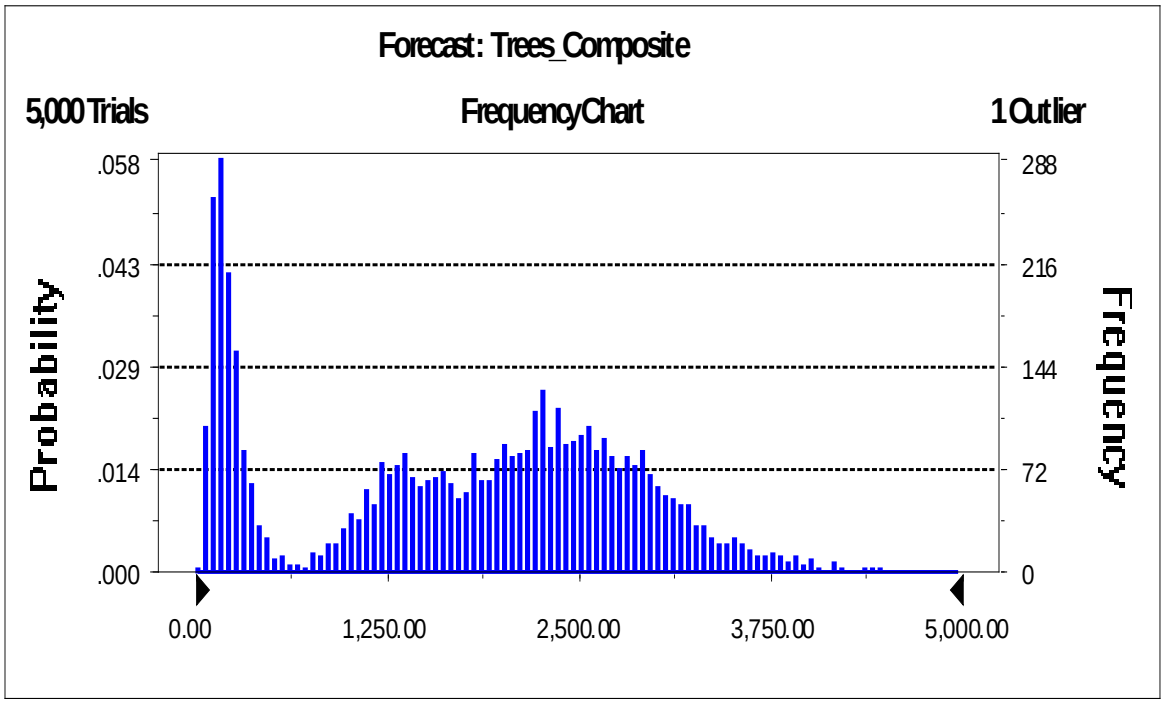


Figure D-13: Trees Transfer Coefficient – Composite Probability Density Function Simulation

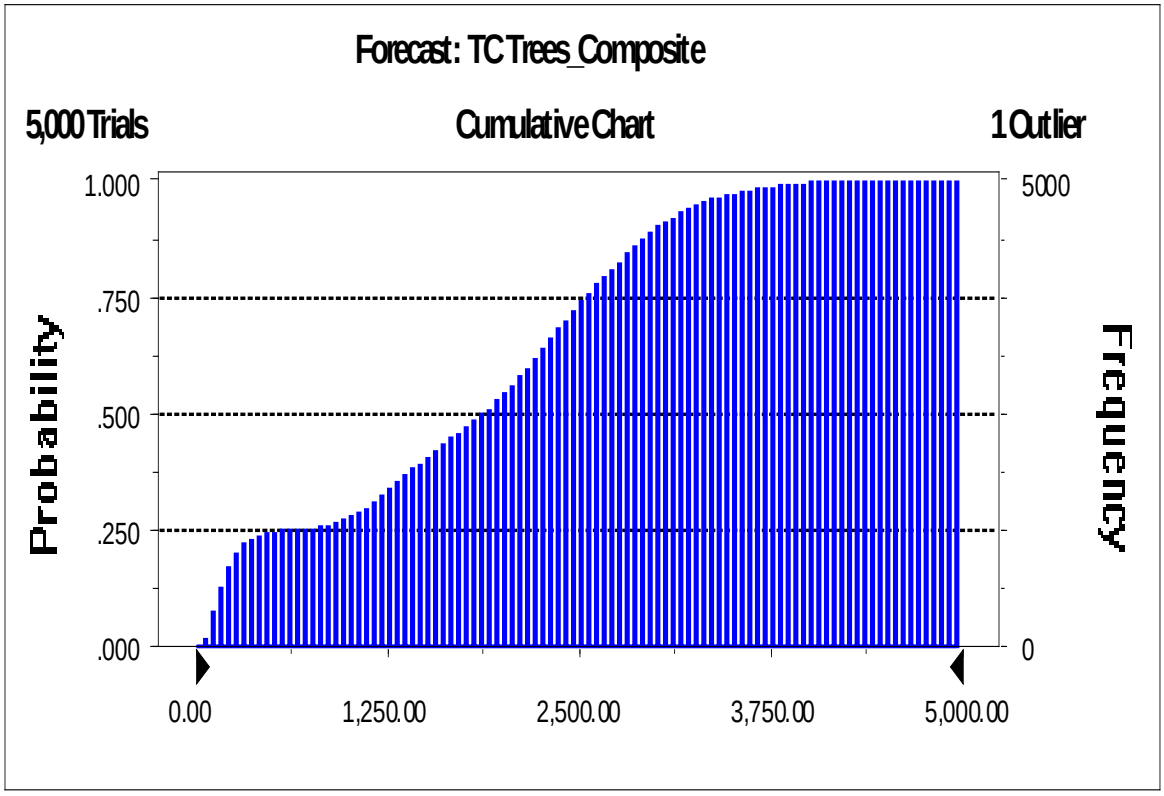


Figure D-14: Trees Transfer Coefficient – Composite Cumulative Distribution Function Simulation

Summary statistics for each composite distribution are provided below in *Table D-47*[Note: it is recognized that treating each data point independently is technically incorrect due to the "nested" structure of the data set (i.e., transfer coefficients "within" workers, "within" crops, "within" chemicals, etc.), however, resulting statistics are nonetheless reasonable and useful for exposure assessment purposes.]

Table D-47: Statistical Summary – Residential Transfer Coefficients (cm2/hr)			
Statistic	**Gardens**	**Trees**	**Indoor Plants**
Mean	8413	1741	223
50th percentile	3243	1911	197
75th percentile	13035	2583	274
90th percentile	27367	3056	370
95th percentile	31082	3332	443
99th percentile	37777	3949	617
99.9th percentile	47087	4575	901
Range	164 – 41329	85 – 3357	85 – 505
N	67	60	15

D.7.3 Indoor Areas

There are no studies available that measure both exposure and surface residue while subjects are performing typical indoor activities. Therefore, the transfer coefficients used for indoor scenarios are derived from information provided in three different studies: (1) two studies which measured exposure and surface residues while subjects performed a Jazzercise™ routine (Krieger et al., 2000 and Selim, 2004) and (2) a study which measured biomonitoring doses while adults performed scripted activities for 4 hours on carpet (Vaccaro, 1991).

In the Krieger and Selim studies, a Jazzercise™ routine was performed to achieve maximum contact of the entire body with a surface using low impact aerobic movements. All body surfaces (dorsal, ventral, and lateral) contact the treated surface. The potential dermal exposure was measured by using whole-body dosimetry. The dosimeters were expected to normalize differences in surface contact and to increase the total sample area relative to patches. The assumption is that the dosimeter represents the skin and that the dose retained by the dosimeter is equivalent to dermal exposure.

In the Krieger study, adult males performed two 20-minute Jazzercise routines, which yielded a transfer coefficient of 50,953 cm^2/0.67 hr for chlorpyrifos. In the Selim study, adult males performed one 20-minute Jazzercise routine, which yielded transfer coefficients of 18,736 cm^2/0.33 hr for pyrethrin, 20,354 cm^2/0.33 hr for PBO and 21,572 cm^2/0.33 hr for MGK-264.

Table D-48: Transfer coefficients based on Jazzercise			
Krieger (2000)[a] -- Chlorpyrifos			
Subject	Total exposure (μg/40 min)	Average transferable residue from study (μg/cm^2)	Transfer Coefficient (cm^2/40 min)
1	2,524	0.27	9,348
2	1,466	0.27	5,430
3	28,980	0.27	107,333
4	3,294	0.27	12,200
5	52,590	0.27	194,778

Table D-48: Transfer coefficients based on Jazzercise			
6	22,950	0.27	85,000
7	2,081	0.27	7,707
8	14,730	0.27	54,556
9	4,541	0.27	16,819
10	5,012	0.27	18,563
11	1,328	0.27	4,919
12	1,579	0.27	5,848
13	37,770	0.27	139,889
Arithmetic Mean			50,953
Standard Deviation			62,242
Geometric Mean			23,254
Selim (2004) -- Pyrethrin			
Subject	Total exposure (ug/20 min)	Average transferable residue from study (ug/cm^2)	Transfer Coefficient (cm^2/20 min)
5078	2900	0.34	8,543
1976	3100	0.34	9,133
1966	3400	0.34	10,016
1342	3600	0.34	10,606
8401	4600	0.34	13,552
7219	5000	0.34	14,730
1719	4600	0.34	13,552
6026	4900	0.34	14,435
3454	6300	0.34	18,560
1463	5800	0.34	17,087
7678	7200	0.34	21,211
7777	8500	0.34	25,041
17	9500	0.34	27,987
3714	13000	0.34	38,298
1253	13000	0.34	38,298
Arithmetic Mean			18,736
Standard Deviation			9,732
Geometric Mean			16,723
Selim (2004) -- PBO			
Subject	Total exposure (ug/20 min)	Average transferable residue from study (ug/cm^2)	Transfer Coefficient (cm^2/20 min)
5078	4100	0.61	6,673
1976	6100	0.61	9,928
1966	7100	0.61	11,555
1342	7800	0.61	12,694
8401	8300	0.61	13,508
7219	8200	0.61	13,345
1719	8600	0.61	13,996
6026	9400	0.61	15,298
3454	13000	0.61	21,157
1463	14000	0.61	22,785
7678	14000	0.61	22,785
7777	16000	0.61	26,040
17	18000	0.61	29,295
3714	25000	0.61	40,687
1253	28000	0.61	45,570
Arithmetic Mean			20,354
Standard Deviation			11,237
Geometric Mean			17,825
Selim (2004) -- MGK-264			
Subject	Total exposure (ug/20 min)	Average transferable residue from study (ug/cm^2)	Transfer Coefficient (cm^2/20 min)
5078	7300	0.92	7,935
1976	7400	0.92	8,043
1966	12000	0.92	13,043

Table D-48: Transfer coefficients based on Jazzercise			
1342	11000	0.92	11,957
8401	13000	0.92	14,130
7219	14000	0.92	15,217
1719	15000	0.92	16,304
6026	16000	0.92	17,391
3454	18000	0.92	19,565
1463	19000	0.92	20,652
7678	21000	0.92	22,826
7777	26000	0.92	28,261
17	29000	0.92	31,522
3714	44000	0.92	47,826
1253	45000	0.92	48,913
Arithmetic Mean			21,572
Standard Deviation			12,712
Geometric Mean			18,669

a. From table 2 of Krieger (2000)

In the Vaccaro study, adult males, dressed in bathing suits only, performed different activities over a 4 hour activity period. These activities included: sitting-playing with blocks, on hands and knees crawling, walking on carpet, laying on back, and laying on abdomen. Although activity was minimal during the last 2 activities, considerable surface area was in contact with the carpets during these times. An estimated dermal dose from the Vaccaro (1991) biomonitoring study was estimated to be 10.02 μg/kg (based on biomonitoring and inhalation monitoring results reported in study).

A comparison can be made using the Krieger study (Jazzercise activity) and the Vaccaro study (scripted activity) since both studies used the same chemical, chlorpyrifos, and both included biomonitoring aspects. If the biomonitoring doses from both studies are normalized to the activity time, the values are similar. In the Krieger study, the average biomonitoring dose was 3.3 μg/kg for 40 minutes of activity, or 0.08 μg/kg-min. In the Vaccaro study, the average biomonitoring dose was 12 μg/kg for 4 hours of activity, or 0.05 μg/kg-min. Therefore, it is assumed that the shorter duration of high contact activity (i.e., Jazzercise) can be used to estimate exposure during longer durations of low contact activity (in this case, 4 hours of activity) and the Jazzercise transfer coefficients can be applied to 4 hours of typical indoor activity.

Table D-49: Transfer coefficients adjusted for Activity Time		
Krieger (2000) - Chlorpyrifos		
Adult TC from study (cm^2/40 min)	Adults	children 1 < 2 years old
	Jazzercise TC applied to 4 hours of typical indoor activity (cm^2/hr)	Jazzercise TC applied to 4 hours of typical indoor activity and adjusted for surface area[a] (cm^2/hr)
9,348	2,337	635
5,430	1,357	369
107,333	26,833	7,293
12,200	3,050	829
194,778	48,694	13,235
85,000	21,250	5,776
7,707	1,927	524
54,556	13,639	3,707
16,819	4,205	1,143
18,563	4,641	1,261
4,919	1,230	334
5,848	1,462	397

Table D-49: Transfer coefficients adjusted for Activity Time			
139,889		34,972	9,505
Arithmetic mean	50,953	12,738	3,462
Standard Deviation	62,242	15,561	4,229
Geometric mean	23,254	5,813	1,580
Selim (2004) - Pyrethrin			
Adult TC from study (cm^2/20 min)		Adults	children 1 < 2 years old
		Jazzercise TC applied to 4 hours of typical indoor activity (cm^2/hr)	Jazzercise TC applied to 4 hours of typical indoor activity and adjusted for surface area[a] (cm^2/hr)
8,543		2,136	581
9,133		2,283	621
10,016		2,504	681
10,606		2,651	721
13,552		3,388	921
14,730		3,682	1,001
13,552		3,388	921
14,435		3,609	981
18,560		4,640	1,261
17,087		4,272	1,161
21,211		5,303	1,441
25,041		6,260	1,701
27,987		6,997	1,902
38,298		9,574	2,602
38,298		9,574	2,602
Arithmetic mean	18,736	4,684	1,273
Standard Deviation	9,732	2,433	661
Geometric mean	16,723	4,181	1,136
Selim (2004) - PBO			
Adult TC from study (cm^2/20 min)		Adults	children 1 < 2 years old
		Jazzercise TC applied to 4 hours of typical indoor activity (cm^2/hr)	Jazzercise TC applied to 4 hours of typical indoor activity and adjusted for surface area[a] (cm^2/hr)
6,673		1,668	453
9,928		2,482	675
11,555		2,889	785
12,694		3,174	863
13,508		3,377	918
13,345		3,336	907
13,996		3,499	951
15,298		3,825	1,040
21,157		5,289	1,438
22,785		5,696	1,548
22,785		5,696	1,548
26,040		6,510	1,769
29,295		7,324	1,991
40,687		10,172	2,765
45,570		11,392	3,096
Arithmetic mean	20,354	5,089	1,383
Standard Deviation	11,237	2,809	764
Geometric mean	17,825	4,456	1,211
Selim (2004) – MGK-264			
Adult TC from study (cm^2/20 min)		Adults	children 1 < 2 years old
		Jazzercise TC applied to 4 hours of typical indoor activity (cm^2/hr)	Jazzercise TC applied to 4 hours of typical indoor activity and adjusted for surface area[a] (cm^2/hr)
7,935		1,984	539
8,043		2,011	547
13,043		3,261	886
11,957		2,989	812
14,130		3,533	960

Table D-49: Transfer coefficients adjusted for Activity Time			
15,217		3,804	1,034
16,304		4,076	1,108
17,391		4,348	1,182
19,565		4,891	1,329
20,652		5,163	1,403
22,826		5,707	1,551
28,261		7,065	1,920
31,522		7,880	2,142
47,826		11,957	3,250
48,913		12,228	3,324
Arithmetic mean	21,572	5,393	1,466
Standard Deviation	12,712	3,178	864
Geometric mean	18,669	4,667	1,269

a. 73% reduction factor ($0.53 m^2$ / $1.95 m^2$).

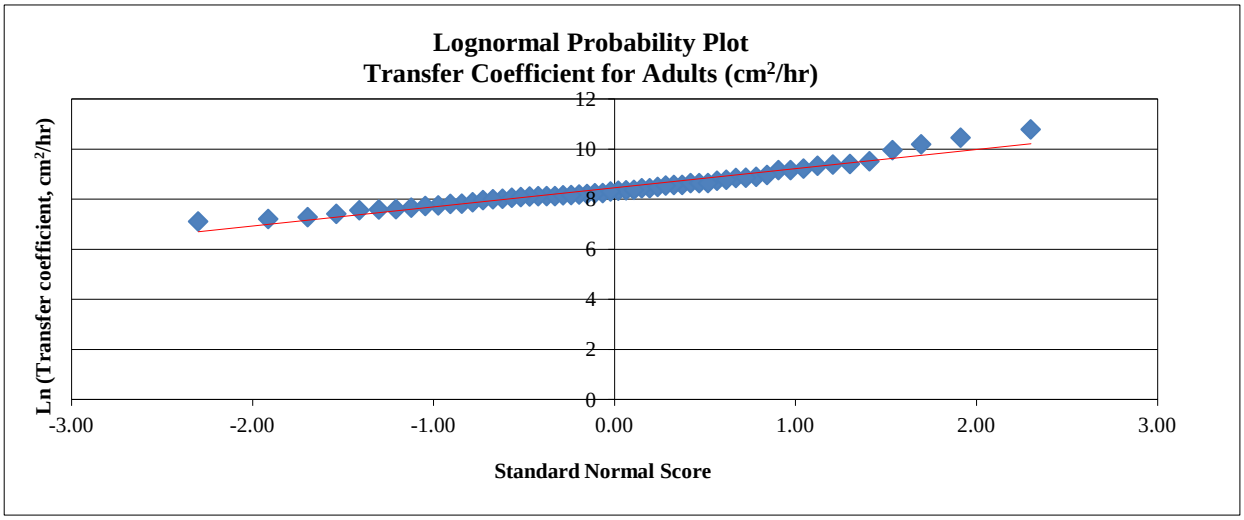


Figure D-15: Indoor Environments – Adult Transfer Coefficient Lognormal Probability Plot

Table D-50: Indoor Environments Statistical Summary – Transfer Coefficient (cm2/hr)		
Statistic	**Adults**	**children 1 < 2 years old[a]**
50th percentile	4,700	1,300
75th percentile	7,800	2,100
95th percentile	17,000	4,600
99th percentile	28,000	7,600
99.9th percentile	50,000	14,000
AM (SD)	6,800 (8,200)	1,800 (2,200)
GM (GSD)	4,700 (2.16)	1,300 (2.16)
Range	1,200 – 49,000	330 – 13,000

[a] A 73% reduction in the adult transfer coefficient is recommended because of the differences of body surface areas between adults and children (1 < 2 years old).
AM (SD) = arithmetic mean (standard deviation)
GM (GSD) = geometric mean (geometric standard deviation)

D.7.4 Treated Pets

Post-application dermal exposure can be predicted using estimates for residue transfer to individuals contacting treated pets during certain activities and exposure durations. Residue transfer from a given formulation and activity is an empirical value, known as the transfer coefficient (TC). Dermal TCs were developed for liquid and solid pet product formulations. The following is a summary of the exposure studies used in the quantification of pet treatment TCs and the corresponding data sets of each exposure study.

The Agency did not identify any studies which were conducted to observe homeowner activities with a treated pet. While studies were conducted to determine the fraction of application rate transferred from the treated pet to a human or artificial (mannequin) hand, these data are limited in that the scripted activity patterns employed (i.e., a pre-determined number of wipes to the animal's coat) and hand only exposure measurements, limit their utility for the estimation of actual activities, contact and resulting exposure to the whole body of exposed individuals.

An applicator and groomer study were reviewed and identified as the best measure of exposure that could occur from interactions with treated pets because these studies included the direct measurement of exposures to applicators or pet groomers. Since these individuals directly handled pesticide products and had direct contact with treated pets it is expected that their resulting exposures are a reasonable approximation of upper bound estimates of contact with a treated animal. In the absence of direct exposure data for this scenario (e.g., homeowner activity with a treated pet), the Agency assumes that the application and grooming activities are likely to result in a protective estimate of exposure than just the evaluation of petting, hugging or sleeping with a pet.

The TCs used to assess dermal post-application pet exposure were developed from two studies representing application and grooming activities with dogs, one using carbaryl shampoo and the other using carbaryl dust; which represent TCs liquid and solid formulations, respectively. Data were gathered while human volunteers applied pesticide products to various dogs of differing sizes and fur lengths. Volunteers in the carbaryl shampoo study groomed the animals as well as applying the product. Pet exposure TCs can be defined as animal surface area contact per unit time (cm^2/hr), or the ratio of exposure rate, measured in mass of chemical per time (e.g., µg/hr), to residue, measured in mass of active ingredient per surface area of the animal (e.g., $\mu g/cm^2$).

The mass of active ingredient per surface area of the animal ($\mu g/cm^2$) used to determine the TCs were adjusted for the dust and shampoo studies. The applicator/groomer studies were not performed in a manner which measured active ingredient per surface area of the animal. Therefore, the residue available on the animal for transfer was predicted by multiplying an average fraction of application rate (F_{AR}) value (0.0096) by the active ingredient per surface area ($\mu g/cm^2$) estimated from the studies. This adjustment has the effect of increasing TC estimates, thus resulting in value which is more protective of human health. Furthermore, the selection of the arithmetic mean F_{AR} value, in lieu of recommended screening level F_{AR} value (0.020) further increases TC estimates for the dust and shampoo studies. A full description of the F_{AR} input is detailed in the next section.

Since TCs were established from studies using adult volunteers, they have been scaled to adjust for assessment of child exposure. The Agency assumes that the surface area of a child 1 < 2 years old is 73% less than that of an average adult. The adjustment is based upon a ratio of the mean surface area of 1 < 2 year lifestage, 0.53 m^2, and the value of the combined average of mean total surface area for males and females, 1.95 m^2, from the Exposure Factors Handbook 2011 Edition (U.S. EPA, 2011).

Formulation: Liquid

Application Method: Aerosols, Collars, Dips, Pump Sprays, Shampoos, Sponges and Spot-Ons

Table D-51: Adult and Child Transfer Coefficients for Liquid Formulations

Statistic	Transfer Coefficent (cm^2/hour)[a,b]	
	Adult	1 < 2 years old
50th percentile	3,600	980
75th percentile	6,400	1,700
95th percentile	15,000	3,900
99th percentile	26,000	7,000
99.9th percentile	49,000	13,000
AM (SD)	5,200 (5,300)	1,400 (1,400)
GM	3,600	980
GSD	2.33	2.33
Range	522-12,846	NA[c]
N	16	NA[c]

Notes:
a. Representative of individuals wearing short-sleeve shirts, shorts, and no chemical-resistant gloves.
b. Dermal liquid formulation TC based on a lognormal distribution fit with data from MRID 46658401.
c. NA = Not applicable. Child values were derived by scaling adult data.

Each adult transfer coefficient was log-transformed and plotted to evaluate its fit to a lognormal distribution. The data appears to reasonably fit a lognormal distribution as shown in the *Figure D-16* below.

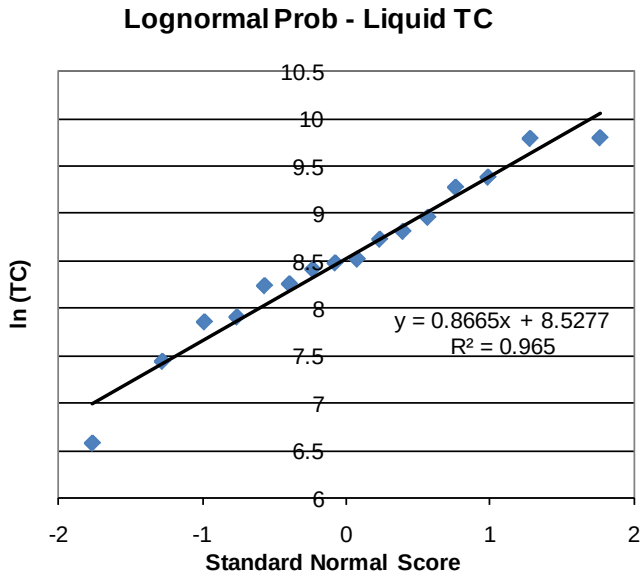


Figure D-16: Liquid Formulation Transfer Coefficient Lognormal Probability Plot

Table D-52: Available Exposure Study Identification Information	
Citation	Mester, T.C. (1998). Dermal Exposure and Inhalation Exposure to Carbaryl by Commercial Pet Groomers During Applications of Adams ™ Carbaryl Shampoo
EPA MRID	44658401
EPA Review	D287251
	Contractor (Versar, Inc.) review 12/4/98
MRID = Master Record Identification	

Study Description: 16 different commercial pet groomers were monitored while treating dogs with carbaryl, an active ingredient used to control fleas and ticks, using a ready-to-use (RTU) disposable shampoo bottle. Each application consisted of treating 8 dogs by soaking (2-3 minutes), treating with the shampoo, letting the shampoo sit for 5 minutes, then rinsing, drying and combing the dog. Application times for treating all 8 dogs ranged from 149 to 295 minutes and the amount of carbaryl applied ranged from approximately 0.0008 to 0.008 lbs. Dermal exposure was measured using inner whole body dosimetry (underneath pants, a short-sleeved shirt and a smock) and hand washes (no chemical-resistant gloves were worn). Inhalation exposure was measured using standard pumps (set at 1.5 liter per minute), cassettes, and tubing. Recoveries from field fortifications of exposure sampling matrices were generally above 80%.

Table D-53: MRID 44658401 TC Data Summary

Person ID	AaiH[1] (mg)	Total Dermal Exposure (mg)	Duration (hr)	Animal Surface Area (cm^2)	ai on Dog Available for Transfer[2] (mg/cm^2)	TC Adult[3] (cm^2/hr)	TC Child[4] (cm^2/hr)
1	2,290	15.4	2.88	31,603	0.00070	7,646	2,065
2	684	11.7	2.58	12,313	0.00053	8,498	2,294
3	916	2.6	3.07	28,726	0.00031	2,775	750
4	2,004	5.5	2.48	17,002	0.00113	1,959	530
5	1,641	10.4	3.08	26,067	0.00061	5,574	1,505
6	1,205	4.0	3.18	25,148	0.00046	2,722	735

Table D-53: MRID 44658401 TC Data Summary							
Person ID	**AaiH[1] (mg)**	**Total Dermal Exposure (mg)**	**Duration (hr)**	**Animal Surface Area (cm^2)**	**ai on Dog Available for Transfer[2] (mg/cm^2)**	**TC Adult[3] (cm^2/hr)**	**TC Child[4] (cm^2/hr)**
7	659	4.5	2.93	19,937	0.00032	4,810	1,299
8	373	5.1	2.72	24,210	0.00015	12,749	3,442
9	600	2.2	4.03	19,665	0.00029	1,861	503
10	1,747	27.9	3.88	30,047	0.00056	12,846	3,468
11	945	1.8	3.17	20,140	0.00045	1,230	332
12	3,720	15.0	4.05	31,231	0.00114	3,234	873
13	1,132	8.3	4.92	22,305	0.00049	3,456	933
14	1,148	8.6	3.45	15,911	0.00069	3,594	970
15	706	2.5	3.03	35,946	0.00019	4,430	1,196
16	1,929	1.4	3.00	20,140	0.00092	522	141

[1] Amount of active ingredient Handled.
[2] The total ai deposited on the dog (mg/cm^2) = AaiH (mg)/ Surface Area Animals (cm^2) * 0.0096 (0.96% is the arithmetic mean F_{AR} value which is applied to adjust the total amount of ai per surface area (mg/cm^2) on the dog to an amount estimated to be available for transfer).
[3] Adult TC = Total Dermal Exposure (mg) / (Duration (hr) * (ai on Dog Available for Transfer (mg/cm^2)).
[4] Child TC = Adult TC adjusted by 71% for reduction from adult to child mean surface areas.

Formulation: Solids

Application Method: Dusts and Powders

Table D-54: Adult and Child Transfer Coefficients for Solid Formulations		
Statistic	**Transfer Coefficent (cm^2/hour)[a,b]**	
	Adult	**1-2 years old**
50th percentile	120,000	31,000
75th percentile	170,000	47,000
95th percentile	310,000	84,000
99th percentile	470,000	130,000
99.9th percentile	740,000	200,000
AM (SD)	140,000 (92,000)	38,000 (25,000)
GM	120,000	31,000
GSD	1.82	1.82
Range	28,754-318,503	NA[c]
N	20	NA[c]

Notes:
a. Representative of individuals wearing short-sleeve shirts, shorts, and no chemical-resistant gloves.
b. Dermal solid formulation TC based on a lognormal distribution fit with data from MRID 44439901.
c. NA = Not applicable. Child values were derived by scaling adult data.

Each adult transfer coefficient was log-transformed and plotted to evaluate its fit to a lognormal distribution. The data appears to reasonably fit a lognormal distribution as shown in the figure below.

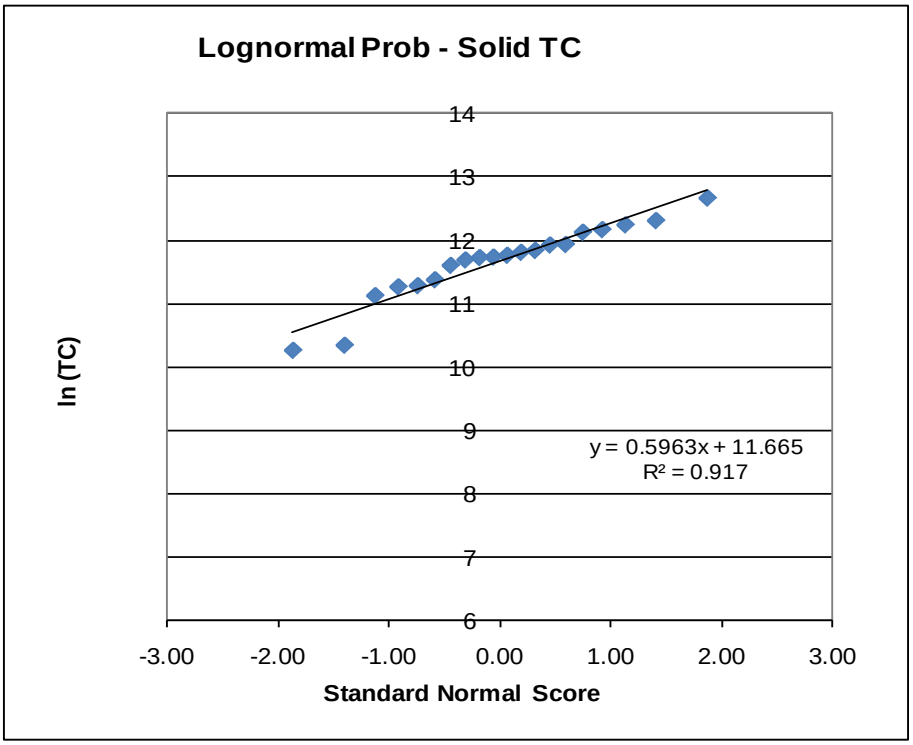


Figure D-17: Solid Formulation Transfer Coefficient Probability Plot

Table D-55: Available Exposure Study Identification Information	
Citation	Merricks, D. (1997) Carbaryl Applicator Exposure Study During Application of Sevin 5 Dust to Dogs by the Non Professional
EPA MRID	44439901
EPA Review	Contractor (Versar, Inc.) review
MRID = Master Record Identification	

Study Description: A total of 40 individuals – 20 with and 20 without chemical-resistant gloves – were monitored while applying a dust formulation (5% carbaryl) to dogs. Each application, lasting approximately 7 minutes, consisted of an individual using a 1 lb shaker can to apply an average of 0.15 lbs of dust (0.008 lbs carbaryl) to 3 dogs, then rubbing the dust into the dog's coat. Dermal exposure was measured using inner and outer whole body dosimetry and hand washes. Inhalation exposure was measured using standard pumps (set at 2 liter per minute), cassettes, and tubing. Recoveries from field fortifications of exposure sampling matrices were generally above 90%.

Table D-56: MRID 44439901 TC Data Summary							
Person ID	**AaiH[1] (mg)**	**Total Dermal Exposure (mg)**	**Duration (hr)**	**Animal Surface Area (cm^2)**	**ai on Dog Available for Transfer[2] (mg/cm^2)**	**TC Adult[3] (cm^2/hr)**	**TC Child[4] (cm^2/hr)**
3	1,361	30.1	0.13	12,921	0.0010	223,241	60,275
4	7,257	82.9	0.12	12,313	0.0057	125,492	33,883
7	3,629	10.9	0.22	19,801	0.0017	28,754	7,764

Table D-56: MRID 44439901 TC Data Summary							
Person ID	**AaiH[1] (mg)**	**Total Dermal Exposure (mg)**	**Duration (hr)**	**Animal Surface Area (cm^2)**	**ai on Dog Available for Transfer[2] (mg/cm^2)**	**TC Adult[3] (cm^2/hr)**	**TC Child[4] (cm^2/hr)**
8	1,814	24.6	0.12	10,670	0.0016	129,042	34,841
10	3,629	61.8	0.08	14,977	0.0023	318,503	85,996
13	907	8.15	0.12	15,526	0.00056	124,425	33,595
14	1,361	10.76	0.10	16,443	0.00079	135,237	36,514
16	3,175	18.73	0.13	19,044	0.0016	87,652	23,666
19	3,175	15.95	0.13	20,005	0.0015	78,403	21,169
20	5,443	104.8	0.17	11,598	0.0045	139,336	37,620
23	2,268	22.2	0.08	17,113	0.0013	208,691	56,347
24	9,979	84.4	0.08	18,342	0.0052	193,564	52,262
26	4,082	15.4	0.12	20,275	0.0019	68,208	18,416
29	454	5.9	0.08	11,416	0.00038	185,812	50,169
30	4,082	14.4	0.13	11,324	0.0035	31,148	8,410
33	6,804	31.5	0.12	26,680	0.0025	109,985	29,696
34	3,175	23.5	0.13	20,743	0.0015	119,847	32,359
36	2,722	23.4	0.08	14,255	0.0018	153,037	41,320
39	2,722	13.6	0.12	17,841	0.0015	79,794	21,544
40	1,814	13.9	0.08	15,911	0.0011	151,735	40,968

[1] Amount of active ingredient Handled.
[2] The total ai deposited on the dog (mg/cm^2) = AaiH (mg)/ Surface Area Animals (cm^2) * 0.0096 (0.96% is the arithmetic mean F_{AR} value which is applied to adjust the total amount of ai per surface area (mg/cm^2) on the dog to an amount estimated to be available for transfer).
[3] Adult TC = Total Dermal Exposure (mg) / (Duration (hr) * (ai on Dog Available for Transfer (mg/cm^2)).
[4] Child TC = Adult TC adjusted by 71% for reduction from adult to child mean surface areas.

Fraction of TC from Hands (Fai_{hands})

The TCs used to estimate post-application dermal exposure were developed using data from two studies representing application and grooming activities with dogs, as described in *Section 8.2.2, Post-Application Dermal Exposure Assessment*, of the Treated Pet Section. The TCs for solid and liquid pet pesticide formulations are based upon whole body exposure (mg a.i.) of the volunteers involved in the studies. In order to adjust dermal exposure (DE) to a value which is more representative of that anticipated for the children hands, a ratio of hand exposure to total body exposure (as measured in both studies) was performed. In addition, since child surface area is less than adults, hand surface area was adjusted using the method described in *Section 2.3*. The resulting values represent the fraction of a.i. from hands for solid and liquid formulations. *Table D-57* and *Table D-58* provide a summary Fai_{hands} liquid and solid formulation data values for use in child post-application incidental ingestion exposure assessment, respectively.

Table D-57: MRID 44658401 FAI hands Data Summary – Liquid Formulation				
Person ID	**AaiH[1] (mg)**	**Total Dermal Exposure (mg)**	**Hand Exposure (mg)**	**Fraction Total Dermal Exposure from Hands[2] ($F_{AI\ hands}$)**
1	2,290	15.4	0.29	0.019
2	684	11.7	0.18	0.015
3	916	2.6	0.13	0.051

4	2,004	5.5	0.25	0.045
5	1,641	10.4	0.12	0.012
6	1,205	4.0	0.16	0.041
7	659	4.5	0.082	0.018
8	373	5.1	0.11	0.020
9	600	2.2	0.062	0.028
10	1,747	27.9	0.47	0.017
11	945	1.8	0.29	0.17
12	3,720	15.0	0.15	0.0097
13	1,132	8.3	0.12	0.014
14	1,148	8.6	0.14	0.016
15	706	2.5	0.24	0.094
16	1,929	1.4	0.11	0.074
			Average	0.040

[1] Amount of active ingredient Handled
[2] Fraction Total Dermal Exposure from Hands (FAI_{hands}) = Hand Exposure/ Total Dermal Exposure

Table D-58: MRID 44439901 Fai_{hands} Data Summary – Solid Formulation

Person ID	AaiH[1] (mg)	Total Dermal Exposure (mg)	Hand Exposure (mg)	Fraction Total Dermal Exposure from Hands[2] (Fai_{hands})
3	1361	30.1	5.8	0.19
4	7257	82.9	12.5	0.15
7	3629	10.9	3.9	0.35
8	1814	24.6	5.4	0.22
10	3629	61.8	8.1	0.13
13	907	8.15	4.9	0.61
14	1361	10.76	4.5	0.42
16	3175	18.73	10.5	0.56
19	3175	15.95	11.6	0.73
20	5443	104.8	11.9	0.11
23	2268	22.2	7.3	0.33
24	9979	84.4	24.6	0.29
26	4082	15.4	4.4	0.28
29	454	5.9	3.9	0.65
30	4082	14.4	6.0	0.42
33	6804	31.5	5.1	0.16
34	3175	23.5	4.6	0.19
36	2722	23.4	6.8	0.29
39	2722	13.6	9.1	0.67
40	1814	13.9	7.7	0.55
			Average	0.37

[1] Amount of active ingredient Handled
[2] Fraction Total Dermal Exposure from Hands (Fai_{hands}) = Hand Exposure/ Total Dermal Exposure

D.8 Estimates for Residential Activity Duration

D.8.1 Gardens, Trees, and "Pick-your-own" Farms

Based on analysis of a residential survey (Johnson, et al., 1999) and the U.S. EPA's Exposure Factors Handbook 2011 Edition (U.S. EPA, 2011), considered the best available data sources for

this information, activity duration is presented below for similar activities conducted at home and at "pick-your-own" farms.

Home Activities

Activity durations for activities associated with gardens and trees at home were derived from a survey (Johnson, et al., 1999) and Tsang and Klepeis, 1996 (presented in 1997 EPA Exposure Factors Handbook; Vol. III, Table 15-62). While Tsang and Klepeis, 1996 includes information information on "time spent working with soil in a garden or other circumstances working" for all lifestages including youths, the data are presented as hours/month, thus difficult to interpret daily exposure times necessary for exposure assessments of short duration. The survey, on the other hand, asked about specific types of residential landscaping and maintenance activities and the amount of time an individual spends conducting such activities quantified in "hours per week" and "days per week". However, because this survey only included individuals 18 years or older, Tsang and Klepeis, 1996 was used to adjust these results for those under 18 years.

Johnson, et al., 1999 surveyed households regarding types of residential landscaping and maintenance activities and the amount of time an individual spends conducting such activities quantified in "hours per week" and "days per week". Though the survey did not ask for specific crop/activity durations (i.e., how long do you pick apples per day?) – which could potentially correspond to transfer coefficients from specific reentry exposure studies – the information on general activities can be used in conjunction with the composite transfer coefficients derived to represent broad categories of residential garden and tree activities. *Table D-59* and *Table D-60* below present a summary of the survey data.

Table D-59: Residential Gardens and Trees – Activity Duration (% response)

Activity	N	Hours per week										
		< 1	1	2	3	4-5	6-7	8-10	11-15	16-20	> 20	DNK
Vegetable Garden	364	0.1	15.1	13.5	11.9	14.7	8.8	6.7	4.2	2.6	2.1	20.2
Flower Garden	519	0.8	20.9	17.4	8.0	10.9	7.5	4.0	2.1	--	--	27.9
Roses	252	1.4	34.2	22.8	5.5	9.4	2.6	0.8	0.5	--	--	21.7
Shrubs/bushes	456	0.8	32.8	14.7	4.3	8.2	1.2	2.5	0.3	--	--	34.9
Fruit/Nut trees	123	0.8	24.9	6.5	3.8	12.7	3.0	3.4	1.3	--	--	41.9

Source: National Gardening Association Survey (Johnson, et al., 1999).
DNK = did not know

Table D-60: Residential Gardens and Trees – Activity Duration (% response)

Activity	N	Days per week								
		< 1	1	2	3	4	5	6	7	DNK
Vegetable Garden	364	0.2	17.4	22.2	15.3	7.7	11.3	3.9	10.3	11.9
Flower Garden	519	1.2	26.7	17.1	15.5	5.5	6.9	3.1	8.2	15.5
Roses	252	1.6	28.5	17.5	10.9	2.9	4.4	1.9	10.0	21.0
Shrubs/bushes	456	2.8	35.8	16.8	5.2	0.7	1.1	0.1	3.9	32.2
Fruit/Nut trees	123	2.4	22.8	13.0	5.2	1.0	1.7	2.3	6.7	43.7

Source: National Gardening Association Survey (Johnson, et al., 1999).
DNK = did not know

Exposure assessment values for "hours per day" had to be implicitly derived from the survey since responses were given only in "hours per week" and "days per week". To derive "hours per

day", the "hours per week" values were divided by 2 (i.e., 2 days per week). The survey showed that greater than 60% of respondents for most activities reported 1 – 3 days performing that activity per week. Therefore, normalizing the "hours per week" responses by a factor of 2 is not an unreasonable assumption to derive daily exposure times for the purposes of exposure assessment. Additionally, the responses were adjusted proportionally to the fraction who responded "did not know" (i.e., 21% of "did not know" responses were distributed equally amongst the other responses). The results for "hours per day" are shown in *Table D-61* below:

Table D-61: Residential Gardens and Trees – Activity Duration (% response)[1]

Activity	Hours per day[2]									
	< 0.5	0.5	1	1.5	2-2.5	3-3.5	4-5	5.5-7.5	8-10	> 10
Vegetable Garden	0.13	18.9	16.9	14.9	18.4	11.0	8.4	5.3	3.3	2.6
Flower Garden	1.1	29.2	24.3	11.2	15.2	10.5	5.6	2.9	--	--
Roses	1.8	44.3	29.5	7.1	12.2	3.4	1.0	0.65	--	--
Shrubs/bushes	1.2	50.6	22.7	6.6	12.7	1.9	3.9	0.46	--	--
Fruit/Nut trees	1.4	44.1	11.5	6.7	22.5	5.3	6.0	2.3	--	--

[1] Percent responses adjusted proportionally per activity's "did not know".
[2] Hours per day derived by dividing "hours per week" values by 2.
Source: National Gardening Association Survey (Johnson, et al., 1999).
DNK = did not know

After calculating "hours per day", the responses, given as percentages, were used in conjunction with the upper bound of each range to derive cumulative percentile distributions. The distributions were truncated at 16 hours per day to subtract for 8 hours of sleep. Also, note that vegetable gardening was the only activity with results reported for "8-10" and "> 10" hours per week (derived from 16-20 and > 20 hours per week). *Table D-62* below presents the cumulative percentiles for each activity.

Table D-62: Cumulative Percentile Distributions for Activity Durations for Gardens and Trees

Activity Duration (hrs/day)	Cumulative %tiles				
	Vegetable Gardening	Flower Gardening	Roses	Shrubs/Bushes	Fruit/Nut Trees
0	0	0	0	0	0
0.5	19	30	46	52	46
1	36	55	76	75	57
1.5	51	66	83	81	64
2.5	69	81	95	94	86
3.5	80	91	98	96	92
5	89	97	99	99.5	97
7.5	94	99	99.5	99.9	99
10	97	--	--	--	--
16	100	100	100	100	100

Note: Vegetable gardening was the only activity with results reported for "8-10" and "> 10" hours per week (derived from 16-20 and > 20 hours per week), thus the upper bound reported value for all activities except for vegetable gardening is 7.5 hours per day.

Next, custom cumulative distributions were constructed for gardens and trees, respectively. The distribution for activities in gardens was constructed by combining, via a 5000 trial Monte Carlo simulation, the cumulative distributions for each vegetable gardening and flower gardening in equal proportion (i.e., 50% each). The distribution for activities in trees was derived similarly

with the cumulative distributions for each roses, shrubs/bushes, and fruit/nut trees used in equal 33% proportions.

Probability and cumulative density functions are provided in the figures below. A statistical summary follows in *Table D-63*.

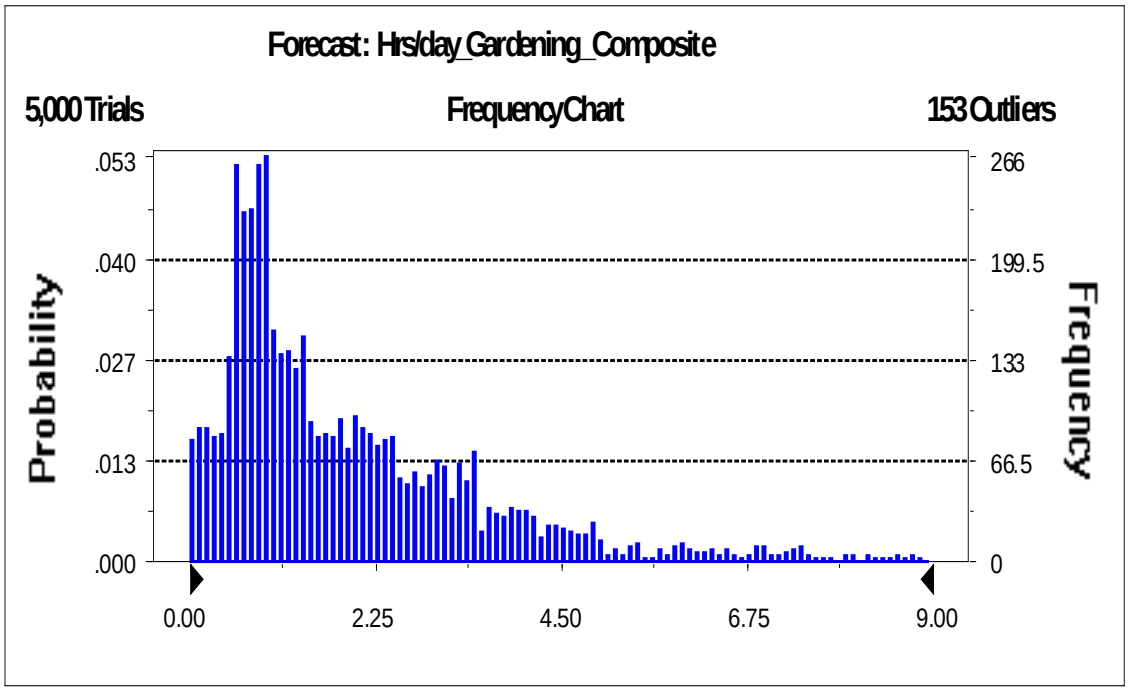


Figure D-16: Gardening Exposure Duration – Composite Probability Density Function Simulation

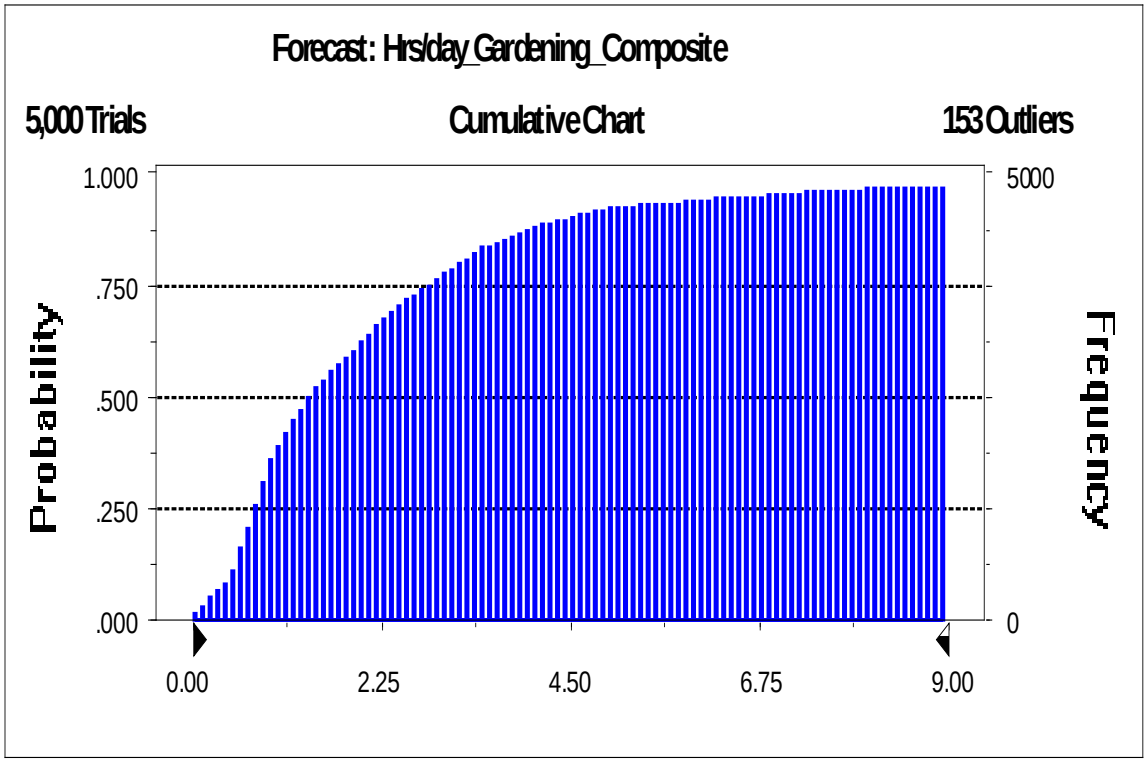


Figure D-17: Gardening Exposure Duration – Composite Cumulative Density Function Simulation

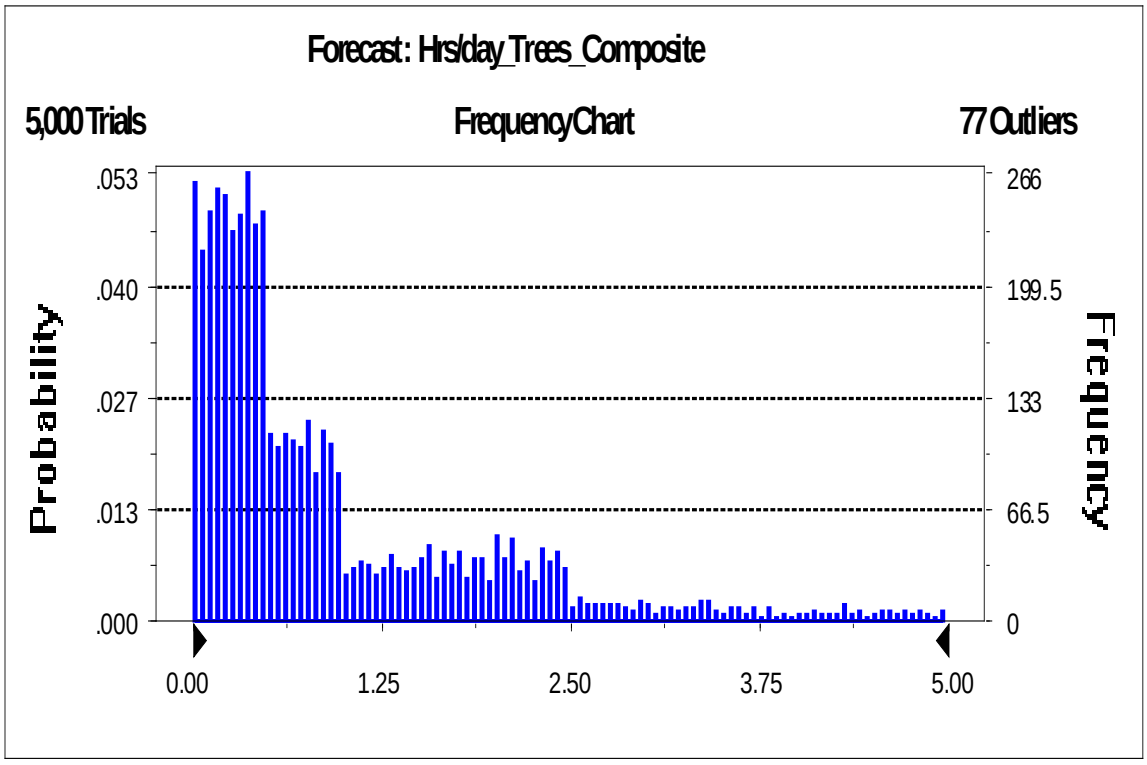


Figure D-20: Trees Exposure Duration – Composite Probability Density Function Simulation

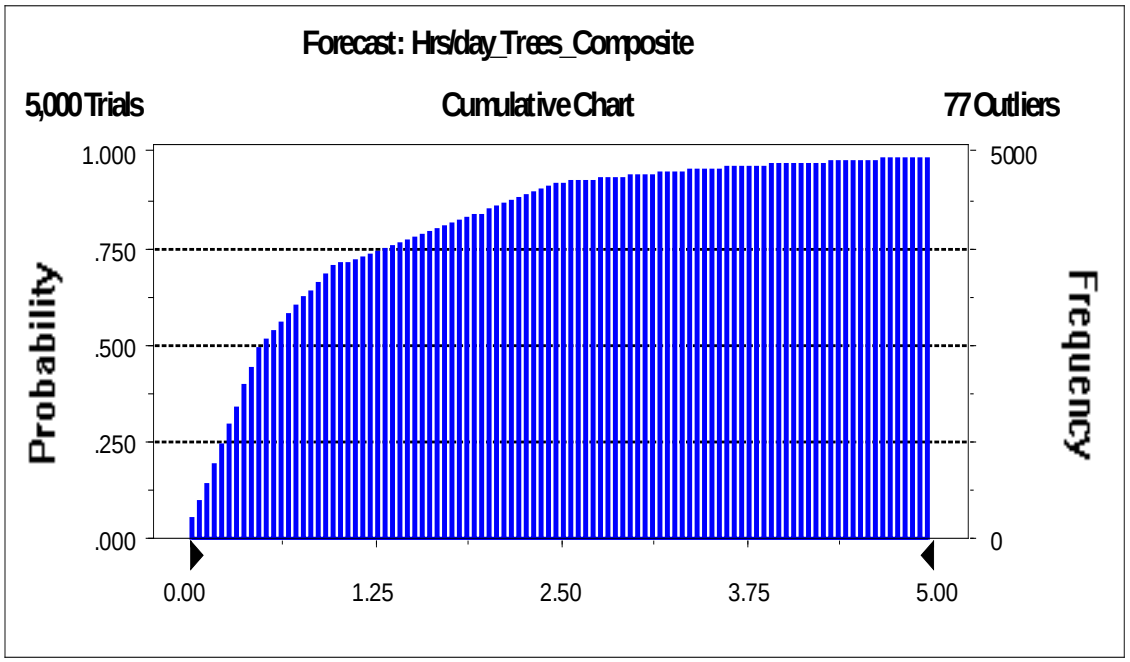


Figure D-21: Trees Exposure Duration – Composite Cumulative Density Function Simulation

Next, because the survey included only those older than 18, Tsang and Klepeis, 1996 (presented in 1997 EPA Exposure Factors Handbook; Vol. III, Table 15-62) was used to adjust this data for youths conducting similar activities. Tsang and Klepeis, 1996 (presented in 1997 EPA Exposure Factors Handbook; Vol. III, Table 15-62) provides distributions for "time spent working with soil in a garden or other circumstances" in hours per month. Comparing the distributions, it is apparent that adults spend approximately twice the amount of time as youths for this scenario. *Table D-63* below presents these datasets.

Table D-63: Adult to Youth Activity Duration Ratios from Tsang and Klepeis, 1996 (presented in 1997 EPA Exposure Factors Handbook; Vol. III, Table 15-62)

Percentile	5	10	25	50	75	90	95	98	99
Adults (18-64 yrs.)	0	0	0	0	3	16	40	90	200
Youths (5-11 yrs.)	0	0	0	0	2	10	20	50	60
Adult:Youth Ratio	NA	NA	NA	NA	1.5	1.6	2	1.8	3.3

Using the survey information from Johnson, et al., 1999 and Tsang and Klepeis, 1996, a statistical summary of activity durations associated with gardens and trees at home are presented below.

Table D-64: Home Gardens and Trees – Activity Duration (hrs/day) Statistical Summary

Statistic	Vegetable and Flower Gardens		Fruit, Nut, and Ornamental Trees/Bushes/Shrubs and Indoor Plants	
	Adults	Youths	Adults	Youths
Mean	2.2	1.1	1.0	0.5

Table D-64: Home Gardens and Trees – Activity Duration (hrs/day) Statistical Summary				
Statistic	**Vegetable and Flower Gardens**		**Fruit, Nut, and Ornamental Trees/Bushes/Shrubs and Indoor Plants**	
	Adults	**Youths**	**Adults**	**Youths**
50th percentile	1.4	0.7	0.5	0.25
75th percentile	2.9	1.5	1.4	0.7
90th percentile	4.5	2.3	2.4	1.2
95th percentile	6.9	3.5	3.4	1.7
99th percentile	13	6.5	6.3	3.2
99.9th percentile	16	8	15	7.5
Notes: - Distributions are truncated at 16 hours per day. - Durations for youths derived as ½ that of adult activity durations.				

"Pick-your-own" Farms

Activities at "pick-your-own" farms are likely to be similar to those conducted at home (e.g., picking fruits), however the duration of the activities are likely to be different since people and families are away from their home and likely at the farm for recreation. Tsang and Klepeis, 1996 (presented in the 1997 EPA Exposure Factors Handbook; Vol. III Table 15-112) includes data for the amount of time "spent outdoors at a farm" and is considered a reasonable surrogate for time spent at a "pick-your-own" farm. The data indicates that adults ages 18-64 ranged from 5 minutes to 16 hours per day while youths aged 5-11 ranged from 25 minutes to 4.4 hours per day. Unlike the survey for home activities, it is possible to differentiate between adults and youths. The summary statistics are provided below in *Table D-65*.

Table D-65: Time Spent at "Pick-your-own" Farms (hrs/day) Statistical Summary											
Lifestage	**Age (years)**	**Statistics**									
		N	**Mean**	**Summary Percentiles**							
				5	**25**	**50**	**75**	**90**	**95**	**98**	**99**
Adults	18-64	91	5.0	0.3	1.3	3.8	8.3	10.6	13.0	15.6	15.9
Youths	5-11	7	1.9	0.4	0.8	1.7	2.2	4.4	4.4	4.4	4.4
Source: Tsang and Klepeis, 1996 (presented in the 1997 EPA Exposure Factors Handbook; Vol. III Table 15-112)											

D.8.2 Treated Pets

Exposure Time (ET)

The exposure time (ET) for adults and children were derived from Tsang and Klepeis, 1996 (as presented in 1997 Exposure Factors Handbook Table 15-77) and summarized in Tables D-67 and D-68 below. Animal care is defined in the 1997 Exposure Factors Handbook as "care of household pets including activities with pets, playing with the dog, walking the dog and caring for pets of relatives, and friends." The data identified the time spent with an animal while performing household activities as recorded in 24 hour diaries by study volunteers. The defined activities may not necessarily represent the time volunteers were actively engaged in constant contact with the animal. However, HED conservatively assumes that the exposure times recorded represent continual contact. This assumption is implicit in the formulas used to assess

post-application dermal and incidental oral routes of exposure for children 1 < 2 and adults 16 < 80 years old.

Table D-66: Daily Exposure Time (ET) with Pets (Children 1 < 2 years old)	
Statistic	**Time (hours)**
5th percentile	0.05
25th percentile	0.5
50th percentile	1.0
75th percentile	1.5
90th percentile	2.3
95th percentile	2.3
AM (SD)	1.0 (0.74)
AM (SD) = arithmetic mean (standard deviation)	

Table D-67: Daily Exposure Time (ET) with Pets (Adults)	
Statistic	**Time (hours)**
5th percentile	0.05
25th percentile	0.17
50th percentile	0.5
75th percentile	1.0
90th percentile	1.8
95th percentile	2.5
AM (SD)	0.77 (1.1)
AM (SD) = arithmetic mean (standard deviation)	

D.9 Estimates of Hand-to-Mouth Events per Hour

Frequency of hand-to-mouth events is an important variable for hand-to-mouth Post-application exposure assessments. Data on the frequency of hand-to-mouth events are limited and difficult to collect. The generic estimates for frequency of hand-to-mouth events are based on the Xue et al. (2007) meta-analysis. This article examined hand-to-mouth frequency data from 9 available studies representing 429 subjects and more than 2,000 hours of behavior observation. Results of this analysis indicate that age and location are important for hand-to-mouth frequency, but study and gender are not. In fact, hand-to-mouth frequency is significantly greater indoors than outdoors. As a result, hand-to-mouth frequency for outdoor environments is presented in this Appendix separately from hand-to-mouth frequency for indoor environments.

D.9.1 Outdoors - Turf

The index lifestage assessed for hand-to-mouth activity for the outdoor environment is the children 1 < 2 years old lifestage. The estimates of hand mouthing frequency (events/hour) for children 1 < 2 years old were derived from 4 studies representing 32 participants. *Table D-68* provides the raw data.

Table D-68: Outdoor-Turf Hand-to-Mouth Frequency Data			
ID	**Study**	**Age (years)**	**Hand-to-Mouth Frequency (events/hr)**
315M12	Beamer et al., 2008[1]	1	1
081F13		1.13	18
764M20		1.666667	22
328F22		1.833333	2
768M23		1.916667	7
681M23		1.916667	26
453F01	Leckie, 2002[2]	1	2
550M01		1	2
248M01		1	23
958F01		1	57
id104	Tulve et al., 2002[3]	1.166667	0
id104		1.166667	6
id104		1.166667	12
id194		1.25	8
id120		1.75	17
id190		1.75	20
id190		1.75	35
id764		1.833333	8
id150		1.833333	10
id764		1.833333	17
id012	Black et al., 2005[4]	1	3
id014		1	7
id015		1	42
id020		1.166667	5
id019		1.166667	7
id023		1.333333	1
id024		1.416667	39
id025		1.5	4
id026		1.583333	15
id027		1.666667	8
id029		1.75	5
id030		1.833333	16

[1] Beamer, P., Key, M.E., Ferguson, A.C., Canales, R.A., Auyeung, W., Leckie, J.O. (2008). Time Activity Assessment of Young Farmworker Children in California. In revision, *Journal of Environmental Research*.

[2] Greene, M.A. (2002). Mouthing times among young children from observational data. U.S. Consumer Product Safety Commission, Bethesda, MD.

[3] Tulve, N., Suggs, J., McCurdy, T., Cohen Hubal, E., & Moya, J. (2002). Frequency of mouthing behavior in young children. *Journal of Exposure Analysis and Environmental Epidemiology*, *12*(4), 259–264.

[4] Black, K., Shalat, S. L., Freeman, N. C. G., Jimenez, M., Donnelly, K. C., & Calvin, J. A. (2005). Children's mouthing and food handling behavior in an agricultural community on the U.S./Mexico border. *Journal of Exposure Analysis and EnvironmentalEpidemiology*, *15*, 244–251.

D.9.2 Indoor

The index lifestage assessed for hand-to-mouth activity for the indoor environment is the children 1 < 2 years old lifestage. The estimates of hand mouthing frequency (events/hour) for children 1 < 2 years old were derived from 5 studies representing 243 participants. *Table D-69* provides the raw data.

Table D-69: Indoor Hand-to-Mouth Frequency Data

ID	Study	Age (years)	Hand-to-Mouth Frequency (events/hr)
Children 1 < 2 years old			
315M12	Beamer et. al, in prep[1]	1	15
081F13		1	48
764M20		2	63
674F22		2	14
328F22		2	35
768M23		2	29
681M23		2	30
00201136	Greene, 2002[2]	1	50
00201136		1	82
00206446		1	13
00206446		1	20
TXK16769		1	20
TXK16769		1	31
00206443		1	4
TXK31661		1	15
00206443		1	17
TXK31661		1	31
ILK34447		1	24
ILK34447		1	24
ILK67031		1	5
ILK67031		1	13
ILK66422		1	36
ILK66422		1	63
TXK24860		1	7
TXK24860		1	22
ILK37758		1	10
ILK37758		1	40
ILK51607		1	5
ILK51607		1	13
ILK92729		1	22
ILK92729		1	68
TXK37439		1	4
TXK37439		1	11
00204534		1	7
00204534		1	10
ILK98213		1	32
ILK98213		1	43

Table D-69: Indoor Hand-to-Mouth Frequency Data			
ID	**Study**	**Age (years)**	**Hand-to-Mouth Frequency (events/hr)**
ILK83625		1	7
ILK83625		1	11
ILK93446		1	14
ILK93446		1	23
ILK44904		1	9
ILK44904		1	32
TXK12275		1	24
TXK12275		1	63
00203429		1	0
00203429		1	2
ILK63757		1	4
ILK63757		1	15
TXK10932		1	4
TXK10932		1	24
ILK92658		1	3
ILK92658		1	15
ILK64770		1	0
ILK64770		1	25
IL106650		1	3
IL106650		1	5
TXK47553		1	21
TXK47553		1	35
TXK15447		1	16
TXK15447		1	22
TXK57344		1	12
TXK57344		1	47
TXK39510		1	34
TXK39510		1	53
TXK03500		1	22
TXK03500		1	27
TXK15315		1	7
TXK15315		1	23
TXK34418		1	7
TXK34418		1	21
TXK14690		1	6
TXK14690		1	27
ILK39523		1	5
ILK39523		1	10
ILK88461		1	4
ILK88461		1	5
ILK43787		1	12
ILK43787		1	28
ILK91233		1	0
ILK91233		1	0
TXK02791		1	12
TXK02791		1	43

Table D-69: Indoor Hand-to-Mouth Frequency Data			
ID	**Study**	**Age (years)**	**Hand-to-Mouth Frequency (events/hr)**
00200973		2	1
00200973		2	6
TXK04568		2	39
TXK04568		2	78
TXK36066		2	14
TXK36066		2	17
IL105497		2	27
IL105497		2	65
ILK55650		2	4
ILK55650		2	6
TXK54694		2	18
TXK54694		2	33
ILK96974		2	6
ILK96974		2	17
ILK90093		2	4
ILK90093		2	9
ILK41454		2	2
ILK41454		2	8
TXK49183		2	4
TXK49183		2	8
ILK95130		2	3
ILK95130		2	29
ILK48848		2	1
ILK48848		2	3
TXK29304		2	17
TXK29304		2	31
ILK75432		2	0
ILK75432		2	0
ILK86318		2	11
ILK86318		2	36
ILK83808		2	107
ILK83808		2	113
IL104760		2	0
IL104760		2	8
ILK82433		2	3
ILK82433		2	21
ILK87131		2	15
ILK87131		2	23
ILK81166		2	2
ILK81166		2	8
00200925		2	17
00200925		2	24
TXK57947		2	1
TXK57947		2	15
ILK52051		2	0
ILK52051		2	10

Table D-69: Indoor Hand-to-Mouth Frequency Data			
ID	**Study**	**Age (years)**	**Hand-to-Mouth Frequency (events/hr)**
ILK49347		2	7
ILK49347		2	21
TXK36720		2	11
TXK36720		2	24
TXK28972		2	11
TXK28972		2	37
ILK52599		2	56
ILK52599		2	80
id890		1	0
id876		1	2
id876		1	3
id876		1	4
id932		1	5
id932		1	8
id187		1	9
id932		1	10
id975		1	10
id876		1	15
id890		1	18
id890		1	24
id932		1	24
id975		1	30
id975		1	30
id187		1	38
id975		1	41
id187		1	87
id126	Tulve et al., 2002[3]	1	5
id126		1	14
id126		1	19
id126		1	23
id167		1	0
id711		1	5
id104		1	7
id711		1	10
id711		1	18
id167		1	19
id711		1	20
id167		1	32
id167		1	32
id705		1	10
id162		1	12
id705		1	14
id705		1	18
id705		1	20
id162		1	24

Table D-69: Indoor Hand-to-Mouth Frequency Data			
ID	**Study**	**Age (years)**	**Hand-to-Mouth Frequency (events/hr)**
id194		1	28
id194		1	29
id162		1	32
id194		1	37
id162		1	72
id101		1	0
id101		1	0
id122		1	0
id101		1	2
id101		1	3
id837		1	3
id837		1	5
id723		1	6
id837		1	8
id723		1	11
id122		1	14
id122		1	16
id122		1	24
id837		1	24
id132		2	37
id132		2	54
id768		2	38
id768		2	62
id768		2	108
id108		2	2
id108		2	3
id108		2	4
id108		2	4
id190		2	9
id120		2	10
id190		2	11
id120		2	24
id150		2	0
id150		2	0
id103		2	12
id103		2	24
id103		2	27
id150		2	27
id764		2	29
id103		2	30
id110		2	0
id748		2	0
id748		2	4
id748		2	6
id748		2	7

Table D-69: Indoor Hand-to-Mouth Frequency Data			
ID	**Study**	**Age (years)**	**Hand-to-Mouth Frequency (events/hr)**
id110		2	16
id110		2	32
id012	Black et al., 2005[4]	1	5
id015		1	11
id013		1	21
id014		1	35
id018		1	4
id017		1	16
id016		1	29
id019		1	23
id020		1	26
id022		1	9
id021		1	13
id023		1	7
id024		1	21
id025		2	36
id026		2	14
id027		2	12
id028		2	8
id029		2	18
id030		2	24
id031		2	10
r208	Reed et al., 1999[5]	2	11
r201		2	0

[1] Beamer, P., Key, M. E., Ferguson, A. C., Canales, R. A., Auyeung, W., & Leckie, J. O. (in preparation). Time activity assessment of young farmworker children in California.
[2] Greene, M.A. (2002). Mouthing times among young children from observational data. U.S. Consumer Product Safety Commission, Bethesda, MD.
[3] Tulve, N., Suggs, J., McCurdy, T., Cohen Hubal, E., & Moya, J. (2002). Frequency of mouthing behavior in young children. *Journal of Exposure Analysis and Environmental Epidemiology*, *12*(4), 259–264.
[4] Black, K., Shalat, S. L., Freeman, N. C. G., Jimenez, M., Donnelly, K. C., & Calvin, J. A. (2005). Children's mouthing and food handling behavior in an agricultural community on the U.S./Mexico border. *Journal of Exposure Analysis and EnvironmentalEpidemiology*, *15*, 244–251.
[5] Reed, K. J., Jimenez, M., Freeman, N. C. G., & Lioy, P. J. (1999). Quantification of children's hand and mouthing activities through a videotaping methodology. *Journal of Exposure Analysis and Environmental Epidemiology*, *9*, 513–520.

D.9.3 Pets

There are currently no data available that specifically address the number of hand-to-mouth events that occur relative to the amount of time a child spends with a pet. As a result, the estimates for frequency of hand-to-mouth events in indoor environments from the Xue et al. (2007) meta-analysis were used as a surrogate. This article examined hand-to-mouth frequency data from 9 available studies representing 429 subjects and more than 2,000 hours of behavior observation. Results of this analysis indicate that age and location are important for hand-to-

mouth frequency, but study and gender are not. In fact, hand-to-mouth frequency is significantly greater indoors than outdoors. As a result, hand-to-mouth frequency for indoor environments was selected for risk analysis of children indoor ingestion from treated pets.

Since the indoor environment data used are not specific to the pet SOP, raw data from the studies and resulting statistical analysis can be found in *D.9.2* of the Appendix.

D.10 Estimates of Object-to-Mouth Events per Hour

Frequency of object-to-mouth events is an important variable for object-to-mouth post-application exposure assessments. Data on the frequency of object-to-mouth events are limited and difficult to collect. The generic estimates for frequency of hand-to-mouth events are based on the Xue et al. (2010) meta-analysis. This article examined object-to-mouth frequency data from 7 available studies representing 438 participants and ~1500 hours of behavior observation. Results of this analysis indicate that age and location are important for object-to-mouth frequency. In fact, object-to-mouth frequency is significantly greater indoors than outdoors. As a result, object-to-mouth frequency for outdoor environments is presented in this Appendix separately from object-to-mouth frequency for indoor environments.

D.10.1 Outdoors - Turf

The index lifestage assessed for object-to-mouth activity for the outdoor environment is the children 1 < 2 years old lifestage. The estimates of object mouthing frequency (events/hour) for children 1 < 2 years old were derived from 3 studies representing 21 participants. *Table D-70* provides the raw data.

Table D-70: Outdoor-Turf Object-to-Mouth Frequency Data

ID	Study	Age (years)	Object-to-Mouth Frequency (events/hr)
id021	AuYeung et al., 2004[1]	1.2	10
id022		1.3	4
id012		1.4	17
id004		1.5	1
id001		1.5	8
id013		1.6	4
id023		1.6	9
315M12	Beamer et al., 2008[2]	1	11
328F22		1.833333	3
681M23		1.916667	5
768M23		1.916667	21
104	Tulve et al., 2002[3]	1.166667	0
104		1.166667	0
104		1.166667	14
194		1.25	5
190		1.75	6
120		1.75	8
190		1.75	14

150		1.833333	3
764		1.833333	4
764		1.833333	38

[1] AuYeung, W., Canales, R.A., Beamer, P., Ferguson, A.C., Leckie, J.O. (2004). Young Children's Mouthing Behavior: An Observational Study via Videotaping in a Primarily Outdoor Residential Setting. *Journal of Children's Health*, *2*(3-4), 271-295.
[2] Beamer, P., Key, M.E., Ferguson, A.C., Canales, R.A., Auyeung, W., Leckie, J.O. (2008). Time Activity Assessment of Young Farmworker Children in California. In revision, *Journal of Environmental Research*.
[3] Tulve, N., Suggs, J., McCurdy, T., Cohen Hubal, E., & Moya, J. (2002). Frequency of mouthing behavior in young children. *Journal of Exposure Analysis and Environmental Epidemiology*, *12*(4), 259–264.

D.10.2 Indoors

The index lifestage assessed for object-to-mouth activity for the indoor environment is the children 1 < 2 years old lifestage. The estimates of object mouthing frequency (events/hour) for children 1 < 2 years old were derived from 4 studies representing 137 participants. *Table D-71* provides the raw data.

Table D-71: Indoor Object-to-Mouth Frequency Data

ID	Study	Age (years)	Object-to-Mouth Frequency (events/hr)
Children 1 < 2 years old			
id001	AuYeung et al., 2004[1]	2	11
315M12	Beamer et al., 2008[2]	1	32
081F13		1	32
764M20		2	29
328F22		2	11
674F22		2	21
681M23		2	18
768M23		2	44
00501670	Green, 2002[3]	1	0
00501670		1	3
00206446		1	6
00206446		1	9
IL101540		1	11
TXK04115		1	18
00201136		1	19
ILK67044		1	21
ILK67044		1	25
00201136		1	25
TXK04115		1	26
IL101540		1	34
ILK54587		1	49
ILK54587		1	67
ILK67031		1	6
ILK66422		1	8

Table D-71: Indoor Object-to-Mouth Frequency Data			
ID	Study	Age (years)	Object-to-Mouth Frequency (events/hr)
ILK92729		1	9
TXK31661		1	10
TXK24860		1	10
TXK31661		1	11
ILK51607		1	12
TXK16769		1	14
ILK67031		1	14
ILK66422		1	16
ILK51607		1	16
ILK92729		1	18
TXK37439		1	18
00206443		1	19
TXK37439		1	19
TXK16769		1	22
ILK34447		1	22
ILK37758		1	25
TXK24860		1	26
ILK34447		1	33
00206443		1	38
ILK37758		1	41
00203429		1	6
ILK98213		1	6
00203429		1	6
ILK98213		1	7
ILK63757		1	8
ILK63757		1	8
00204534		1	11
TXK12275		1	11
00204534		1	14
ILK83625		1	16
ILK83625		1	16
ILK44904		1	17
ILK44904		1	19
TXK10932		1	19
ILK93446		1	21
TXK10932		1	21
ILK93446		1	27
TXK12275		1	32
ILK92658		1	2
TXK47553		1	3
ILK92658		1	5
IL106650		1	6
IL106650		1	6
TXK47553		1	7
TXK57344		1	11
TXK15447		1	12

Table D-71: Indoor Object-to-Mouth Frequency Data			
ID	Study	Age (years)	Object-to-Mouth Frequency (events/hr)
TXK57344		1	12
ILK64770		1	12
TXK15447		1	13
ILK64770		1	15
TXK39510		1	18
TXK39510		1	19
ILK88461		1	1
TXK15315		1	3
TXK15315		1	3
ILK88461		1	5
ILK39523		1	6
TXK34418		1	9
TXK03500		1	11
TXK14690		1	12
TXK34418		1	13
ILK39523		1	14
TXK14690		1	18
TXK03500		1	18
ILK43787		1	21
ILK43787		1	23
ILK91233		2	1
ILK91233		2	4
00200973		2	10
00200973		2	10
TXK04568		2	10
TXK02791		2	15
TXK04568		2	16
TXK02791		2	26
ILK90093		2	2
ILK95130		2	3
ILK95130		2	5
TXK49183		2	5
TXK49183		2	6
TXK36066		2	7
ILK96974		2	8
IL105497		2	8
ILK90093		2	9
ILK41454		2	10
ILK55650		2	12
TXK36066		2	12
ILK41454		2	14
ILK96974		2	14
TXK54694		2	16
TXK54694		2	17
IL105497		2	34
ILK55650		2	38

Table D-71: Indoor Object-to-Mouth Frequency Data			
ID	Study	Age (years)	Object-to-Mouth Frequency (events/hr)
IL104760		2	1
ILK75432		2	2
ILK75432		2	2
IL104760		2	3
TXK29304		2	5
TXK29304		2	7
ILK86318		2	10
ILK48848		2	14
ILK83808		2	17
ILK48848		2	19
ILK83808		2	23
ILK86318		2	28
00200925		2	2
ILK81166		2	5
TXK57947		2	8
ILK82433		2	15
TXK57947		2	15
00200925		2	17
ILK87131		2	17
ILK82433		2	20
ILK81166		2	21
ILK87131		2	25
ILK52051		2	7
ILK52051		2	15
ILK49347		2	19
ILK49347		2	31
r208	Tulve et al., 2002[4]	2	2
r201		2	0
890		1	9
876		1	18
932		1	19
876		1	21
932		1	24
876		1	33
932		1	34
187		1	41
975		1	45
975		1	50
890		1	58
890		1	58
876		1	69
187		1	84
187		1	84
932		1	89
975		1	90
975		1	112

Table D-71: Indoor Object-to-Mouth Frequency Data			
ID	Study	Age (years)	Object-to-Mouth Frequency (events/hr)
126		1	36
126		1	38
126		1	62
126		1	73
711		1	12
104		1	17
711		1	32
167		1	37
167		1	51
711		1	54
167		1	67
167		1	72
711		1	87
705		1	17
194		1	24
705		1	30
194		1	31
162		1	43
162		1	45
194		1	47
705		1	48
705		1	72
162		1	98
162		1	204
101		1	0
101		1	0
122		1	0
101		1	10
837		1	10
101		1	24
837		1	27
122		1	28
837		1	36
723		1	38
122		1	50
837		1	54
122		1	62
723		1	72
132		2	32
132		2	59
768		2	22
768		2	24
768		2	53
108		2	7
190		2	18
108		2	19

Table D-71: Indoor Object-to-Mouth Frequency Data			
ID	Study	Age (years)	Object-to-Mouth Frequency (events/hr)
108		2	20
190		2	31
108		2	40
120		2	41
120		2	120
150		2	2
103		2	8
764		2	21
150		2	68
150		2	75
103		2	82
103		2	96
103		2	147
748		2	2
748		2	6
748		2	24
748		2	54
110		2	60
110		2	64
110		2	81

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D.11 Insect Repellent Application Rates

Background on Repellent Efficacy Studies

Efficacy studies are required as part of the registration process for insect repellent products. Efficacy studies with dosimetry determination are available for aerosols, pump sprays, lotions, and towelettes – formulations that comprise the vast majority of repellent products. These studies are useful in determining an application rate estimate for some repellent exposure scenarios, and have been included in this SOP.

Some insect repellent efficacy studies incorporate "dosimetry determination" that can be used as application rates in the form "mass repellent product per square centimeter of skin". Rates in this form can then be extrapolated to the rest of the body for different application scenarios (e.g., weather, location, etc.) to estimate a total body application. "Dosimetry determination" in efficacy studies is used to determine the dosing rate of repellent products when tested for

efficacy under laboratory and field conditions. For an insect repellent to perform as claimed on the label, a certain concentration of the chemical and thorough coverage of the exposed area is essential. Dosimetry is conducted using 10-12 adult subjects, both males and females. The process starts by designating an area to treat (cm^2) by measuring the length and circumference of the forearm and/or lower leg. Then the test subjects are given a copy of the instructions (part of the label of the proposed product) along with a product sample. After they become familiar with the instructions and the product's formulation and package they will practice treating themselves. During the practice session, a technician will show each test subject how to treat the forearm or leg with the test product to thoroughly and evenly cover the measured area without wasting the product and each test subject practices the treatment the way he/she would use the product under the actual use conditions. Then each subject performs three applications of the product which is measured and reported in mass product per skin surface area.

Because there is large variation in the applied rate of repellent products by the consumers, dosimetry is used to capture that variability – a rate based on these consumer applications is then used as the amount applied during the efficacy trial portion of the study. Besides determining a rate to use in an efficacy trial however, the dosimetry aspect provides an estimate of the actual amount of product applied to a treatment area and also permits statistical analysis to capture the range of application rates individuals will apply for certain types of products. As previously stated, a product-specific estimate of the total amount of repellent applied to the entire body (e.g., total mass per application) would be the most accurate measure of repellent applications. However, absent this kind of information, an extrapolation to the whole body from the dosimetry estimates in these efficacy studies provide the most reliable available application estimates.

The following sections provide an analysis of the dosimetry determination components of various efficacy studies for the purposes of generating product-specific application rates for use in estimating exposure to insect repellents.

Variable AR_F: Formulation-specific application rate (mg product/cm^2skin)

Several efficacy studies on insect repellents of different formulations have been submitted to the Agency and are available for analysis. These studies have been reviewed by OPP and the Human Studies Review Board. Each study used in the creation of this SOP has been found to be acceptable under both GLP and HSRB guidelines.

Aerosols

When aerosol (or pump spray) formulations are tested, the delivered quantity of spray is measured using dosimeter patches (i.e., four 1-inch wide strips of 3M Brand Nexcare Holdfast self adhesive roll gauze) placed strategically on the forearm or leg to intercept a portion of the spray applied which is then extrapolated to the rest of the treated area. Before each spray trial, a technician custom fits the four narrow rings of plastic-backed gauze patches around each person's forearm or leg. The dosimeters are narrow to minimize the extent to which the sensation of the spray falling on the bare skin is altered. For each treatment, there are 4 dosimeters per limb totaling 24 if both limbs are used.

The amount of product captured by each dosimeter patch is determined by the weight difference before and after application. The total captured by all 4 patches (1 inch wide) per trial is added

and then any weight gain or loss in the paired control dosimeters is corrected to obtain a net total weight gain. The total weight of applied product per treated area was calculated by the following algorithm:

$$AR = \frac{\frac{DW}{SD} * LT}{AT}$$

where:

AR	= Application rate of spray product (g /cm^2);
AT	= Area treated, leg or forearm (cm^2);
DW	= Weight of product captured by 4 dosimeters (g);
LT	= Length of treated area, leg or forearm (cm); and
SD	= Total width of 4 dosimeter patches (10.16 cm).

Application rate data from two efficacy studies (EPA MRID 47049501 and 47049502), both measuring the repellent product IR 3535 which contains 20% ai in aerosol form, were available for analysis. Application rates, as measured using the dosimetry determination outlined above, ranged from 0.17 to 3.5 mg aerosol per cm^2 of skin. A lognormal probability plot is presented below.

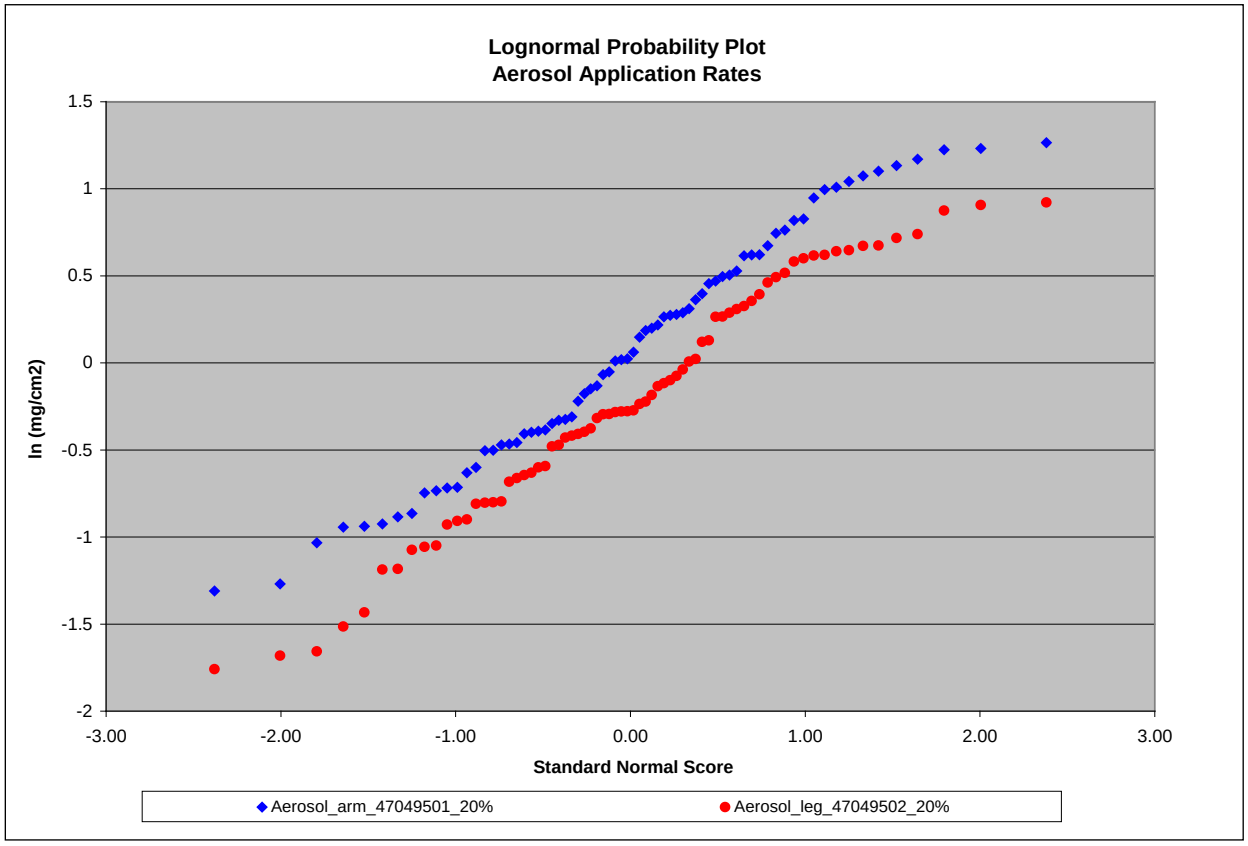


Figure D-22: Lognormal Probability Plot for Aerosol Application Rates

Statistics following combination of the two application rate datasets and analysis as a lognormal distribution are presented in *Table D-72*below.

Table D-72: Statistical Summary – Repellent Aerosol Application Rate (mg product/cm2)	
Statistic	**Application Rate**
50th percentile	0.92
75th percentile	1.48
95th percentile	2.91
99th percentile	4.68
99.9th percentile	7.98
AM (SD)	1.12 (0.93)
GM (GSD)	0.92 (2.01)
Range	0.17 – 3.54
N	144
Based on MRID 47049501 and 47049502 AM (SD) = arithmetic mean (standard deviation) GM (GSD) = geometric mean (geometric standard deviation)	

Pump Sprays

Similar to the studies for aerosols, efficacy studies for pump sprays were available from three MRIDs (47217601, 47535201, and 47535202). MRID 47217601 tested oil of lemon (30% pump spray) and MRIDs 47535201 and 47532502 both tested 7% and 15% picaridin pump sprays. A total of 5 sets of dosimetry samples, conducted as described above, were available from these three studies (two MRIDs each had two sets of dosimetry samples from two different products). Across all pump spray studies the application rates ranged from 0.06 to 2.3 mg spray per cm^2 of skin. A lognormal probability plot showing the distribution of each study is presented below.

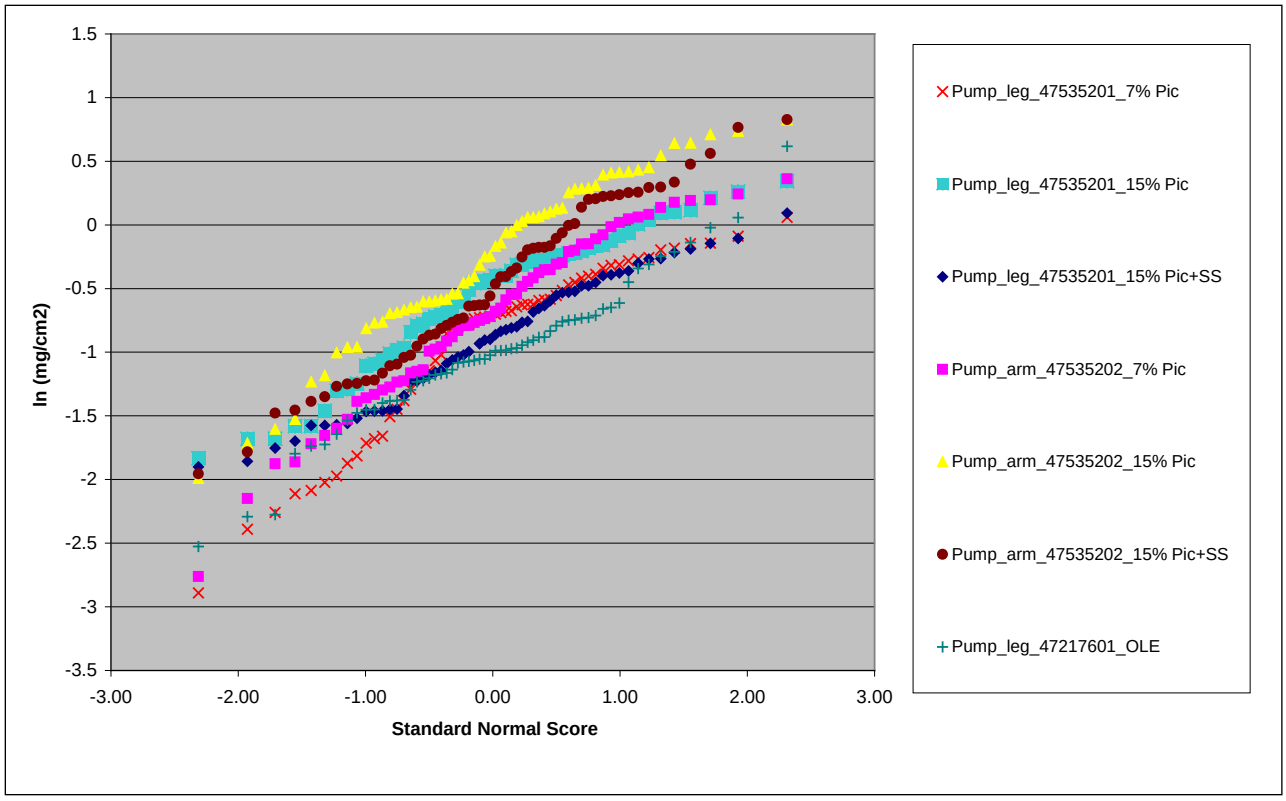


Figure D-23: Pump Spray Application Rate Lognormal Probability Plots

Statistics following combination of the datasets and analysis as a lognormal distribution are presented in *Table D-73* below.

Table D-73: Statistical Summary – Repellent Pump Spray Application Rate (mg product/cm^2)	
Summary Statistic	**Application Rate**
50th percentile	0.50
75th percentile	0.78
95th percentile	1.47
99th percentile	2.29
99.9th percentile	3.78
AM (SD)	0.62 (0.45)
GM (GSD)	0.50 (1.93)
Range	0.06 – 2.29
N	420
Based on MRID 47535201, 47535202, and 47217601 AM (SD) = arithmetic mean (standard deviation) GM (GSD) = geometric mean (geometric standard deviation)	

Lotions

Two studies (EPA MRID 47322401 and 47322501) measuring the efficacy of repellents formulated as lotions are available to estimate application rates based on dosimetry determination. The studies tested the efficacy of Coulston's Duranon Personal Insect Repellent (30% DEET) and Dermaegis Lipo DEET (20% DEET). As previously described, each test

subject applied the lotions three times to designated areas on each of their forearms for a total of 120 applications. The application rate (in mg lotion per cm^2 forearm) is determined simply by weighing the product (bottle) before and after each application and dividing by the surface area of the arm treated.

Overall the application rates in these studies ranged from 0.68 to 4.51 mg lotion per cm^2 of skin. The application rates for each study were plotted on a lognormal probability plot, shown in the figure below, to evaluate the distributions of the datasets.

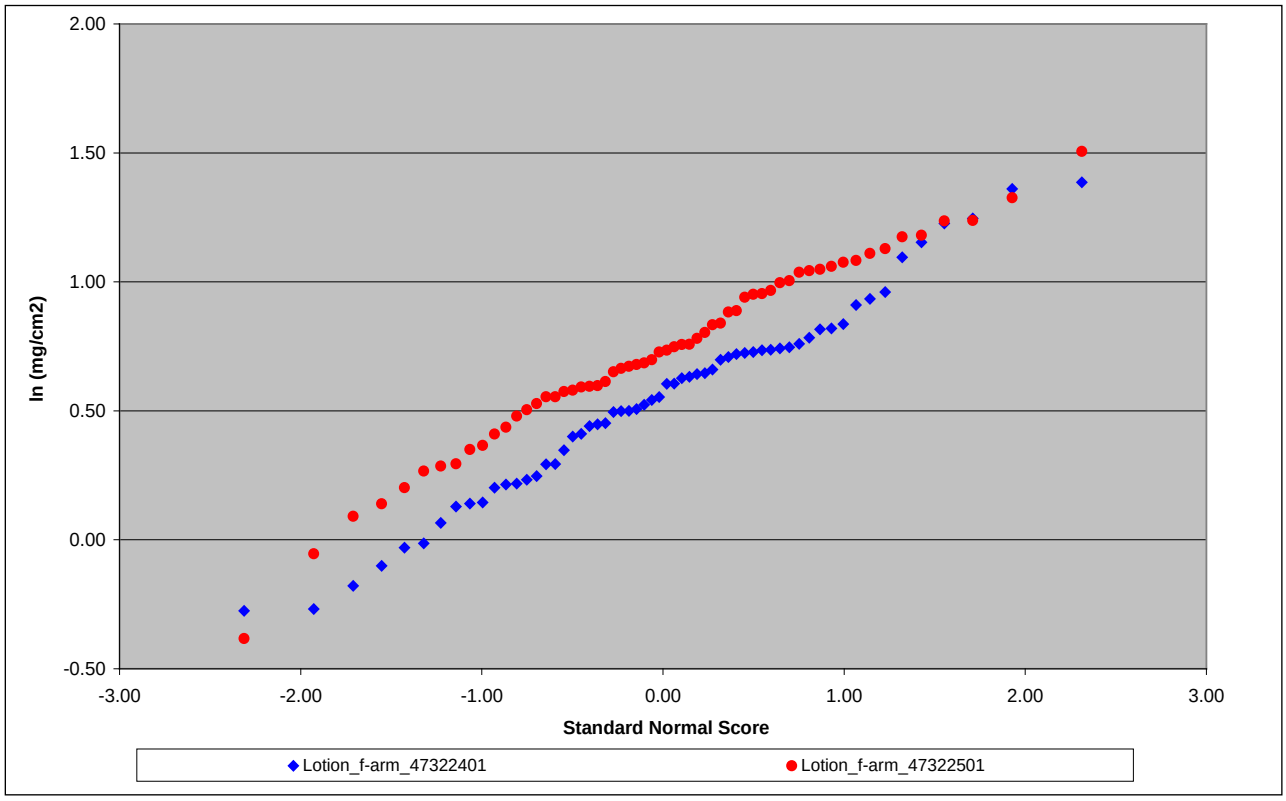


Figure D-24: Lotion Application Rate Lognormal Probability Plots

It is not unexpected that there are differences between the two applications, though at the upper end of each distribution they appear to be fairly similar. Because the intention of this exercise is to yield a distribution of application rates for a future lotion repellent, the datasets were combined. Statistics of this distribution are summarized in *Table D-74* below.

Table D-74: Statistical Summary – Repellent Lotion Application Rate (mg product/cm^2)

Statistic	Application Rate
50^{th} percentile	1.89
75^{th} percentile	2.43
95^{th} percentile	3.52
99^{th} percentile	4.55
99.9^{th} percentile	6.08
AM (SD)	2.03 (0.80)
GM (GSD)	1.89 (1.46)

Range	0.68 – 4.51
N	120
Based on MRID 47322401 and 47322501 AM (SD) = arithmetic mean (standard deviation) GM (GSD) = geometric mean (geometric standard deviation)	

Towelettes

The amount of repellent applied for towelettes is similarly quantified in three replicates and like lotions, dosimeter patches are not required for determining the application – it is simply derived as the weight difference before and after application according to the label. An estimation of loss of active ingredient via evaporation is determined by a exposing a pre-weighed towelette to the air for the same duration the test subject takes to apply the repellent (i.e., a control towelette). Any weight difference of the towelette used for treatment is corrected for loss due to evaporation of the control towelette. The application rate was calculated based on the weight loss of towelette and the applied skin area.

Two available studies (MRIDs 47535201 and 47535202) testing the efficacy of 12% and 6% picaridin towelettes are available to determine towelette application rates. For both towelette studies the application rates ranged from 0.5 to 2.5 mg per cm^2 of skin. A lognormal probability plot showing the distribution of each study is presented below.

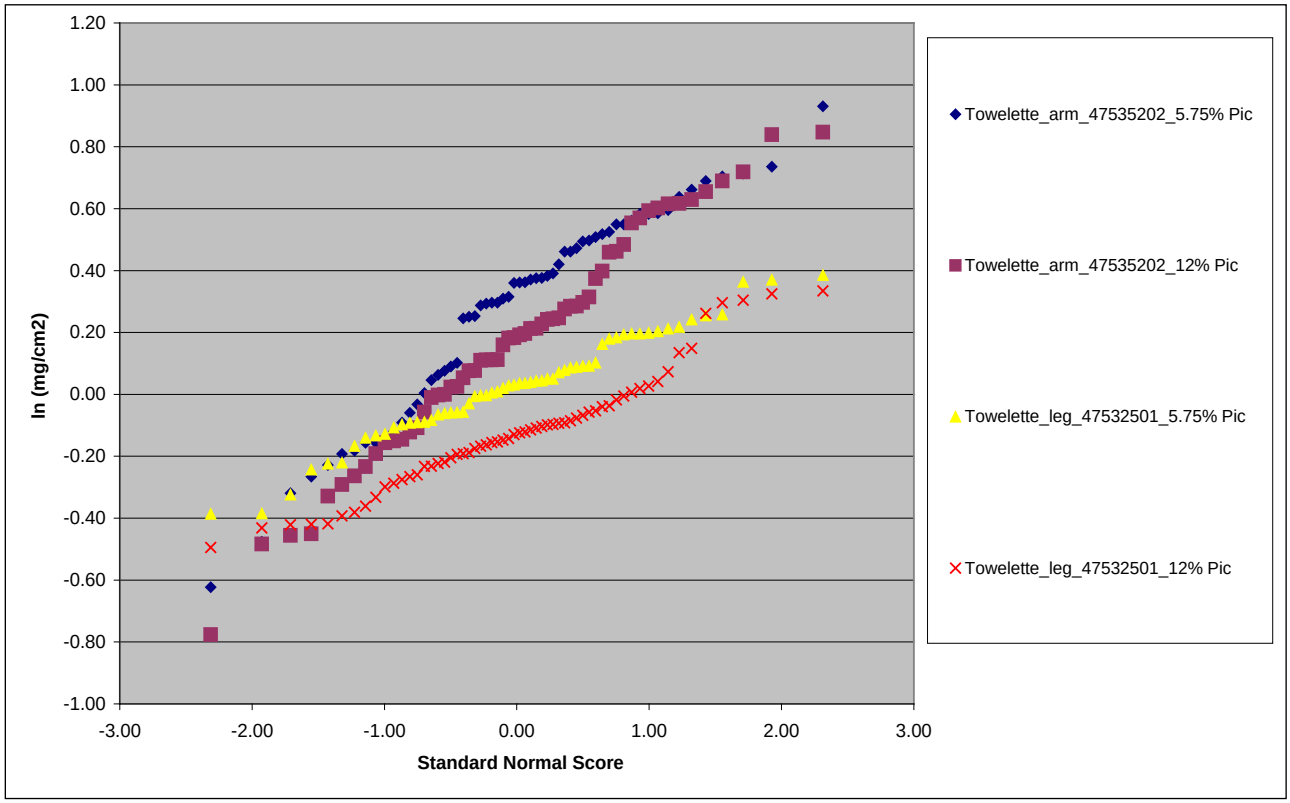


Figure D-25: Towelette Application Rate Lognormal Probability Plots

Statistics following combination of the datasets and analysis as a lognormal distribution are presented in *Table D-75*below.

Table D-75: Statistical Summary – Repellent Towelette Spray Application Rate (mg product/cm^2)	
Statistic	**Application Rate**
50th percentile	1.09
75th percentile	1.34
95th percentile	1.82
99th percentile	2.25
99.9th percentile	2.85
AM (SD)	1.14 (0.36)
GM (GSD)	1.09 (1.36)
Range	0.46 – 2.54
N	240
Based on MRID 47535201, 47535202 AM (SD) = arithmetic mean (standard deviation) GM (GSD) = geometric mean (geometric standard deviation)	

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Pharmacology and toxicology of veterinary isoxazolines: a review

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ABSTRACT

Isoxazoline derivatives have rapidly become cornerstone ectoparasiticides in veterinary medicine, providing high efficacy and long-lasting protection against fleas, ticks, and other arthropods in companion animals and, more recently, in food-producing species. This review summarizes current knowledge on the chemistry, pharmacology, and toxicology of the main veterinary isoxazolines - fluralaner, afoxolaner, sarolaner, and lotilaner - with particular emphasis on safety profiles and broader One Health considerations. Chemically, these compounds are highly lipophilic, fluorinated molecules with distinctive stereochemistry; the selective use of biologically active S-enantiomers has improved potency while limiting off-target effects. Isoxazolines act through non-competitive antagonism of γ-aminobutyric acid (GABA) - and L-glutamate-gated chloride channels in arthropods, resulting in sustained neuronal hyperexcitation and parasite death, with markedly higher affinity for arthropod than mammalian receptors. Pharmacokinetically, the compounds exhibit variable oral bioavailability but share extensive plasma protein binding, large volumes of distribution, low clearance, and long elimination half-lives, which underlie their prolonged clinical efficacy but also raise concerns regarding tissue accumulation and delayed adverse effects. Controlled studies generally demonstrate wide safety margins; however, post-marketing pharmacovigilance has identified rare but sometimes serious neurological adverse events, particularly in predisposed animals or in the context of impaired efflux transport, such as ABCB1/MDR1 mutations or P-glycoprotein inhibition. The authorization of fluralaner for use in laying hens and evidence of residues in eggs approaching established maximum residue limits emphasize the importance of continued residue monitoring and refinement of withdrawal periods. Moreover, the environmental persistence of isoxazolines and their pronounced toxicity to non-target invertebrates highlight emerging ecotoxicological concerns. Collectively, veterinary isoxazolines represent a highly effective yet complex class of antiparasitic agents whose safe and sustainable use requires integrated pharmacological, toxicological, residue, and environmental risk assessment.

1. Introduction

Ectoparasite infestations represent a significant and persistent health challenge in both companion and food-producing animals. They induce direct clinical manifestations, impair animal welfare, and reduce productivity in intensive production systems, leading to substantial economic losses and, in severe cases, mortality (Cosoroabă, 2001; Sárkány et al., 2025). Moreover, they act as important vectors of infectious diseases, affecting humans, companion animals, livestock, and wildlife (Otranto et al., 2013; Pérez de León et al., 2020; Maggi et al., 2022). As only a few vaccines against ectoparasites are currently available, antiparasitic drugs will remain the only effective means of therapy and prevention for many years to come (Selzer and Epe, 2021). These agents are among the most frequently used in veterinary medicine due to the health risks associated with external parasite infestations (Zhou et al., 2022). In recent decades, considerable progress has been made in the development of new ectoparasiticides for companion animals, particulary dogs and cats, both in terms of active ingredients and formulations (Beugnet and Franc, 2012). Similar advances have also been achieved in poultry medicine (EMA, 2017a; Petersen et al., 2021; Sari et al., 2022). Increasing awareness of arthropod-borne diseases and the advantages of oral administration have led to the development of a new class of compounds – the isoxazoline derivatives (Shoop et al., 2014).

Currently, four isoxazolines are approved for use: afoxolaner,

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fluralaner, sarolaner, lotilaner, available in various products for dogs and cats (EMA, 2014a; 2014b, 2015a; 2017b). All those compounds share a similar chemical structure (Fig. 1). The most recent addition to this group is esafoxolaner, the S-enantiomer of afoxolaner. Esafoxolaner received its first marketing authorization in the European Union in 2021 as a component of a combination product (EMA, 2020).

Isoxazoline derivatives constitute a unique group of antiparasitic agents introduced into veterinary practice within the past 15 years. Afoxolaner was approved in 2013 in the United States and one year later in the European Union (FDA, 2013; EMA, 2014b). In 2014, both the FDA and EMA also approved fluralaner (EMA, 2014a; FDA, 2014). Subsequent compounds were introduced in the following years: sarolaner in 2015 in the European Union and in 2016 in the United States, and lotilaner in 2017, followed by the introduction of the S-enantiomer of afoxolaner (esafoxolaner), rather than a distinct chemical entity, as part of combination veterinary products approved by the EMA in 2020 (EMA, 2015b; 2017b, 2020; FDA, 2016). These agents are characterized by a rapid onset of action, prolonged therapeutic efficacy after a single dose, and high effectiveness (Cherni et al., 2016).

Currently, fluralaner is registered for use in dogs (oral tablets, spot-on, and subcutaneous injectable solution), in cats (spot-on), in poultry, sheep (oral, drinking water) and for cattle (pour-on) (EMA, 2014a; 2017a; MAPA Brazil, 2022; da Costa et al., 2023; Reckziegel et al., 2024; APVMA, 2025). Sarolaner is administered to dogs as oral tablets and to cats as a spot-on solution (EMA, 2015a). Lotilaner has been approved for oral administration in both dogs and cats, and since 2023, also as an ophthalmic solution (Xdemvy) for the treatment of blepharitis in humans caused by *Demodex* (EMA, 2017b; FDA, 2023). Afoxolaner is available exclusively as oral tablets for dogs, its pure isomer S-afoxolaner is marketed in combination spot-on formulations for cats (EMA, 2014b; 2020). A detailed list of all approved isoxazoline-containing products, categorized by target species, is provided in the Supplementary Table 1.

One of the most widely used products is Bravecto (fluralaner), available in over 80 countries, including the United States, European Union member states, Australia, and Latin America. Due to its long duration of action (up to 12 weeks), it has gained broad popularity. In addition to conventional chewable formulations, long-acting injectable formulations of fluralaner have also been developed, providing protection against ectoparasites for up to 12 months (e.g., Bravecto Quantum in the United States, Bravecto injectable in the European Union, and Bravecto 365 in Latin America) (EMA, 2023; MIDA, 2024; FDA, 2025). Although exact global sales data for isoxazoline compounds are not publicly available, fluralaner-containing products are widely used worldwide in ectoparasite control; notably, according to MSD Animal Health, more than 350 million doses of Bravecto have been distributed in over 100 countries since its introduction in 2014 (MSD Animal Health, 2025). However, despite this extensive use and the large number of administered doses, reports of adverse effects – previously considered rare – are being increasingly documented (Palmieri et al., 2020). This growing body of evidence highlights the need for a more comprehensive evaluation of the safety profile of isoxazoline compounds.

Given the widespread and expanding use of isoxazoline derivatives, the diversity of their chemical and stereochemical features, the marked variability in their pharmacokinetic profiles, and the growing body of evidence concerning neurological adverse events, residue deposition in food-producing animals, and environmental persistence, a consolidated evaluation of current knowledge has become essential. Accordingly, the aim of this review is to critically synthesize existing data on the pharmacology and toxicology of fluralaner, afoxolaner, sarolaner, and lotilaner, encompassing their chemical properties, mechanisms of action, pharmacokinetics, safety profiles, residue behavior, and ecotoxicological risks. By integrating these perspectives, the review seeks to provide a coherent framework for interpreting the benefits and limitations of these compounds and to clarify the key areas where further investigation is required.

2. Chemistry of isoxazoline compounds

Fluralaner, lotilaner, afoxolaner, and sarolaner are fluoro- and chloro-organic compounds belonging to the isoxazoline class of ectoparasiticides. These molecules are highly lipophilic, have molecular weights exceeding 500 Da, and are poorly soluble in water, but dissolve readily in solvents such as dimethyl sulfoxide (DMSO) or dimethylformamide (DMF). (Table 1).

A key structural feature of these agents is the presence of fluorine atoms, which profoundly influence their chemical and pharmacological properties. Naturally occurring organofluorine compounds are rare; *Streptomyces cattleya*, for example, produces them via the enzyme fluorinase (O'Hagan et al., 2002). Beyond such isolated cases, organofluorine chemistry is largely synthetic and underpins a wide array of applications, including pharmaceuticals, agrochemicals, polymers,

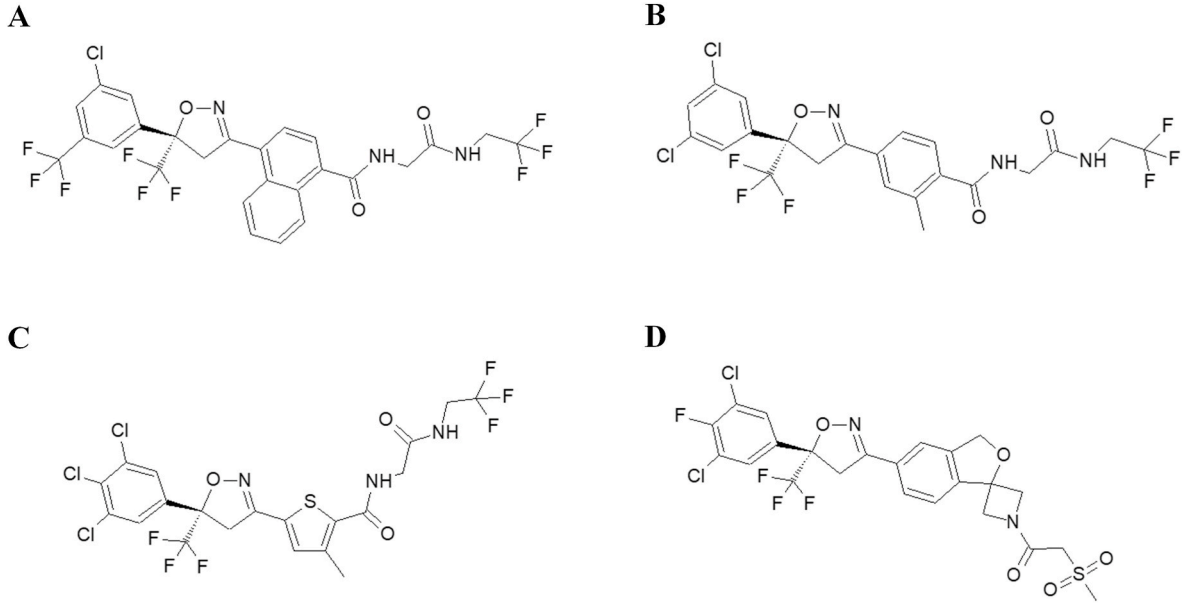


Fig. 1. Chemical structures of afoxolaner (A), fluralaner (B), lotilaner (C) and sarolaner (D).

Table 1
Selected physicochemical properties of isoxazoline compounds.

Property	Fluralaner	Afoxolaner	Sarolaner	Lotilaner
Molecular formula	$C_{22}H_{17}Cl_2F_6N_3O_3$	$C_{26}H_{17}ClF_9N_3O_3$	$C_{23}H_{18}Cl_2F_4N_2O_5S$	$C_{20}H_{14}Cl_3F_6N_3O_3S$
Molecular weight (g/mol)	556.3	625.9	581.4	596.8
Water solubility	0.082 mg/L (very low)	Insoluble	Not reported (likely very low/insoluble)	Insoluble
Solubility in organics	Soluble in DMSO and DMF (~30 mg/mL)	Slightly soluble in DMSO, ethanol	Slightly soluble in DMSO, ethanol	Slightly soluble in DMSO, ethanol
Appearance	White to off-white powder/solid	White to off-white powder/solid	White to off-white powder/solid	White to off-white powder/solid
XlogP3-AA	5.6	6.7	3.4	6.6

refrigerants, lubricants, and surfactants.

3. The role of fluorine in drug design

The carbon–fluorine bond is one of the strongest in organic chemistry, with the bond energy higher than C-C or C-H. The corresponding bond energies (kJ/mol) are as follows: C-C 332, C-H 415, and C-F 486. Bond dissociation energy depends also on neighboring atoms and functional groups in the molecule, however regardless of the context, the C–F bond usually has a higher dissociation energy than C-H (Lemal, 2004). This makes organofluorine compounds highly stable and resistant to oxidation. Fluorine's high electronegativity alters electron distribution when it replaces hydrogen, often modifying the reactivity of nearby functional groups. For example, acetic acid has a pKa of 4.8, whereas trifluoroacetic acid exhibits a pKa of 0.2 due to the strong electron-withdrawing effect of fluorine atoms (Garavagno et al., 2024). The van der Waals radius of fluorine (1.47 Å) is only slightly larger than that of hydrogen (1.20 Å), which means the size of substituted molecules does not significantly change. This plays a key role in drug design, as fluorine substitution does not disrupt steric properties of molecules or their affinity to receptor proteins or enzymes. Fluorinated drugs typically exhibit increased stability, longer half-life in the body, higher biological activity, and better membrane permeability compared to their hydrogen analogues. The presence of fluorine can also suppress susceptibility of certain molecules to demethylation, hydroxylation, and oxidation (e.g., ezetimibe) (Henary et al., 2024), allowing the design of drugs with extended activity and reduced active dose. Fluorination of methyl groups can improve membrane permeability by increasing lipophilicity (e.g., triazoles) (Ullah et al., 2022). These characteristics make fluorination a cornerstone strategy in the design of modern pharmaceuticals. Isoxazoline derivatives fulfill these criteria, and their fluorinated structures strongly influence their pharmacological efficacy and toxicological profile.

4. Chirality, biological activity, and enantiomeric selectivity of isoxazolines

Isoxazoline derivatives contain a chiral center at position 3 of the isoxazoline ring. The presence of this chiral carbon gives rise to two optical isomers, or enantiomers, which are non-superimposable mirror images of each other. These enantiomers rotate plane-polarized light in opposite directions (levorotation and dextrorotation) and are designated as *S* and *R* or *D* and *L*, depending on the nomenclature system. A 1:1 mixture of both forms is referred to as a racemate.

Although enantiomers possess identical chemical properties, their biological activities can differ dramatically. For instance, L-glucose, though sweet, is not metabolized by humans (Wright et al., 2011), and the two optical forms of sotalol differ in pharmacological action: L-sotalol functions as a β-blocker, whereas D-sotalol shows antiarrhythmic activity (Funck-Brentano C, 1993). In more extreme cases, such as thalidomide, opposite enantiomers have distinct and even adverse effects – the R-enantiomer exhibits anticancer properties, while the S-enantiomer is teratogenic and causes fetal malformations (Tokunaga et al., 2018). These examples illustrate how stereochemistry directly determines pharmacological outcomes, a principle highly relevant to isoxazoline derivatives.

In nature, most biomolecules exist in a single enantiomeric form (e.g., amino acids, sugars), and biological macromolecules such as proteins typically interact selectively with one stereoisomer. Recognition of these functional differences led the U.S. Food and Drug Administration (FDA) in 1992 to issue guidelines requiring separate evaluation of enantiomers at early stages of drug development (FDA's Policy, 1992).

The individual enantiomers of isoxazoline compounds also differ significantly in biological activity (McComic et al., 2026). S-fluralaner is 33 - 39 times more active against certain parasites than the R-form (Zhang et al., 2020), while S-sarolaner exhibits high efficacy against fleas and ticks, in contrast to the inactive R-enantiomer (McTier et al., 2016; Zheng et al., 2025). Similarly, studies conducted by Boehringer Ingelheim demonstrated that only S-afoxolaner was active against *Ctenocephalides felis*, whereas the R-form was inactive, and in the study by Prullage et al. (2021), S-afoxolaner showed high efficacy against *Ixodes ricinus* and *Ixodes scapularis* (Beugnet, 2021; Soré et al., 2025). This stereoselectivity is likely associated with the higher affinity of S-enantiomers for GABA receptors, whereas R-forms exhibit minimal receptor binding. Such stereochemical specificity directly contributes to the distinct pharmacological and toxicological profiles observed among veterinary isoxazolines (Zheng et al., 2025; McComic et al., 2026).

Consequently, the use of purified S-enantiomers may contribute to improved pharmacokinetic predictability and reduced variability, as reported for enantioselective isoxazoline compounds (Zheng et al., 2025). The selective use of active S-enantiomers is also reflected in the development of veterinary medicinal formulations. For example, Credelio tablets from Elanco contain pure S-lotilaner (Soré et al., 2025). Similarly, S-afoxolaner is used as the active enantiomer in the topical combination product NexGard Combo for cats, whereas other formulations, such as NexGard and NexGard Spectra, contain the racemic mixture of afoxolaner.

Given these pronounced enantioselective differences, separate assessment of S and R enantiomers in pharmacokinetic and toxicological studies is essential. Failure to distinguish between them may lead to misinterpretation of therapeutic concentrations or safety margins. The selective use of biologically active S-enantiomers, as seen in veterinary isoxazolines, represents a significant advance in rational antiparasitic drug design.

5. Chemical preparation of enantiomers

Producing single enantiomer drugs presents multiple challenges, and several chemical and physical methods have been developed to obtain pure or enriched forms. Common strategies include asymmetric synthesis, enrichment of racemic mixtures, and purification through preparative chromatography.

The development of stereoselective synthesis has twice been recognized with the Nobel Prize in Chemistry. In 2001, W.S. Knowles, R.

Noyori, and K.B. Sharpless were awarded for catalytic enantioselective synthesis, and in 2021 B. List and D.W.C. MacMillan were honored for the development of asymmetric organocatalysis (Nobel Prize Committee, 2001; Nobel Prize Committee, 2021). These achievements revolutionized modern chiral drug synthesis.

In pharmaceutical manufacturing, the choice of production method must balance efficiency, yield, and cost (economic aspects are increasingly important in current drug design and production). Chromatographic separation is rarely used on an industrial scale due to high costs, whereas catalytic chiral synthesis is generally preferred for large-scale production. Isoxazoline derivatives are relatively new compounds, introduced less than two decades ago, and their manufacturing remains under patent protection, particularly concerning the enrichment of S-stereoisomers (ie. US Patent US8466115B2, WIPO Patents WO2022016490A1 and WO2017176948A1). This contributes to their relatively high prices, though cost reductions are expected following patent expiry and the introduction of generic formulations.

6. Mode of action of Isoxazoline compounds

The primary mechanism of action of isoxazoline derivatives involves non-competitive binding to γ-aminobutyric acid (GABA) - and L-glutamate-gated chloride channels in the nervous system of arthropods, leading to inhibition of chloride ion influx and disruption of neuronal signaling (Gassel et al., 2014; Weber and Selzer, 2016). This results in sustained neuronal excitation, hyperactivity of the nervous system, and ultimately paralysis and death of the parasite (Kuntz and Kammandiminti, 2017).

Importantly, the mechanism of action of isoxazolines differs from that of earlier classes of ectoparasiticides. These compounds display much higher selectivity for arthropod receptors compared to their mammalian counterparts, including those of humans (Weber and Selzer, 2016). Gassel et al. (2014) demonstrated that fluralaner binds to arthropod GABA receptors with significantly greater affinity than to mammalian receptors, a property that underlies its wide safety margin. This receptor selectivity is considered a key factor contributing to the insecticidal and acaricidal efficacy of isoxazolines while minimizing neurotoxic risk in mammals.

Sager et al. (2025) investigated the electrophysiological effects of several isoxazolines on GABA receptors in humans and dogs, showing that sarolaner, afoxolaner, and fluralaner inhibited receptor activity, whereas lotilaner exhibited minimal effect, suggesting a potentially higher neurological safety profile. Furthermore, Bouzat (2012) and Sieghart (2015) demonstrated that fluralaner can interact in vivo with members of the Cys-loop receptor family in vertebrates, which are primarily expressed in the central nervous system. This interaction may explain the observations of Gaens et al. (2019), who reported transient neurological symptoms – such as generalized ataxia, myoclonus, tremors, muscle contractions, and dysphagia – in dogs, coinciding with the expected time of peak plasma fluralaner concentration. The authors suggested that these effects could result from off-target receptor inhibition.

Although such adverse effects remain rare, these findings highlight the need for further research into the relationship between the mechanism of action and the safety profile of isoxazoline derivatives in veterinary practice.

7. Spectrum of activity of veterinary isoxazolines

Fluralaner exhibits broad ectoparasiticidal activity in dogs, cats, and poultry. In dogs, a single oral or topical administration provides up to 12 weeks of control of flea infestations caused by *Ctenocephalides felis* and other *Ctenocephalides spp*., as well as multiple tick species including *Ixodes ricinus, Dermacentor reticulatus, Dermacentor variabilis,* and *Rhipicephalus sanguineus* (European Commission Bravecto, 2014a; 2016; Gassel et al., 2014; Fourie et al., 2015; Djuric et al., 2019). Beyond its activity against fleas and ticks, fluralaner demonstrates therapeutic efficacy against several mite infestations. Treatment of generalized demodicosis caused by *Demodex canis* has been reported (Fourie et al., 2015; Djuric et al., 2019), while high efficacy has also been documented against *Sarcoptes scabiei var. canis* and the ear mite *Otodectes cynotis* (Taenzler et al., 2016, 2017). In cats, topical fluralaner provides up to 12 weeks of protection against *C. felis* and *I. ricinus,* and is effective in eliminating *O. cynotis* infections (EMA, 2016; Taenzler et al., 2017). In poultry, fluralaner administered via drinking water (Exzolt®) is effective against the poultry red mite *Dermanyssus gallinae* in commercial laying hens, with substantial reductions in mite loads and no adverse effects on egg production (EMA, 2017a; Huyghe et al., 2017; Soares et al., 2022).

Afoxolaner, approved for use in dogs, has documented activity against *C. felis* and *C. canis* for approximately five weeks following a single oral dose, and is also indicated for flea allergy dermatitis control (European Commission NexGard SPC, 2014; Beugnet et al., 2016). Its tick spectrum includes *I. ricinus, D. reticulatus,* and *R. sanguineus* (Beugnet et al., 2016). Afoxolaner further demonstrates efficacy against *Demodex canis* in generalized canine demodicosis (Beugnet et al., 2016), *S. scabiei var. canis* (Hampel et al., 2018), and *O. cynotis* (Carithers et al., 2016), highlighting its broad acaricidal activity.

Sarolaner, licensed for dogs (Simparica®), provides one month of protection against *C. felis* and *C. canis,* with rapid onset of adulticidal activity (Simparica SPC, Zoetis, 2024; McTier et al., 2016). Its tick spectrum includes *D. reticulatus, I. hexagonus, I. ricinus*, and *R. sanguineus* (Six et al., 2016; Simparica SPC, Zoetis, 2024). Sarolaner also shows efficacy against generalized demodicosis and *O. cynotis* in controlled studies (Six et al., 2016; Becskei et al., 2018), as well as *S. scabiei var. canis* (Simparica SPC, Zoetis, 2024). In cats, the combination product containing sarolaner (Stronghold Plus®) is approved for the treatment of *C. felis, I. ricinus*, and *O. cynotis* (Stronghold Plus SPC, Zoetis, 2017).

Lotilaner, approved for dogs and cats (Credelio®), provides one month of control of *C. felis* and *C. canis*, and is active against several tick species including *I. ricinus, I. hexagonus*, *D. reticulatus*, and *R. sanguineus* following oral administration with food (Credelio SPC – dogs, Elanco, 2017; Credelio SPC – cats, Elanco, 2018; Cavalleri et al., 2017; Cavalleri et al., 2018). Lotilaner is also effective against canine demodicosis caused by *Demodex spp*. after repeated monthly dosing (Snyder et al., 2017). In human medicine, a 0.25% ophthalmic lotilaner formulation (Xdemvy®) was recently approved for the treatment of *Demodex folliculorum* –associated blepharitis (FDA Xdemvy label, 2023).

Esafoxolaner, the active isomeric component of the feline combination product NexGard Combo®, exhibits activity comparable to S-afoxolaner. It is approved for the treatment and prevention of *C. felis*, as well as for the control of *I. ricinus, I. scapularis,* and *R. sanguineus* infestations in cats (NexGard Combo, 2023; Tielemans et al., 2021). The product is also indicated for the treatment of *O. cynotis* and for mild to moderate notoedric mange caused by *Notoedres cati* in cats (NexGard Combo SPC, Boehringer Ingelheim, 2023).

Together, these data demonstrate that veterinary isoxazolines share a broad but species-specific spectrum of activity against fleas, ticks, and several mite species of clinical relevance. Differences in duration of efficacy, target parasite range, and approved host species reflect variations in molecular properties, formulation types, and regulatory submissions rather than fundamental differences in mode of action. Comprehensive evaluation of these indications is essential for their appropriate application in clinical practice.

8. Pharmacokinetics

The distinctive pharmacokinetic properties of isoxazolines – including absorption, distribution, metabolism, and elimination – underlie their prolonged clinical efficacy. Despite structural similarities among members of this chemical class, their pharmacokinetic parameters vary considerably.

Following oral administration in dogs, the reported bioavailability values are 26% for fluralaner (Kilp et al., 2014), 85% for sarolaner (McTier et al., 2016), 73.9% for afoxolaner (Letendre et al., 2014), and 25% for lotilaner (Toutain et al., 2017). Walther et al. (2014) demonstrated that the absorption of fluralaner is enhanced and more predictable when administered with food. This observation is consistent with the general behaviour of lipophilic orally administered drugs, whose absorption may increase under fed conditions owing to improved dissolution and solubilisation within the gastrointestinal tract. A similar pattern was observed for lotilaner, whose bioavailability increased markedly in fed animals – from 24% to 82% in dogs and from 8.4% to 100% in cats (Toutain et al., 2018). These findings indicate that feeding conditions may substantially influence the systemic availability of some orally administered isoxazolines and should therefore be taken into account when interpreting interspecies pharmacokinetic differences and expected clinical efficacy. In poultry, however, the situation appears to be different. Sari et al. (2022) demonstrated that neither feed intake nor water hardness significantly influenced the pharmacokinetic profile of fluralaner in laying hens administered via drinking water, including under fed conditions. This suggests that fluralaner administration in laying hens is relatively insensitive to variations in feeding conditions and water hardness, which is of practical importance in commercial poultry production systems. Nevertheless, the pharmacokinetic behaviour of fluralaner at the level of absorption is not directly comparable between species such as dogs and poultry. This is largely attributable to fundamental differences in feeding systems and diet composition. Diets of dogs and cats are typically rich in fat and protein, whereas poultry feed differs substantially in composition, which may influence gastrointestinal processing of the compound. Proteins may exhibit sorptive properties, while lipids can enhance the solubility of lipophilic molecules such as fluralaner, thereby affecting its absorption. In addition, differences in pharmaceutical formulation may further contribute to interspecies variability. In poultry, fluralaner is administered as a liquid formulation via drinking water, whereas in dogs it is typically provided as a solid oral dosage form (chewable tablet), which may also influence its pharmacokinetic profile.

The reported maximum plasma concentrations (Cmax) also differ among compounds: 1.7 μg/mL for afoxolaner, 3.4 μg/mL for fluralaner, 1.1 μg/mL for sarolaner, and 1.5 μg/mL for lotilaner (Letendre et al., 2014; Kilp et al., 2014; McTier et al., 2016; Toutain et al., 2017). The time to reach Cmax (Tmax) varies from 2 to 6 h for afoxolaner, approximately 24 h for fluralaner, <24 h for sarolaner, and 2 – 4 h for lotilaner (Kilp et al., 2014). This variability likely reflects formulation-related challenges associated with highly lipophilic molecules exhibiting low aqueous solubility and limited solubility in organic solvents, together with the influence of enterohepatic recirculation described for fluralaner, sarolaner, and lotilaner (Kilp et al., 2014; EMA, 2017; 2017b; Toutain et al., 2017). Overall, the oral bioavailability of isoxazolines ranges from 8.4% to 100%, depending on feeding conditions, whereas topically administered formulations show approximately 25% systemic bioavailability (Zhou et al., 2022). These findings emphasize the need for precise dosing recommendations and discourage extrapolation between compounds or across species.

Isoxazolines share several pharmacokinetic characteristics, including extensive plasma protein binding (>99.9%), low clearance rates, and large volumes of distribution - approximately 3 L/kg for afoxolaner, fluralaner, and sarolaner, and around 6 L/kg for lotilaner (Kilp et al., 2014; McTier et al., 2016; Toutain et al., 2017; Zhou et al., 2022). These properties, largely attributable to the molecular lipophilicity of the compounds, favor accumulation in lipid-rich tissues. This feature explains their prolonged efficacy but may also contribute to potential accumulation within the central nervous system and the risk of neurotoxic effects (Palmieri et al., 2020).

Elimination half-life is a key pharmacokinetic parameter determining the prolonged clinical efficacy of isoxazolines. Reported values are approximately 16 days for afoxolaner (Letendre et al., 2014), 12 - 15 days for fluralaner (Kilp et al., 2014), and up to 30 days for lotilaner (Toutain et al., 2017), based on both oral and intravenous pharmacokinetic data, whereas values for sarolaner (11 - 12 days) have been determined following oral administration only (McTier et al., 2016). In dogs and cats, fluralaner exhibits a dose-dependent half-life, which contributes to its prolonged duration of efficacy (Rakotonanahary et al., 2017). Kilp et al. (2014) also suggested that enterohepatic recirculation may further prolong the persistence of fluralaner in the body by enabling reabsorption of drug excreted in bile.

After oral administration, all four isoxazolines are eliminated primarily in faeces as unchanged parent compounds, with only a minor contribution from metabolites (EMA, 2012, 2014a, 2017b; EMA, 2015a; Toutain et al., 2018). The rate of elimination may vary between species – for example, rats eliminate fluralaner more rapidly than dogs (EMA, 2014a, 2014b). This limited biotransformation was further supported by Gonzalez et al. (2017), who showed that more than 90% of fluralaner is excreted unchanged, and by Pittermannová et al. (2021), who suggested that the compound undergoes only minimal metabolism.

Given that the pharmacokinetics of fluralaner, afoxolaner, and lotilaner have also been investigated following intravenous administration (Kilp et al., 2014; Letendre et al., 2014; Toutain et al., 2017, 2018), it is noteworthy that only fluralaner is currently available as a long-acting subcutaneous formulation (EMA, 2023). This formulation substantially modifies its pharmacokinetic profile, particularly with respect to prolonged systemic exposure and duration of activity. Regulatory data indicate gradual absorption from the injection site, a median Tmax of 37 days, and a mean terminal half-life of 130 days, with plasma concentrations remaining within the therapeutic range for up to 12 months after administration (EMA, 2023). Moreover, unchanged fluralaner following subcutaneous administration is excreted predominantly in faeces, whereas renal elimination appears to play only a minor role, consistent with the elimination pathway observed after oral administration, as the route of administration primarily affects the rate and extent of elimination rather than its primary route (EMA, 2023). This prolonged systemic exposure is consistent with the intrinsic pharmacokinetic properties of fluralaner observed after intravenous administration, including low plasma clearance, a relatively large apparent volume of distribution, and a prolonged terminal half-life, all of which support extensive tissue distribution and slow elimination (Kilp et al., 2014, 2016).

In summary, the pharmacokinetics of isoxazolines – characterized by extensive protein binding, low clearance, and long elimination half-lives – account for their prolonged therapeutic efficacy. However, these same features may also contribute to tissue accumulation and extended persistence of adverse effects, underscoring the importance of further studies linking pharmacokinetic behavior with safety outcomes in veterinary use. Moreover, the pharmacokinetic behavior of these compounds has potential implications for public health. Fluralaner, for instance, is approved for use in laying hens, where its high lipophilicity and prolonged half-life may result in accumulation in eggs and edible tissues. Consequently, the persistence of isoxazolines in food-producing animals warrants careful monitoring, as residue deposition could impact consumer safety. In this context, pharmacokinetic data for isoxazolines in other species remain limited. This is particularly relevant in the context of off-label use of isoxazoline derivatives in species other than those for which they are currently registered. In horses, Morgan et al. (2025) demonstrated that orally administered fluralaner at doses of 10 and 25 mg/kg was safe, well tolerated, and remained detectable in plasma for approximately 42 days. In pigs, the available data are considerably more limited and primarily concern afoxolaner, for which therapeutic efficacy against mange has been reported (Smith et al., 2020). In rabbits, several isoxazoline derivatives, including lotilaner, afoxolaner, and fluralaner, have shown high efficacy against ectoparasitic infestations (Sheinberg et al., 2017; Romero Núñez et al., 2020; Machado et al., 2025).

Taken together, these findings indicate growing interest in the use of

isoxazolines beyond their conventional indications in dogs, cats, and poultry. However, the availability of pharmacokinetic data in other species remains clearly limited or, in some cases, absent. Therefore, further evaluation of withdrawal periods and residue kinetics is warranted in food-producing animals (hens, cattle), including those not yet established as target species. These aspects highlight the need for continued evaluation of withdrawal times and residue kinetics in species intended for human consumption.

9. Drug resistance

Experimental evidence indicates that resistance to fluralaner can be selected under laboratory conditions in non-target arthropods. Norris et al. (2023) demonstrated that repeated selection of *Musca domestica* with fluralaner resulted in the development of a resistant strain, characterized by reduced susceptibility compared with unselected populations. Subsequent mechanistic investigations indicated that resistance in this model was associated with decreased cuticular penetration, consistent with reduced internal exposure to the compound (Scott et al., 2024). In parallel, Chen et al. (2025) reported cytochrome P450-mediated cross-resistance to fluralaner and isocycloseram in *Myzus persicae*, identifying CYP6CY3 as a key metabolic determinant of reduced fluralaner sensitivity.

In the currently available scientific literature and major public databases, reports explicitly addressing resistance to veterinary isoxazolines remain scarce and where documented, pertain primarily to fluralaner (Norris et al., 2023; Scott et al., 2024; Chen et al., 2025). At present, there are no published reports documenting confirmed resistance to fluralaner or other isoxazolines in target ectoparasites of companion animals under field conditions. Nevertheless, given the expanding and increasingly intensive use of isoxazolines and evidence that these compounds and their residues can enter and persist in the environment, environmental exposure to these substances is likely to increase. Their chemical stability and prolonged persistence may further contribute to sustained environmental presence. Under such conditions, and considering the experimentally demonstrated potential for resistance development, the emergence of resistance in target ectoparasites should be regarded as a plausible future risk rather than an established phenomenon, warranting continued monitoring and further investigation.

10. Safety profiles and reported adverse events of Isoxazoline compounds

Although isoxazoline derivatives have gained widespread use in veterinary medicine due to their high efficacy against ectoparasites, concerns have been raised regarding their safety profile, particularly in relation to neurological adverse events. Evidence from both experimental studies and post-marketing surveillance has contributed to a better understanding of their tolerability in animals.

Limited penetration of isoxazolines into the central nervous system has been attributed, at least in part, to the activity of efflux transporters at the blood - brain barrier, including P-glycoprotein (P-gp) (Dowling, 2006; Drag et al., 2022). This protective mechanism restricts drug accumulation in the brain under physiological conditions and is considered an important determinant of the neurological safety profile of these compounds. Although direct experimental evidence is not available for all members of the isoxazoline class, existing data indicate that P-gp–mediated efflux contributes to limited CNS exposure. In line with this interpretation, fluralaner has demonstrated a wide margin of safety even in dogs carrying the ABCB1/MDR1 mutation, indirectly supporting the role of efflux transport mechanisms in limiting CNS accumulation (Walther et al., 2014; Drag et al., 2022). Impairment of efflux function—due to genetic factors, pharmacological inhibition, or overdose—may nevertheless increase CNS exposure and thereby predispose susceptible animals to neurological adverse effects.

Under normal physiological conditions, P-gp prevents significant drug accumulation in the brain, thereby contributing to overall safety. However, in cases of overdose, co-administration with P-gp inhibitors, or in animals carrying the ABCB1/MDR1 gene mutation, this protective mechanism may be compromised, increasing the risk of neurotoxic effects such as tremors, ataxia, and seizures (Dowling, 2006; Swain et al., 2013). Additional risk factors include MDR1 mutations predisposing to drug hypersensitivity in certain dog breeds (Gramer et al., 2011), as well as individual variability in pharmacokinetic parameters such as gastrointestinal pH, gastric emptying time, intestinal transit, plasma protein binding, age, and sex (Sagawa et al., 2009).

Given their long elimination half-lives, high lipophilicity, and extensive plasma protein binding, isoxazolines may persist in the body for extended periods. These pharmacokinetic properties, while beneficial for maintaining sustained antiparasitic efficacy, they may also predispose to delayed or cumulative neurotoxic effects, particularly in animals with impaired metabolism or P-gp dysfunction. Therefore, pharmacokinetic behavior should be considered an integral component of the safety assessment of isoxazoline derivatives.

Several controlled studies have evaluated the safety of fluralaner in poultry and companion animals. Soares et al. (2022) demonstrated that oral administration of fluralaner via drinking water at the therapeutic dose (0.5 mg/kg body weight, twice at a 7-day interval) was well tolerated in hens, with no adverse effects on egg production or quality. Similarly, Huyghe et al. (2017) confirmed the safety of fluralaner in breeder hens, reporting no effects on egg count, mass, fertility, or hatchability. Prohaczik et al. (2017) showed that even doses three to five times higher than recommended caused no clinical abnormalities or reductions in egg production.

Long-term safety studies in dogs yielded comparable findings. Kuntz and Kammandiminti (2017) administered lotilaner orally once a month for 8 months at up to five times the maximum recommended dose and found no toxicologically relevant changes in clinical, hematological, or histopathological parameters. Additional investigations in non-traditional species also confirmed a favorable safety profile. Oral administration of afoxolaner (NexGard®) at 2 mg/kg in Burmese pythons caused no observable adverse effects (Gamez et al., 2020), while a single oral dose of 68 mg in pigs resulted only in mild pruritus (Bernigaud et al., 2018). Similarly, the long-acting injectable formulation of fluralaner administered in dogs was well tolerated, as demonstrated both in EMA assessment documentation and in the field study reported by Petersen et al. (2024) (EMA, 2023).

Despite promising experimental safety data, post-marketing pharmacovigilance has documented neurological adverse events associated with isoxazoline use. In an online survey of veterinarians and pet owners ("Project Jake"), Palmieri et al. (2020) collected 2751 responses, of which 1594 dogs had received a flea/tick parasiticide and 1325 an isoxazoline product. These survey findings were compared with publicly available adverse event (AE) reports from the U.S. Food and Drug Administration (FDA) and the European Medicines Agency (EMA). For the FDA database, 32 374 reportable AE in dogs were identified between January 2013 and September 2017; within these reports, death was recorded in 2.4% and 2.5% of AE associated with afoxolaner and fluralaner respectively, and seizures in 6.9% and 2.8%, while the corresponding proportions for sarolaner were 3.2% for death and 20.5% for seizures. EMA data for isoxazoline products over a longer time frame (2013 - 2019), as summarized and reported by Palmieri et al. (2020), showed markedly higher proportions of serious neurological adverse events, with the percentage of reports including death ranging from 4.76% to 28.6% and those including seizures from 9.0% to 55.1% across the four isoxazoline compounds. The authors emphasized that these figures represent the distribution of clinical signs within spontaneously reported adverse events, rather than incidence rates in the treated dog population, and that under-reporting and reporting bias likely influence both FDA and EMA datasets.

Additional evidence has been provided by Bates et al. (2024), who

analyzed reports of neurological adverse effects associated with isoxazoline exposure in both dogs and cats. Their study highlighted that neurological signs such as tremors, ataxia, seizures, and altered mentation were the most frequently reported manifestations following exposure to isoxazolines, occurring across different compounds within the class. Importantly, the authors noted that these events were reported in animals both with and without a prior history of neurological disease, underscoring the variability in individual susceptibility. Consistent with pharmacovigilance data, Bates et al. (2024) concluded that while neurological adverse effects remain uncommon relative to the widespread use of isoxazolines, their occurrence warrants continued vigilance and systematic reporting to better define predisposing factors and risk profiles.

More post-marketing data from the FDA's CVM ADE Comprehensive Clinical Detail Report provide further insight into the safety profiles of these agents in clinical use. Analysis of adverse event reports (Table 2) indicates that afoxolaner is most frequently associated with reactions involving the gastrointestinal system, the skin and subcutaneous tissue, and the nervous system, which together constitute the predominant categories of submissions. Reports concern primarily dogs, reflecting the species in which the compound is most widely used. Overall, the profile of adverse event categories documented for afoxolaner aligns closely with that described for other members of the isoxazoline class.

For fluralaner, gastrointestinal disorders represent the most frequently reported category, followed by neurological and behavioral disturbances, and thereafter by reactions affecting the skin and subcutaneous tissue. Reports of perceived lack of efficacy and general or administration-site reactions occur less commonly. Although the general distribution of categories resembles that of the other compounds, the relative weight of neurological and dermatological reports provides a characteristic profile for fluralaner within the class.

Sarolaner is most commonly associated with neurological and behavioral disturbances together with gastrointestinal disorders, which collectively form the dominant reporting categories. In dogs, these reactions predominate, whereas reports in other species remain comparatively infrequent. Overall, the distribution of adverse event categories mirrors that noted for afoxolaner, with neurological and gastrointestinal signs forming the core of reported clinical manifestations.

For lotilaner, gastrointestinal disturbances constitute the most frequently reported category, followed by general systemic or administration-site reactions and reports of perceived lack of efficacy. Less frequent categories include metabolic and nutritional disturbances, dermatological reactions, hematological or immunological findings, behavioral changes, and renal, urinary or neurological signs. Reactions involving other systems appear only sporadically within the dataset.

Taken together, the four compounds demonstrate both shared and compound-specific characteristics. Gastrointestinal reactions represent the most consistently reported category across the isoxazoline class as a whole, a finding that may reflect common physiological response patterns observed in post-marketing safety data and the widespread use of orally administered formulations. Neurological and behavioral disturbances are also frequently documented and correspond to the known pharmacodynamic targets of isoxazolines, which modulate arthropod ligand-gated chloride channels and may, under susceptible conditions, affect mammalian pathways. Fluralaner shows a comparatively prominent representation of dermatological reactions, whereas sarolaner exhibits a relatively greater proportion of neurological and behavioral reports. Lotilaner presents a more evenly distributed pattern among less frequent categories, with gastrointestinal and general systemic reactions forming its principal profile. Despite these differences, all four

Table 2
Summary of the reported frequency of adverse events associated with four veterinary isoxazoline derivatives based on data from the FDA Center for Veterinary Medicine Adverse Drug Event (CVM ADE) Comprehensive Clinical Detail Report Listing.

Side effect	Afoxolaner		Fluralaner		Lotilaner		Sarolaner		Mean
	CVM ADE Comprehensive Clinical Detail Report Listing; Cumulative Date Range: 04-Sep-2013 -thru- 31-Jul-2018		CVM ADE Comprehensive Clinical Detail Report Listing; Cumulative Date Range: 25-May-2014 -thru- 31-Jul-2018		CVM ADE Comprehensive Clinical Detail Report Listing; Cumulative Date Range: 18-Jan-2018 -thru- 31-Jul-2018		CVM ADE Comprehensive Clinical Detail Report Listing; Cumulative Date Range: 24-feb-2016 -thru- 31-jul-2018		
	Number of reports	Percentage of total (%)	Number of reports	Percentage of total (%)	Number of reports	Percentage of total (%)	Number of reports	Percentage of total (%)	Percentage of total (%)
Gastrointestinal disorders	15078	26.8	17771	32.7	166	33.81	2284	22.58	29.0
Nervous system disorders icluding behavioral disorders	11032	19.61	8968	16.5	48	9.78	3830	37.87	20.9
Skin and subcutaneous tissue disorders	12543	22.3	5016	9.2	37	7.54	553	5.47	11.1
Lack of efficacy	4965	8.83	7100	13.1	53	10.79	698	6.9	9.9
General disorders and administration site conditions	2787	4.95	3679	5.5	58	11.81	800	7.91	7.5
Metabolic and nutrition disorders	3189	5.67	2964	6.8	51	10.39	511	5.05	7.0
Blood, lymphatic and immune system disorders	1347	2.39	2250	3.4	29	5.91	340	3.36	3.8
Urinary system and kidneys	956	1.70	1848	2.0	23	4.68	242	2.39	2.7
Respiratory, thoracic and mediastinal disorders	1473	2.62	1094	4.1	9	1.83	195	1.93	2.6
Hepatobiliary disorders	1023	1.82	1357	2.5	2	0.41	232	2.29	1.8
Eye, ear and labyrinth disorders	937	1.67	904	1.7	7	1.43	176	1.74	1.6
Musculoskeletal and connective tissue disorders	741	1.32	609	1.1	4	0.81	122	1.21	1.1
Cardio disorders	251	0.45	452	0.8	2	0.41	51	0.5	0.5
Vascular disorders	62	0.11	92	0.2	1	0.2	56	0.55	0.3
Reproductive system and breast disorders	62	0.11	213	0.4	1	0.2	24	0.24	0.2

compounds share a broadly similar qualitative structure of adverse event reporting, likely reflecting their related mechanisms of action and shared physicochemical properties.

When the distributions of adverse event categories are aggregated across all four isoxazolines, gastrointestinal disorders emerge as the most frequently reported group, followed by neurological and behavioral disturbances, skin and subcutaneous tissue disorders, reports of perceived lack of efficacy, general systemic or administration-site reactions, and metabolic or nutritional disorders. This consolidated profile provides an integrated overview of the types of reactions most often associated with isoxazoline use. The synthesis presented here is our own analysis based on the available FDA CVM ADE Comprehensive Clinical Detail Report Listings. The discrepancy between the broad safety margins observed in controlled studies and the relatively high number of post-marketing reports suggests the presence of individual susceptibility factors. Potential contributors include genetic variability in drug metabolism, differences in blood–brain barrier permeability, and drug–drug interactions affecting pharmacokinetics.

Interpretation of these patterns must take into account several important limitations. The FDA CVM ADE datasets cover different and non-overlapping time windows for each compound: afoxolaner from 4 September 2013 to 31 July 2018, fluralaner from 25 May 2014 to 31 July 2018, lotilaner from 18 January 2018 to 31 July 2018, and sarolaner from 24 February 2016 to 31 July 2018. These discrepancies preclude direct comparison of numerical report counts, particularly for lotilaner, which has the shortest period of post-marketing observation. Furthermore, the CVM ADE database documents adverse event reports rather than the number of individual animals affected. A single animal may be associated with multiple entries, and the total number of animals exposed to each compound is unknown. As a consequence, the data permit characterisation of the relative distribution of adverse event categories between compounds, but they do not allow estimation of incidence, prevalence, or risk within the treated population. The dataset therefore provides insight into patterns of reported reactions but cannot be used to infer their true frequency in clinical practice.

In summary, while isoxazoline derivatives are generally regarded as safe and effective antiparasitic agents, veterinarians should remain alert to potential gastrointestinal and neurological adverse effects, particularly in predisposed individuals. Further studies are needed to clarify the mechanisms underlying these rare reactions in the context of the extensive global use of this drug class, and to better characterize the risk factors contributing to interindividual variability in safety outcomes.

11. Isoxazoline residues in animal products and public health implications

An additional safety concern regarding isoxazoline derivatives, particularly when used in food-producing animals, involves the potential presence of drug residues in edible tissues and animal-derived products intended for human consumption. Recently, Cui et al. (2024) investigated fluralaner residues in eggs from laying hens treated with therapeutic doses of fluralaner administered via drinking water on days 0 and 7. The highest mean concentration detected during a 23-day monitoring period was 1235 μg/kg on day 13 – approaching the European Union's maximum residue limit (MRL) of 1300 μg/kg established for eggs and poultry tissues (EMA, 2017).

According to Commission Regulation (EU) No. 2021/1757, the approved MRLs for fluralaner are 500 μg/kg in muscle, 1500 μg/kg in fat, 1000 μg/kg in liver, and 1300 μg/kg in eggs, reflecting the compound's lipophilic nature and extensive tissue distribution (EMA, 2017). Residue depletion studies show that fluralaner is eliminated slowly from poultry, with detectable concentrations persisting for up to two weeks, consistent with the 14-day withdrawal period recommended for meat and offal, while no withdrawal period is required for eggs under the approved conditions of use (European Medicines Agency EMA, Committee for Veterinary Medicinal Products CVMP, 2022; Cui et al., 2024).

The public health relevance of these findings becomes particularly evident when considered in the context of large-scale egg production and frequent dietary exposure. Poland, for example, is one of the major egg-producing countries in Europe, with annual production reaching approximately 10.0 - 10.3 billion eggs in 2020 - 2021, and it remains the largest poultry meat producer in the European Union, accounting for 20.5% of total EU poultry output in 2024 (Agroberichten Buitenland, 2023; Eurostat, 2025). In addition, available estimates indicate that egg consumption in Poland remains substantial, with approximately 139 - 162 eggs consumed per person annually in recent years (Agroberichten Buitenland, 2024). In such settings, even a low frequency of non-compliant use, off-label administration, or insufficient adherence to approved treatment conditions may translate into a substantial absolute number of eggs or poultry products entering the market with residue concentrations approaching regulatory thresholds.

From a toxicological and regulatory perspective, this issue is particularly relevant for food products such as eggs and poultry meat that may be consumed regularly and repeatedly over long periods. EMA and EFSA have emphasized the importance of harmonized human dietary exposure assessment for residues of veterinary medicines in food of animal origin, reflecting the relevance of chronic consumer exposure through repeated intake rather than isolated consumption events (EMA/EFSA, 2023).

Accordingly, the concern is not limited to occasional exceedances of maximum residue limits (MRLs), but also includes the possibility of sustained low-level dietary exposure if residue control or compliance with authorized conditions of use is inadequate. This may be especially relevant in populations with high habitual consumption of eggs or poultry products, particularly considering the high lipophilicity and strong protein binding of isoxazolines, which may favor their retention and accumulation in biological tissues.

In this context, the implications of residue persistence should also be considered in relation to toxicological thresholds, such as the no observed adverse effect level (NOAEL), which forms the basis for establishing the acceptable daily intake (ADI). Consequently, even low-level, long-term dietary exposure may be relevant if it approaches a significant fraction of the ADI, particularly in populations with high and habitual consumption of animal-derived products.

The issue may also extend beyond poultry. Fluralaner-based formulations have been evaluated in cattle in Brazil, where therapeutic efficacy against major ectoparasites has been demonstrated (da Costa et al., 2023), and a topical formulation has been registered for use in this species (Supplementary Table 1). In this context, the public health relevance of residue persistence should also be considered in relation to countries with high consumption of animal-derived foods. In Brazil, beef consumption remains high, at approximately 37.4 kg per capita per year, while domestic chicken meat consumption exceeds 46 kg per capita annually (ABIEC, 2024; USDA Foreign Agricultural Service, 2025).

Although residue depletion data for bovine tissues remain limited, the combination of persistent pharmacokinetic properties, expanding use in food-producing animals, and high dietary intake of animal products further supports the need for careful monitoring.

The properties that make fluralaner pharmacologically attractive - its high lipophilicity, long elimination half-life, and extensive distribution - also increase the potential for accumulation in animal-derived products. As such, the pharmacokinetic persistence of isoxazolines in food-producing animals has implications not only for veterinary safety but also for public health protection. Continued residue surveillance and further depletion studies are essential to ensure consumer safety and regulatory compliance.

12. Environmental toxicity and ecotoxicological risks of Isoxazoline compounds

Environmental exposure to isoxazoline derivatives has become an

increasingly important component of their overall toxicological evaluation. Although these compounds are primarily administered to individual companion animals, their widespread global use (Supplementary Table 2) has raised concerns regarding unintended environmental release and potential effects on non-target organisms. This issue has gained additional relevance following the authorization of fluralaner for use in laying hens, where treatments are conducted at the flock level and may involve the simultaneous administration of the drug to thousands to tens of thousands of birds. In intensive poultry production systems – particularly in countries that are major global egg producers – the cumulative amount of fluralaner entering the environment via litter, manure, and associated waste streams may substantially exceed inputs resulting from companion animal use. Consequently, the original VICH GL6 guideline (EMA/VICH, 2000), which assumed negligible ecological risk due to the small quantities administered to individual animals, no longer adequately reflects current conditions, particularly in light of both the rapid global expansion of pet ownership and the large-scale application of isoxazolines in commercial poultry production (Diepens et al., 2022; Wells and Collins, 2022).

Isoxazolines may enter the environment through multiple pathways, including shedding from hair, excretion in urine and faeces, and direct contamination of water bodies when treated animals swim or bathe (Domingo-Echaburu et al., 2021). Residues have also been detected in shed hair used by wild birds for nest construction, indicating indirect environmental transfer, and secondary transfer between dogs has been documented (Diepens et al., 2022). Faecal excretion, however, represents the primary route of environmental exposure, with fluralaner concentrations in the faeces of treated dogs reaching up to 44 000 μg/kg – several orders of magnitude higher than levels observed in urine or hair (Diepens et al., 2022). Because fluralaner is excreted largely unchanged and persists in faeces for several weeks, dung dependent organisms such as dung beetles and coprophagous flies are likely to experience prolonged exposure (Du Toit et al., 2012).

In companion animals, environmental emissions are diffuse and difficult to quantify, and may be partially mitigated by waste collection and disposal practices. In contrast, in poultry production, fluralaner is currently the only isoxazoline in use and is administered at lower doses per kilogram of body weight; however, treatments are conducted at the flock level, and manure is routinely applied to land, resulting in direct and concentrated environmental exposure. Consequently, although total input per animal may be lower, environmental release in poultry systems is more predictable and locally intensified. These differences highlight the importance of considering not only the magnitude of use but also the structure and pathways of environmental emission when assessing the ecological risk of isoxazoline compounds.

Ecotoxicological studies indicate that many invertebrates are highly sensitive to the neurotoxic effects of isoxazolines. For fluralaner, 48-h LD_{50} values range from 2.9 to 65.6 ng per insect in species such as *Haematobia irritans* and *Tribolium castaneum*, while oral LC_{50} values for *Drosophila melanogaster* and *Aedes aegypti* range from 1.8 to 12 ppm (Wells and Collins, 2022). The compound also exhibits high acute toxicity toward *Daphnia magna* (LC_{50} = 0.047 mg/L; EMA, 2017). Lotilaner excreted by treated mice has been shown to cause significant mortality in mosquito larvae; however, no detectable toxicity to fish has been observed (Cooper, 2023). Ecotoxicity data for afoxolaner and sarolaner remain limited, restricting comprehensive assessment of their environmental hazard profiles.

Environmental risk assessment (ERA) data further indicate that fluralaner is highly persistent, with DT_{50} values of up to 196 days in aquatic sediments and very low water solubility (0.1 mg/L), both of which favor environmental accumulation (EMA, 2021). These physicochemical properties are consistent with its classification as highly toxic to aquatic invertebrates, and its ability to exert potent insecticidal effects at extremely low concentrations raises significant ecological concern (Wells and Collins, 2022). Despite its low water solubility, fluralaner may still pose a risk to aquatic organisms. This is supported by general environmental principles describing lipophilic organic compounds, which tend to accumulate in sediments and biological tissues, thereby enabling exposure even at very low dissolved concentrations (Karickhoff et al., 1979; Liu et al., 2019). Available evidence further suggests that isoxazolines, particularly fluralaner, exhibit considerable environmental stability which, in combination with slow elimination and prolonged excretion, may result in continuous input of residues into the environment. This is especially relevant for long-acting injectable formulations, where sustained release over extended periods may contribute to chronic environmental exposure and increase the likelihood of ecotoxicological effects.

The regulatory maximum residue limits (MRLs) established for fluralaner in edible tissues – discussed earlier in the context of food safety – also reflect its slow elimination, high lipophilicity, and persistence in biological matrices. From an ecotoxicological perspective, relatively high permissible residue levels, particularly in fatty tissues and eggs, underscore the extent of tissue retention and the potential for environmental dissemination through the disposal of poultry offal, manure, carcass waste, or egg-processing by products. These waste streams may act as point sources of contamination, creating exposure pathways for scavengers, decomposer organisms, and other non-target species. The recent detection of fluralaner residues approaching MRL levels in eggs from treated laying hens (Cui et al., 2024) further highlights its persistence in biological matrices. Detectable residues may remain for up to two weeks, despite the approved withdrawal period being zero days for eggs and 14 days for meat and offal.

Given the millions of doses administered annually (Supplementary Table 2), the high stability and persistence of these compounds in the environment, and residue levels indicating prolonged retention in animal tissues, there is a clear need for expanded research into environmental fate, sublethal effects (e.g., oxidative stress in fish), and broader ecological consequences (Wagner, 2020; Jiang and Old, 2025). Similar concerns have been raised for other widely used ectoparasiticides. In the case of compounds such as fipronil and imidacloprid, their widespread use and initial regulatory acceptance were followed by accumulating evidence demonstrating adverse effects on non-target organisms, particularly pollinators (Perkins and Goulson, 2023; EMA, 2023; Joachim et al., 2025). In this context, environmental risk assessments of veterinary ectoparasiticides indicate that emissions should, wherever possible, be minimized at the point of use (EMA, 2012). In practice, this includes strict adherence to approved conditions of use, avoidance of unnecessarily frequent treatments, and the use of combination products only when clearly justified (EMA, 2012; EMA, 2023). Although such measures have not yet been specifically standardized for isoxazolines, they remain consistent with general principles of environmental risk mitigation for veterinary medicinal products with the potential to affect aquatic ecosystems and dung fauna.

Although isoxazoline-based parasiticides are considered selectively safe for mammals at therapeutic doses, their impact on non-target species – particularly insects and aquatic invertebrates – raises significant concerns. Current ecotoxicological databases remain incomplete, and existing risk-mitigation strategies rely largely on responsible user behavior rather than regulatory controls (EMA, 2023). In this context, it is important to consider whether isoxazoline residues may pose a risk to non-target organisms, including both pollinators and dung-associated invertebrates, particularly given their increasing use and physicochemical properties that favor environmental persistence.

13. Summary and future perspectives

Historically, many chemotherapeutic agents used in veterinary medicine were initially developed for human medicine and subsequently adapted for animal use. However, parasiticides represent a distinct group, as several compounds were originally developed as agricultural insecticides and only later introduced into veterinary practice. Examples include organophosphates such as metrifonate, as

well as more recent compounds such as imidacloprid and fipronil, which were first widely used in crop protection before being repurposed as ectoparasiticides in animals (Tingle et al., 2003; Jeschke et al., 2011; Sparks and Nauen, 2015).

In the case of isoxazolines, the development pathway was partially similar but ultimately divergent. These compounds were initially identified within agrochemical discovery programs aimed at developing novel insecticides with modes of action distinct from existing classes (Sparks, 2013; Selzer and Epe, 2021). However, unlike imidacloprid or fipronil, isoxazolines were not widely commercialized for crop protection. Instead, selected compounds from this class were subsequently developed and optimized for use in veterinary medicine as highly effective ectoparasiticides. At a later stage, interest has also emerged regarding their potential applications in human medicine, reflecting a broader pattern observed for certain antiparasitic agents. A notable example is ivermectin, which was first introduced in veterinary medicine and only later adopted in human medicine, including large-scale use in the control of onchocerciasis (Crump and Ōmura, 2011).

In 2023, the FDA approved the first ophthalmic preparation containing lotilaner for the treatment of *Demodex blepharitis*. Additional phase II clinical trials have been undertaken to evaluate a 2% lotilaner gel for rosacea associated with *Demodex folliculorum*, and in April 2024 recruitment concluded for another phase II study assessing oral lotilaner administration in humans. These developments underscore the potential translational value of isoxazolines beyond veterinary parasitology.

Pharmacokinetic and safety data generated across multiple animal species may provide a robust foundation for future human applications. Nevertheless, interspecies extrapolation must be approached with caution. Although fundamental pharmacokinetic processes are broadly conserved among mammals, the occurrence of neurological adverse effects reported in veterinary practice emphasizes the need for thorough evaluation of neurotoxicity, exposure thresholds, and susceptibility in humans. Further investigation into both the therapeutic potential and the mechanistic basis of neurotoxicity remains essential.

In veterinary and environmental health, several additional areas of potential application merit attention. Burgess et al. (2020) demonstrated that fluralaner exhibits potent activity against synanthropic filth flies, including horn flies, screwworm flies, and multiple strains of the house fly, suggesting its utility against insect populations exhibiting resistance to conventional insecticides. This observation is particularly relevant in light of the recent re-emergence of the New World screwworm (*Cochliomyia hominivorax*) in parts of South and Central America and on Caribbean islands – an event that has renewed global concern regarding insecticide resistance, control failures, and the need for novel parasiticides with distinct modes of action. Isoxazolines, due to their unique binding profile and high selectivity for arthropod ligand-gated chloride channels, may offer an alternative tool for integrated pest management in such contexts.

Despite these promising findings, significant knowledge gaps persist. Further research is required to characterize the toxicity of excreted residues following treatment of dogs and cats, particularly their effects on coprophagous insects such as dung beetles, as well as potential impacts on aquatic organisms. The expanding use of isoxazolines – including their emergence in human medicine – may create additional environmental entry points, amplifying the relevance of comprehensive ecotoxicological evaluation. Consequently, new environmental toxicity data are urgently needed to inform realistic ERA scenarios (Berny et al., 2024).

In summary, isoxazoline derivatives represent an important class of antiparasitic compounds with substantial and growing relevance across veterinary, environmental, and potentially human medicine. Their distinctive pharmacokinetic and pharmacodynamic properties, coupled with high efficacy, have made them indispensable tools in modern ectoparasite control. Yet their potent neuroactive mechanisms, prolonged persistence, and expanding environmental footprint highlight the need for continued, multidisciplinary research to address remaining gaps in pharmacology, neurotoxicity, residue kinetics, and ecological impact. Ensuring their safe and sustainable use will depend on refining safety assessments, guiding responsible application, and mitigating emerging toxicological and environmental risks through continued pharmacovigilance, residue monitoring, and environmental risk assessment.

CRediT authorship contribution statement

Paulina Markowska-Buńka: Writing – review & editing, Writing – original draft, Visualization, Supervision, Resources, Project administration, Conceptualization. **Bartosz Rasiński:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Software, Resources, Project administration, Investigation, Data curation. **Hubert Ziółkowski:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Resources, Project administration, Methodology, Investigation, Data curation, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

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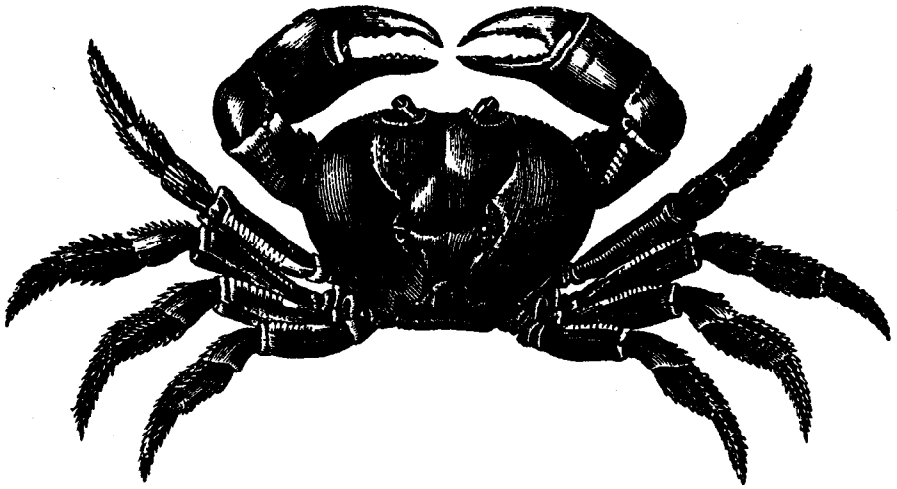
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Evaluation of

Copper- and Tributyltin-containing Compounds

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PART ONE — PROGRAM TO REGULATE COPPER AND TRIBUTYLTIN

Nita A. Davidson

Introduction

In February 1994, AB 3394 was introduced by Assembly Member Byron Sher (D, Palo Alto) to address excessive discharges of copper and tributyltin into bays, estuaries, and inland surface waters. The bill would have allowed the California Regional Water Quality Control Boards (Regional Boards) to prohibit the sale, use, and discharge of copper-containing root control compounds, and copper- or tributyltin-containing cooling water additives, once the Regional Boards determined that these compounds 1) interfered with obtaining water quality objectives or 2) prevented compliance with national pollutant discharge elimination system (NPDES) permits. The sponsors of the bill assumed that the Regional Boards have the authority to regulate the sale or use of pesticides on a local basis. However, under current law, the Department of Pesticide Regulation (DPR) has exclusive authority to regulate the sale and use of pesticides throughout California and customarily does so through administrative rather than legislative processes.

After several discussions with Assembly Member Sher, his staff, and representatives from Publicly Owned Treatment Works (POTWs), the California Environmental Protection Agency and DPR determined that an administrative solution would quickly achieve the goals of AB 3394, under DPR's current regulatory authority (Department of Pesticide Regulation, 1994). In August 1994, DPR, along with the cooperation and assistance of the State Water Resources Control Board (State Board) and Regional Boards, established a high-priority program to address the sale and use of copper- and tributyltin-containing pesticides.

The Copper and Tributyltin Program

The copper and tributyltin program was created to develop an administrative solution to concerns raised about the water quality impacts in the San Francisco Bay Area by pesticides containing copper and tributyltin. Staff of the Environmental Monitoring and Pest Management Branch of DPR formed a work group to accomplish the tasks involved in evaluating the copper and tributyltin problem. Based on information at hand, the work group identified the San Francisco Bay Area counties in the Regional Board's San Francisco Bay Region (Region 2) as areas of greatest concern. These counties include (1) San Francisco, (2) Santa Clara, (3) San Mateo, (4) Alameda, (5) Contra Costa, (6) Solano, (7) Napa, (8) Marin, and (9) Sonoma.

Searching the literature and requesting information from interested parties

Staff assembled pertinent literature, collecting in-house publications and reprints of journal articles contributed by the Palo Alto Regional Water Quality Control Plant (RWQCP) (a POTW) and Region 2. To ensure that important references had not been overlooked, staff obtained 169 abstracts on environmental monitoring of copper and tributyltin. Information

compiled from these references is included in parts Two and Three of this report, which describe the fate of copper and tributyltin in the environment.

For the evaluation of the pest management alternatives portion, staff assembled 44 abstracts for copper and 683 for tributyltin. As the alternatives portion was completed, a growing list of contacts contributed even more material. Staff also sent out requests for additional literature to interested parties, including managers of POTWs, County Agricultural Commissioners, University of California Cooperative Extension Horticultural Advisors, and registrants of copper- and tributyltin-containing pesticidal products.

Identifying sites where copper- and tributyltin-containing pesticides are used

Staff identified sites where copper- and tributyltin-containing pesticides are used (e.g., sewers, drains, cooling water systems), and used the sites to search DPR's Pesticide Label Database (PLD) for product labels of copper- and tributyltin-containing pesticides and alternatives that do not contain these compounds. This component was essential to verify products currently registered in California that are specifically used for the identified sites. In addition to gathering product labels and interviewing arborists, public works engineers, and managers of cooling water systems, the pest management team compiled a comprehensive list of copper and tributyltin alternatives. The alternatives to copper are divided into municipal and residential use categories; within these categories, they are further described by duration of effectiveness, major limitations, and approximate cost (Part Four). The analysis prepared for tributyltin describes tributyltin substitutes; lists specific products registered in California; describes limitations of each class of alternative; and provides cost ranges for treatment, maintenance, and cleanup for each product (Part Five).

Administrative options for regulating copper- and tributyltin-containing compounds

Options include promoting a voluntary program among users of copper- and tributyltin-containing products or employing one of three regulatory options (Part Six). These options include 1) canceling copper- and tributyltin-containing products throughout California without regard to regionally specific discharge problems, 2) designating the products as restricted materials to prevent non-licensed users from purchasing and using them, and 3) prohibiting sale and use of the products on a regional basis. This report will provide the basis for a decision to proceed with one of the three options.

Establishing Water Quality Objectives

Water quality objectives are established by the State Board, which evaluates scientific studies of the effects of contaminants on organisms and biological communities (SFBRWQCB, 1992a). Effluent limitations based on water quality objectives are then established for discharges from POTWs; effluent limitations are based on the depth of the water body where the discharge leaves

the POTW. If effluent limitations violate conditions of discharge permits, the Regional Board could fine POTWs up to $25,000 per day.

Water quality objectives for copper

In 1986, Region 2 adopted amendments revising the Water Quality Control Plan for the San Francisco Bay Basin (Basin Plan). This version of the Basin Plan was rescinded in September 1994 and is currently under revision. One amendment included a site-specific water quality objective for copper in the San Francisco Bay. Region 2 received funding from the State Board and the United States Environmental Protection Agency to develop the site-specific objectives for shallow- and deep-water effluent limitations (discharges from POTWs). In October 1992, Region 2 adopted a site-specific water quality objective for total copper in San Francisco Bay of 4.9 micrograms per liter (µg/L) (= parts per billion [ppb]) based on the protection of aquatic life (SFBRWQCB, 1992b). This amendment to the Basin Plan (Resolution 92–128) adopted a deep-water effluent limitation of 37 µg/L, and a 4.9 µg/L limitation for shallow-water discharges. Because concentrations of copper higher than 4.9 µg/L were measured through most of the estuary, Resolution 92–128 established goals for reducing mass emissions of copper by the year 2003 of 20 percent for storm water, and 25 percent for riverine sources and municipal and industrial discharges.

A later amendment (Resolution 93–61) to the Basin Plan established a mass-based approach to determine copper loading for the San Francisco Bay (SFBRWQCB, 1993). Because copper levels exceeded mass-loading limitations throughout the South Bay, one POTW, Palo Alto RWQCP, which discharges to shallow water, was told to reduce its copper load by 32 percent. (The load reduction for the two other shallow-water dischargers, San Jose and Sunnyvale, remained at 25 percent.) In annual mass loading, this is equivalent to 720 pounds, 32 percent less than the 1,060 pound baseline discharge.

In 1993, Region 2 issued a Cease and Desist Order (CDO) to the Palo Alto RWQCP upon renewal of its NPDES permit because violations of the new copper discharge limitations were anticipated. The CDO set up a three-year schedule for compliance with the mass limit and a five-year schedule for concentration limit compliance for Palo Alto and similar schedules for San Jose and Sunnyvale. The conditions of the CDO generated a comprehensive outreach program targeted toward public, commercial, and industrial sectors.

Water quality objectives for tributyltin

In 1992, Region 2 adopted a shallow-water effluent limitation for tributyltin of 5 parts per trillion (ppt) (= 0.005 µg/L) for the San Francisco Bay. In studies conducted by the State Board in the late 1980s, high levels of organic tin compounds (butyltins) were found in river and lake marinas (see Part Three, this report). The high concentrations of butyltins were attributed to the use of tributyltin-containing antifouling hull paints on boats.

From 1992 to 1994, samples from discharges in Palo Alto (RWQCP) exceeded the effluent limit of tributyltin (Kelly D. Moran, pers. comm.). Staff of the Palo Alto RWQCP searched for various tributyltin sources and ruled out antifouling hull paints. They found that tributyltin-containing discharge from cooling water systems was the most obvious source in their service areas (RWQCP, 1993; RWQCP, 1994).

Sources of copper and tributyltin for South Bay POTWs

Loading of metals for the three POTWs that discharge south of the Dumbarton Bridge (Palo Alto, San Jose, and Sunnyvale) is exacerbated by the shallow water and slow replenishment of fresh water in the South Bay (Lacy, 1993). Sources of copper from municipal and industrial discharge in the South Bay make up 25% of the annual average loading of copper. Sources of copper discharge via sewers, storm drains, and rivers include abandoned mines, drinking water pipes, brake linings, copper-containing root control compounds, human wastes, food wastes, and laundry graywater (Larry Walker Associates, 1994). The Palo Alto RWQCP monitored residential, industrial, and commercial wastewater to establish the source of metals in their effluent (RWQCP, 1994). They also studied specific discharge sources, such as machine shops, vehicle service facilities, and cooling towers.

Two studies identified copper sulfate root control compounds as contributing three to ten percent of copper recovered in the effluent of POTWs (Larry Walker Associates, 1994; SRI International, 1991). In Martinez, the Central Contra Costa Sanitary District (CCCSD) initiated a research and implementation project to identify and quantify sources of trace metals in residential wastewater (Larry Walker Associates, 1994). The study found that of all metals evaluated, copper should be given high priority for control, and residential source control efforts should focus on reducing use of copper-containing root control compounds. In Palo Alto, residential use of copper sulfate for tree roots in 1990 accounted for 36 to 42 pounds of elemental copper, approximately 10 percent of the total copper loading (SRI International, 1991).

Unlike copper, potential sources of tributyltin are entirely pesticidal. They include biocidal cooling water systems additives, antifouling paints and stains, protective wood treatments, disinfectant commercial toilet bowl cleaners, and disinfectant carpet and upholstery cleaners (Department of Pesticide Regulation, 1993). In Palo Alto, RWQCP staff determined from surveys that the lack of boat maintenance facilities and tributyltin-containing paints or disinfectants pointed to cooling water systems as the single source of tributyltin (Moran, 1994). Staff calculated that one gallon of 2 percent tributyltin solution discharged to the sewer and treated with other wastewater at the RWQCP would contaminate more than 2.4 billion gallons of the effluent, exceeding the 5 ppt tributyltin effluent limitation. Even very small discharges from one or two cooling towers using tributyltin-containing products could put the City of Palo Alto in violation of their discharge permit (Moran, 1994).

Existing local programs for reducing sources of copper and tributyltin

Educational outreach to limit discharges of copper and tributyltin

Since 1990, Palo Alto RWQCP has conducted an aggressive pollution prevention program to comply with discharge limits. Their Clean Bay Business program recognizes local plumbers no longer using copper sulfate for root control, and hardware stores that cooperate by voluntarily not selling these products. RWQCP staff also published a list of auto shops that adopted environmentally sound practices. As of February 1994, RWQCP had published four technical documents on best management practices (BMPs); four user-friendly booklets on BMPs; 11 technical reports; 16 public relations items (including flyers, coupons, door hangers, and buttons); and 40 fact sheets. Only some of these address copper-containing root control compounds, but most deal with the idea of source reduction. As a result of the plant's outreach efforts, cooperation of area businesses and residents, and improved copper-removal efficiency the average annual effluent copper concentration has decreased from 150 µg/L in 1979 to approximately 10 µg/L in 1993. RWQCP's regulatory programs currently address the sewer and storm water discharges of approximately 85 major industrial facilities and more than 1,000 commercial businesses.

The RWQCP created the Cooling Water Systems Program in 1992 to collect information about cooling water systems, develop and promote BMPs for operating and maintaining cooling water systems, and distribute the BMPs to cooling tower users within RWQCP's service area (RWQCP, 1994a). Participants in the program held several public meetings to request input from the regulated community and treatment chemical suppliers. In 1993, the RWQCP developed BMPs that promote appropriate operation and maintenance of cooling water systems to reduce the amount of metals discharged into the Bay while also lowering cooling system costs.

Other governmental agencies in the San Francisco Bay Area besides the Palo Alto RWQCP have published educational material on proper disposal of toxics, some with an emphasis on root control and cooling water systems (San Francisco Bay Area Pollution Prevention Group, 1994). Examples include the City of San Jose Environmental Services Department, the City and County of San Francisco Department of Public Works, Central Contra Costa Sanitary District, and the Sunnyvale Water Pollution Control Plant. A brochure on copper sulfate root killers was developed in April 1994 by 25 Bay Area POTWs and distributed to over 200,000 households throughout the region.

Local ordinances imposed by the cities of Palo Alto and San Jose

Advocates of outreach programs have complained that the task of reducing the amount of metals entering municipal sewers is monumental because effluent limitations are so low—on the level of parts per billion or trillion. For example, the Palo Alto RWQCP calculated that the small volume of tributyltin-containing discharge that causes the plant to violate its effluent limitation makes it impractical to identify and eliminate all the small sources of tributyltin through an inspection and education program (Moran, 1994a).

In response to continued violations of effluent limitations, the City of Palo Alto passed an ordinance in February 1992 that banned the discharge of copper-containing root control compounds containing greater than five percent copper by weight to the sanitary and storm sewer systems. The RWQCP found that banning discharge rather than sale of these products made enforcement of the ordinance difficult; although monitoring the sale of products from retail outlets and plumbers is achievable, monitoring the discharge of copper-based root killers from every household is impossible. RWQCP recognized a loophole with their outreach program when the owner of a chain retail outlet in their service area chose not to participate in a local-government–sponsored program until getting more information from his parent company or professional association (Moran, 1994b).

Following Palo Alto's example, San Jose adopted an ordinance in September 1992 that regulated the sale, use, and discharge of copper-containing root control compounds. San Jose City Council supported the ordinance based on state and federal laws that they believed stated that the City may exercise control over users of its storm drain and sewer systems, and may adopt regulations relating to all substances discharged into these systems, including pesticides. DPR responded that authority to regulate pesticides resides with DPR, pursuant to Food and Agricultural Code § 11501.1, which states that "[n]o ordinance or regulation of local government, including, but not limited to, an action by...a city council...may prohibit or in any way attempt to regulate any matter relating to the registration, sale, transportation, or use of economic poisons, and any of these ordinances, laws, or regulations are void and of no force or effect." Only county agricultural commissioners are authorized to regulate pesticides locally under the supervision and control of DPR. City councils and county boards of supervisors are not permitted to adopt regulations (Food and Agricultural Code, § 11501.1). DPR took the position that both ordinances passed by Palo Alto and San Jose were invalid based on section 11501.1.

Despite good intentions to comply with effluent limitations, POTWs will increasingly face the same dilemma: compliance by imposing local ordinances to reduce loading of toxics, or support of legislation that will prohibit the use of offending toxics in their service area. With the implementation of a successful copper and tributyltin program, local governmental agencies will be able to rely on DPR to provide thorough research on the issue, perform an alternatives analysis, and offer a workable administrative solution to the problem.

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PART TWO — THE FATE OF COPPER IN THE ENVIRONMENT

Pamela C. Wales

Introduction

Copper is a natural constituent of seawater at concentrations from 0.001 to 0.02 parts per million (ppm), and in unpolluted surface waters in the United States at concentrations between 0.001 and 0.010 ppm (Merck, 1989; US EPA, 1984). In natural waters, copper occurs primarily as the Cu^{2+} ion, in both free and complexed forms.

Copper is used in the formulation of a number of pesticidal products. Copper-containing active ingredients are registered for a variety of agricultural and non-agricultural uses in California (Table 1).

Table 1. Representative copper-containing active ingredients and examples of their non-agricultural use.

Active ingredient	Examples of use
Copper sulfate, pentahydrate	Root control in sewer systems. Algal control in lakes, ponds, drainage canals, potable-water reservoirs, swimming pools, spas, hot tubs. Wood preservative.
Copper ethanol-amine complexes	Algal control in swimming pools, hot tubs, spas.
Copper triethanol-amine complexes	Algal control in swimming pools, hot tubs, spas.
Copper napthenate	Wood preservatives and finishes for decks, wood siding and shakes, fences and outdoor wood furniture.
Copper sulfate, basic	Root control in sewer systems.
Copper hydroxide	Anti-fouling paints for ship and boat hulls, and other marine surfaces.
Copper oxide	Anti-fouling paints for ship and boat hulls, and other marine surfaces.
Copper sulfate, anhydrous	Algal control in lakes, ponds, drainage canals, potable-water reservoirs.

Copper sulfate is an inorganic compound, often used as an aquatic algicide and foliar fungicide. The blue crystals are used to control most algal species in surface water, potable water, and rice fields. The chemical is also used to kill tree roots in sewer lines. Copper sulfate is toxic to most plants; however, it can be used as a foliar fungicide when mixed with lime to form Bordeaux mixtures (Royal Society, 1991).

The pentahydrate form of copper sulfate ($CuSO_4 \cdot 5H_2O$) is the type most commonly used (Table 2). Also available in basic and anhydrous formulations, copper sulfate is commonly referred to by a variety of other names, including blue stone, blue vitriol, and blue copperas.

Table 2. Physical and chemical properties of copper sulfate, pentahydrate.

CAS number	7758–98–7
Molecular formula	$CuH_{10}O_9S$
Molecular weight	249.7
Vapor pressure	non-volatile

Environmental fate of copper

Fate in water and sediments

In natural waters, trace metals such as copper can exist in a variety of forms, or species, including those that are dissolved, colloidally dispersed or particulate. Dissolved species consist of several well-characterized inorganic forms (including Cu^{2+} and inorganic complexes such as $CuCO_3$, $Cu(OH)_2$, and $CuCl_2$), and less well-defined complexes with naturally present organic ligands such as phytoplankton metabolites and humic substances (Bruland et al., 1992; Donat et al., 1994; and Kuwabara et al., 1989).

Particulate species include copper associated with colloids, or adsorbed onto or incorporated into particles resuspended from sediments by tidal or storm activity. Particles may be classified as large (> 5 μm) or small (0.4 to 5 μm). Large particles are influenced by storm and tidal activity, turbulence and currents. The particles are typically resuspended from bottom sediments and are rapidly removed by resettling following the disturbance. Some of these organic forms are very stable and once deposited can exist unchanged in sediment for thousands of years (Brügmann, 1984). Large particles can also include living phytoplankton and zooplankton. Small particles typically stay suspended for extended periods of time, and can include free bacteria, small phytoplankton, inorganic and organic detritus, and silt (Bruland et al., 1992; Donat et al., 1994 ; and Kuwabara et al., 1989). Determinations of total copper can include all of these various chemical and physical forms, some of which are not biologically available.

The partitioning, speciation, and complexation of copper by dissolved organic ligands have been studied by several groups (van den Berg, 1982; Sunda and Ferguson, 1983; Brügmann, 1984; van den Berg et al., 1987; Moffett and Zika, 1987; Gardner and Gunn, 1989; Coale and Bruland, 1988; Kuwabara et al., 1989; Nimmo et al., 1989; van den Berg et al., 1990; Coale and Bruland, 1990; Donat and van den Berg, 1992; Bruland et al., 1992; and Donat et al., 1994). They report that the predominant chemical form of copper in seawater is that of an organic complex, and copper speciation is dominated by association with dissolved organic matter. Kuwabara et al. (1989) observed that dissolved copper concentrations vary indirectly with salinity and directly with dissolved organic carbon, and suggest that the trend is a result of organic complexation.

Copper has been demonstrated to have a strong affinity for organic molecules; in fact, in estuarine waters the predominant form of copper is that of an organic species (Nimmo et al., 1989; Gardener and Gunn, 1989). Several authors reported that more than 80% and usually more than 99% of the dissolved copper in estuaries is complexed with organic ligands (Bruland et al., 1992).

Nimmo et al. (1989) reported that 98–99% of all of the copper in Liverpool Bay occurred in organic complexes. Bruland et al. (1992) studied ambient copper speciation during October 1991 and April 1992 in South San Francisco Bay. They reported that of the 3.11 ppb total dissolved copper detected in October, 27% (0.84 ppb) was chelated by a strongly complexing organic ligand, while 65% (2.02 ppb) was associated with a weaker complexing organic ligand, resulting in a total of 92% of the dissolved copper existing as organic complexes. They found 8% (0.25 ppb) of the dissolved copper in inorganic forms, with 0.4% of the total dissolved copper as free Cu^{2+}, and $CuCO_3$ as the dominant inorganic species. Their results from the following April were similar, with over 95% of the total dissolved copper associated with organic complexes, and nearly 5% as inorganic species. They also observed in laboratory studies that the free or inorganic copper was buffered at ambient concentrations; however, when the total dissolved copper exceeded 5 ppb, the copper-complexing organic ligands became fully complexed and any additional copper added beyond that point existed as inorganic species.

Blutstein and Exton (1983) studied the binding capacity of filtered and unfiltered sewage effluent when mixed with seawater of varying salinity. They argue that the high levels of complexing capacity they observed in the vicinity of the sewage outfall is atypical of unpolluted seawater values due to the large amounts of dissolved organic material supplied by the outfall itself.

Fate in aquatic organisms

Bioavailability and bioaccumulation

The impact of copper on the aquatic environment is dependent on the form in which it is present, and may be influenced by a number of other environmental and biological processes that affect bioavailability. Exposure occurs in both solution and particulate phases; from sediments to food supply, organisms are exposed to a variety of physical and chemical forms of copper. In his extensive review of literature concerning the bioavailability of trace metals to aquatic organisms, Luoma (1983) outlined four processes that occur at the organism–environment interface and determine the bioaccumulation of metals:

- The characteristics of the interface itself.
- Reactivity of the metal species with the interface.
- The presence of other molecules that may play either an antagonistic or facilitative role in metal uptake.
- Physical factors such as temperature that may affect the rate of biochemical reactions.

The same mechanisms that control the uptake and transport of substances into tissues also apply to metal transport. The principle mechanisms are diffusion across cellular membranes, active transport across membranes via carrier molecules, endocytosis, and intracellular digestion. Endocytosis (pinocytosis) has been documented in molluscs. Intracellular digestion involves the engulfing of substances (including metals) by vesicles outside of the cell membrane, but within the lumen of the stomach, and the movement of these substance-laden vesicles across the membrane and into the organism. This is the major form of digestion used by molluscs. Of these four mechanisms, most trace metals are transported across the cell membrane via carrier molecules (Luoma, 1983).

According to Luoma (1983), two aspects of metal uptake in aquatic organisms are unique. In some circumstances metal concentration may never reach steady-state. Uptake may occur over the course of a lifetime. Secondly, the ultimate level of bioaccumulation is not solely a function of transportation rates.

The form of the metal present in the food source determines assimilation efficiency (Reinfelder and Fisher, 1991). Several studies have shown that the toxicity and bioavailability of copper are controlled by its free metal ion concentrations instead of by total metal concentrations. Metal species with the highest free energy such as the free copper ion exhibit the greatest bioavailability because they react most readily with the carrier molecules that facilitate the diffusion of essential substances across the cell membrane (Luoma, 1983).

When copper is complexed by organic ligands its toxicity is decreased, presumably by decreasing its free ion concentration (Donat et al., 1994; Daly et al., 1990; and Luoma, 1983). An exception to this involves metals associated with plant cell fluids within living phytoplankton. In one study, metals bound to living phytoplankton cellular fluids were bioavailable and readily assimilated by copepod herbivores, but when associated with plant cell walls and membranes, were defecated by the copepods (Reinfelder and Fisher, 1991).

The dissolved fraction also includes trace metals associated with colloids. The bioavailability of colloidally bound toxic metals is essentially unknown for marine organisms, however, one study carried out with colloidally associated iron suggests that colloidally bound iron is biologically unavailable for direct assimilation and must first be remineralized to a truly dissolved form before assimilation (Rich and Morel, 1990).

Organisms living in eutrophic estuarine waters or environments subject to anthropogenic discharges are less susceptible to trace metal stress than those living in oligotrophic, open-ocean waters. Organic materials, capable of complexing with copper ions, are more abundant in estuarine waters and discharges than in the open ocean, and lead to a reduction in the free ion concentration and, subsequently, the bioavailability (Luoma, 1983). In the open ocean, concentrations of free copper are nearly the same concentrations that will inhibit the growth of some species of phytoplankton and fish embryos, despite the low concentration of total copper. In estuarine waters, total copper concentrations are usually higher than those in the ocean, but free copper ion concentrations may be much lower if organic ligands are present.

Although sediments represent the most concentrated reservoir of metals in aquatic systems, metal concentrations in sediments do not necessarily reflect concentrations that are biologically available (Thomson et al., 1984). As in water, the chemical form of the metal present determines bioavailability. In sediments, particulate size plays an important role; as large metal-laden particles settle rapidly to the estuarine bottom and become buried under subsequent layers of sediment, they become essentially unavailable, and if undisturbed can exist unchanged in the sediments for thousands of years (Brügmann, 1984).

Deaver and Rodgers, Jr. (1994) examined the bioavailability of copper in amended wetland systems. Employing successive ten-day experiments with *Hyalella azteca* and *Chironomus tentans*, they evaluated the bioavailability and toxicity of aqueous and sediment-associated copper from copper sulfate-treated, untreated, and control wetlands. They reported that although in some cases copper remained acutely toxic over the six-month study period, total copper concentrations

in sediment had no relation to bioavailable copper. Thomson et al. (1984) studied the biological availability of sediment copper and reported that neither sediment–metal concentrations nor discharge concentrations were reliable indicators of the bioavailable fraction.

In his review of literature concerning the bioavailability of trace metals to aquatic organisms, Luoma (1983) summarized an extensive survey conducted by Luoma and Bryan in the late 1970s comparing the concentrations of several metals in the sediments of 17 estuaries with concentrations of the same metals in two deposit feeders, the burrowing clam, *Scrobulicaria plana*, and the polychaete worm, *Nephthys diversicolor*. They observed statistically significant but weak correlations between total metals in the tissues of *S. plana* for all metals surveyed, with the exception of copper, while stronger correlations were observed between sediment concentrations of copper and *N. diversicolor*. Similar results have been observed in estuarine snails; however, Luoma notes that studies of such magnitude in other bottom-feeding species have been limited by the poor understanding of their feeding habits.

Johansson et al. (1986) studied the variability in the uptake and partitioning of copper and other metals among the cytosolic proteins in *M. balthica*. They found that uptake of copper (as well as that of other trace metals) into the cytosolic metallothionein-like proteins (MLPs) was dependent on exposure, both in laboratory and natural settings. MLPs are a class of low-molecular-weight, cysteine-rich proteins that strongly bind to trace metals and are thought to play an important role in the metabolism and tolerance of metals in bivalves. They concluded that even though *M. balthica* showed many symptoms of a metal-stressed population, the population as a whole is as much as 50-fold more tolerant to copper than other populations living in other portions of San Francisco Bay. They also stated that despite indications of stress, they had not proven conclusively that Palo Alto populations of *M. balthica* were adversely affected by trace metals, and noted that further studies are needed to understand the relationships between cause and effect when benthic communities undergo changes in their population profiles.

Acute and chronic toxicity

The toxicity of copper to aquatic life is directly related to the activity of the free copper ion (Cu^{2+}) and possibly to some of the associated hydroxy substances. Most organic and inorganic copper complexes tend to be much less toxic than the free copper ion, and also have the ability to reduce the toxicity from total copper. Daly et al. (1990) studied the influence of dissolved organic matter on the toxicity of copper to the Australian freshwater shrimp, *Paratya australiensis*, in laboratory studies. They found the presence of dissolved organic material dramatically reduced the toxicity of copper, presumably through the formation of nontoxic copper organic complexes.

Most toxicity data are reported as either total or dissolved copper, and do not take free copper or complexed copper into account. This complicates the interpretation of the available toxicity data. Furthermore, increasing calcium hardness and associated carbonate alkalinity have been shown to reduce the acute toxicity of copper (U.S. EPA, 1984). A summary of some of the available toxicity data for aquatic species in California are presented in Table 3.

Copper is less toxic to mammals than to aquatic life. There is no evidence that humans have ever been poisoned from consumption of copper in water, or from consuming aquatic organisms with elevated tissue copper concentrations. However, copper is considered to be relatively toxic to

aquatic life and has been found to be chronically toxic in concentrations as low as 10 ppb (SWRCB, 1990).

Presence in the environment

Sources

Trace metals, including copper, enter coastal seawater from a variety of sources (Brügmann, 1984; Thomson et al., 1984; and Lacy, 1993). Examples of sources include:

- Surface runoff
- Atmospheric fallout
- Industrial, commercial, or residential wastewater discharge
- Leachates from landfills
- Leachates from mines
- Recreational, naval, and commercial shipping activities

Concentrations and distribution in marine, fresh, and estuarine waters

San Francisco Bay Region

San Francisco Bay is the largest estuary along the western coast of the United States, with a surface area of 1,240 km^2 (Flegal et al., 1991). It has been described as a three-component system with distinctly different hydrographic and geographic features (Conomus, 1979). These three components are 1) the northern reach, that includes San Pablo and Suisun bays, and the confluence of the Sacramento and San Joaquin rivers, 2) the southern reach, often referred to as the South Bay, and 3) the Central Bay, which connects the other two to the Pacific Ocean at the Golden Gate. The Bay serves as a home for a number of wildlife and waterfowl species, provides a passageway to spawning grounds in inland rivers for salmon and striped bass, and supports a wide variety of sport and commercial fishing. It also provides passageways and harbors for commercial and naval shipping, and has served as a receptacle for wastewater.

Flegal et al. (1991) studied the dissolved trace element cycles in San Francisco Bay. They reported that concentrations of many trace elements including copper in the South Bay were high with respect to concentrations at comparable salinities in the northern part of the system. In part, they attributed this effect to the bifurcated structure of the system. The deep northern reach receives large amounts of freshwater input from the Sacramento and San Joaquin rivers, resulting in a stratification of the water column in the bays and channels, with low-salinity surface currents flowing toward the ocean and comparatively high-salinity bottom currents flowing toward inland regions. In comparison, the predominantly shallow water column of the South Bay is vertically mixed, with wind-driven circulation accounting for the currents that exist in this area.

Table 3. Toxicity of copper to some aquatic species in California.

Species	Life stage	Exposure time	Type of study	Concentration	Comments	Reference
Capitala capitata	Adult	96 hr	LC_{50}	200 mg/L		Reish et al., 1976[a]
Capitala capitata	Adult	28 d	LC_{50}	200 mg/L		Reish et al., 1976[a]
Capitala capitata	Juvenile	96 hr	LC_{50}	200 mg/L		Reish et al., 1976[a]
Nereis diversicolor		96 hr	LC_{50}	500 mg/L		Bryan, 1974[a]
Nereis diversicolor		96 hr	LC_{50}	410–480 mg/L	Acute	Jones et al., 1976[a]
Nereis diversicolor		96 hr	LC_{50}	300 mg/L		Bryan and Hummerstone, 1971[a]
Abalone		48 hr	LC_{50}	85 mg/L		Harrison et al., 1977[a]
Mytilus edulis	Larva	2 hr	LC_{50}	>20,000 mg/L		Wisely and Buck, 1967[a]
Mytilus edulis	Adult	96 hr	LC_{50}	300 mg/L		Davenport, 1977[a]
Mytilus edulis	Adult	96 hr	LC_{50}	>300 mg/L		Abel, 1976[a]
Mytilus edulis	Adult	6 d	LC_{50}	20,000 mg/L		Delhaye and Cornett, 1975[a]
Crassostrea gigas	Embryo		LC_{50}	5.3 mg/L	Acute	Martin et al., 1981[b]
Crassostrea gigas	Embryo		LC_{50}	11.5 mg/L	Acute	Coglianese and Martin, 1981[b]
Mytilus edulis	Embryo		LC_{50}	5.8 mg/L	Acute	Martin et al., 1981[b]
Salmo gairdneri	Adult		LC_{50}	42.5 mg/L	Average acute	U.S. EPA, 1984.
Salmo gairdneri	Adult		LC_{50}	19.01 mg/L	Chronic	McKim et al., 1978[b]
Crassostrea gigas			EC_{50}	9.3-20.4 mg/L	MCV	S.R. Hansen & Associates, 1992
Thalassiosira pseudonana			EC_{50}	4.2–14.1 mg/L	MCV, dissolved	S.R. Hansen & Associates, 1992
Thalassiosira pseudonana			EC_{50}	7.3–28.3 mg/L	MCV, total Cu	S.R. Hansen & Associates, 1992
Thalassiosira pseudonana		~2–4 d	Growth	0.32 mg/L	Growth rate ceased	Sunda and Guillard, 1976
Nannochloris atomus		~2–5 d	Growth	0.003–0.13 mg/L	Growth rate inhibition	Sunda and Guillard, 1976
Lyngbya spp.			Population density	2.5 mg/L (total) or 12 ng/L (free Cu^{2+})	Population density markedly reduced	Leland and Carter, 1984
Spirogyra spp.			Population density	5 mg/L (total) or 25 ng/L (free Cu^{2+})	Population density markedly reduced	

[a] Taylor, D. and L. Carter. 1988.

[b] U.S. EPA, 1984.

There are corresponding differences in hydraulic residence times within the San Francisco Bay system. The estimated mean hydraulic residence time in the northern reach is 1.2 days during high-flow and 60 days during low-flow conditions. In the southern reach, residence times range from 120 days during high-flow and 160 days during low-flow conditions. While nearly all of the freshwater input to the system originates in the northern part of the Bay, it causes a seasonal flushing of the South Bay during winter high-runoff periods (Flegal et al., 1991).

Flegal et al. (1991) collected water samples from 27 locations throughout the Bay (eight from the southern reach, six from the Central Bay, and 13 from San Pablo and Suisun Bay in the northern reach) during April, August, and December 1989 (Table 4). The samples were collected from one meter below the water surface. During the study period, Flegal et al. (1991) reported that the normal seasonal flushing was absent as a result of drought conditions that had existed for three years. They recognized that the protracted low-flow conditions may have resulted in atypical trace element concentrations and distributions during their study period, but stated that these unusual low-flow conditions may become the norm considering the systematic increase in freshwater diversions and increased demands on the water supply from a growing population within the area. The authors attributed the difference in the distribution of copper (and the other trace elements they studied) to the relatively large inputs of anthropogenic wastes to the South Bay. Davis et al. (1990) reported that wastewater discharges of copper to the South Bay ranged from 28–46 kg/day, significantly higher than those from the northern reaches or the Sacramento–San Joaquin River Delta, at 7.4–13 kg/day). Flegal et al. (1991) concluded that inputs from wastewater discharges alone can account for all of the excess dissolved copper in the South Bay

Kuwabara et al. (1989) studied the trace metal associations in the water column of the South Bay during the months of March, April, July, and September of 1985. They reported dissolved copper distributions ranging from 24 to 66 nM and particulate copper distributions ranging from 22 to 65 μg/g. They found dissolved copper concentrations varied directly with the dissolved organic carbon concentration and indirectly with salinity. They also monitored municipal treatment plant effluent to the South Bay during the dry season when they conducted their study. They reported effluent total copper concentration ranges from 30 to 280 nM, and concluded that treatment plant effluent represented a significant source of trace copper input into the South Bay.

Table 4. The distribution of dissolved copper in San Francisco Bay during April, August, and December 1989 (Flegal et al., 1991).

Sample	Dissolved copper concentrations (nmol/kg)		
Location	*April*	*August*	*December*
Extreme South Bay	68	73	43
Dumbarton Bridge	50	63	43
Redwood Creek	47	52	36
San Bruno Shoals	35	40	40
Hayward Flats	33	46	43
San Francisco Airport	31	36	37
San Leandro Channel	29	36	36
Hunter's Point Channel	22	32	23
Berkeley Flats	20	20	21
Golden Gate	17	16	8.5
Alcatraz Island	18	19	8.7
Angel/Treasure Islands	18	22	14
San Rafael Bridge Shore	22	23	17
San Rafael Bridge Channel	25	27	13
San Pedro Point	27	30	17
Petaluma River	31	35	—
Pinole Shoal Channel	32	38	20
Pinole Shoal Shore	29	33	22
Benicia Bridge	38	42	34
Pacheco Creek	38	39	34
Grizzly Bay	40	37	36
Port Chicago	39	—	36
Honkers Bay	37	35	36
Stake Point	—	26	—
Chips Island	36	34	34
New York Slough	36	28	35
Sacramento River	36	29	36

The Water Resources and Geological Division of the U.S. Geological Survey has conducted several studies on, and issued summaries of, the impact of wastewater discharges on the aquatic organisms living in San Francisco Bay (Kuwabara et al., 1989; Johansson et al., 1986; Cain and Luoma, 1985; Luoma et al., 1985; Thomson et al., 1984; Luoma, 1983; and Luoma and Cloern, 1982). In a summary of work concerning the use and protection of San Francisco Bay, Luoma and Cloern (1982) categorized wastewater discharge into continuous and intermittent sources and

identified several specific sources of copper contamination. Point sources, such as municipal discharge or industrial wastes, make up the continuous sources. An example of a continuous point source in San Francisco Bay is the Palo Alto sewage outfall in the South Bay. Two sources of intermittent discharge include seasonally varying storm runoff and fresh water inflows from rivers and streams, and accidental spills, sewage treatment plant breakdowns, and periodic dredging. An example of an intermittent discharge source includes San Francisquito Creek, a source of urban storm runoff.

The concentrations of toxic materials in organisms are often used as indicators of the presence of biologically important contaminants. Luoma and Cloern (1982) summarized and compared the results of several studies conducted in the Bay with those conducted in other California coastal bays. They report that concentrations of copper in the estuarine bivalve, *Macoma balthica*, in the South Bay exceed any previously reported from 37 European estuaries.

Luoma et al. (1985) discussed the concentrations of copper that were measured by Thomson-Becker and Luoma (1985) in the soft tissues of *M. balthica* living in South San Francisco Bay over a period of two to three years, and over a period of eight years at a metal-enriched site. These near-monthly monitoring data showed that the fluctuations of copper were greatest in the clams living at stations with the most metal enrichment and the least dilution and flushing of waste. The metal-enriched site was located 1 km south of a sewage treatment plant that contributed a substantial amount of copper to the area. Native *M. balthica* were collected from the intertidal zone at low tide, dissected, and their tissues and shells were analyzed for copper and other trace metals. Sediments were also collected from the surface oxidized layer at the sediment–water interface and analyzed for the same trace metals. Data were presented in graphs; therefore, exact values were not available. However, a consistent seasonal pattern of copper fluctuations was evident, with copper concentrations varying from approximately 50 to 500 μg/g body weight. The concentrations were reported to increase rapidly between September and November, reaching a maximum between December and March, and returning to a minimum each summer. They noted that this consistent seasonal fluctuation was not evident in the monthly samples of plant effluent, leading them to conclude that inputs from the waste treatment plant were not solely responsible for the changes observed in the clams. Although they reported that the spring decline in copper concentrations often occurred in concert with the decline in salinity associated with the influx of fresh water from the Sacramento and San Joaquin rivers, a direct influence of salinity on copper bioavailability was not established. A relationship between the amplitude of the fluctuations and the monitoring location was established. Fluctuations in the copper concentrations were greatest where both the sediment and animal copper concentrations were highest and the residence time of the water was longest. These conditions occurred at the extreme southern end of the South Bay.

Luoma et al. (1985) also concluded that the seasonal copper concentration fluctuations in *M. balthica* partially resulted from variations in tissue mass, and from hydrodynamic changes that occur annually. They also noted that the use of indicator organisms is the only method available to assess biological availability of metals in an estuary, and therefore, year-to-year variations in the concentrations of metals in estuaries will not be detected from just a few organism samples per year. The determination of seasonal fluctuations and an understanding of the mechanisms in effect require long-term studies.

Cain and Luoma (1985) compared the accumulation of copper in transplanted clams (*M. balthica*) to resident clams in the South Bay near Palo Alto, populations with very different exposure histories. They reported that copper accumulation in the transplants that previously had been exposed to very low levels of copper did not occur during times when increased concentrations of copper in the resident population indicated that exposure to copper was high. Furthermore, the accumulation of copper by the transplanted clams, compared to the resident clams, was not consistent between the summer and winter. The authors noted that summer accumulations were similar between the two groups; however, during the winter period, when environmental exposure was increased, net accumulation by the transplanted clams was much less than the resident population (Figure 1). The authors stated that if uptake and loss rates were the same in both populations, the net quantity of copper accumulated by the transplants should have been greater because they had a lower existing body burden. After eliminating the possibility of the transplantation and caging effects as a reason for the differences, they speculated that the difference in metal accumulation between the two groups might be the result of past environmental exposure. They suggested that the differences may be related to high concentrations of MLPs in resident clams that were routinely exposed to high levels of copper, due to chronic metal exposure. The authors observed that the results of their observations illustrate some of the limitations of using transplants as indicators of pollution impact upon resident populations.

Other locations in California

Young et al. (1979) used the bay mussel *Mytilus edulis* as a bioindicator to determine the contamination of copper and other trace metals in several Southern California harbors and coastal regions, comparing mussel distribution with corresponding bottom sediment values reported from other studies. They measured the concentrations of copper in digestive gland, gonad, and muscle tissues of *M. edulis* from the various locations. They also studied the degree to which aquatic biota can be contaminated by vessel-related activities in coastal and harbor waters, as compared to copper from run-off and aerial fall-out. They reported that 180,000 kg of copper were applied annually to vessels in Southern California, approximately 40,000 kg entered the coastal ecosystem because of storm run-off from surrounding populated areas, about 30,000 kg was contributed from aerial fall-out, and approximately 510,000 kg of copper were discharged via coastal submarine municipal outfalls (Table 5). They concluded that both vessel-related activities and coastal wastewater discharges can contribute to distinct elevations of trace metal pollutants in nearshore marine organisms.

Figure 1. Copper concentrations (μg/g) of resident and transplanted *Macoma balthica* from a copper-contaminated South San Francisco Bay site. Bars indicate ± one standard error of the mean (Cain and Luoma, 1985).

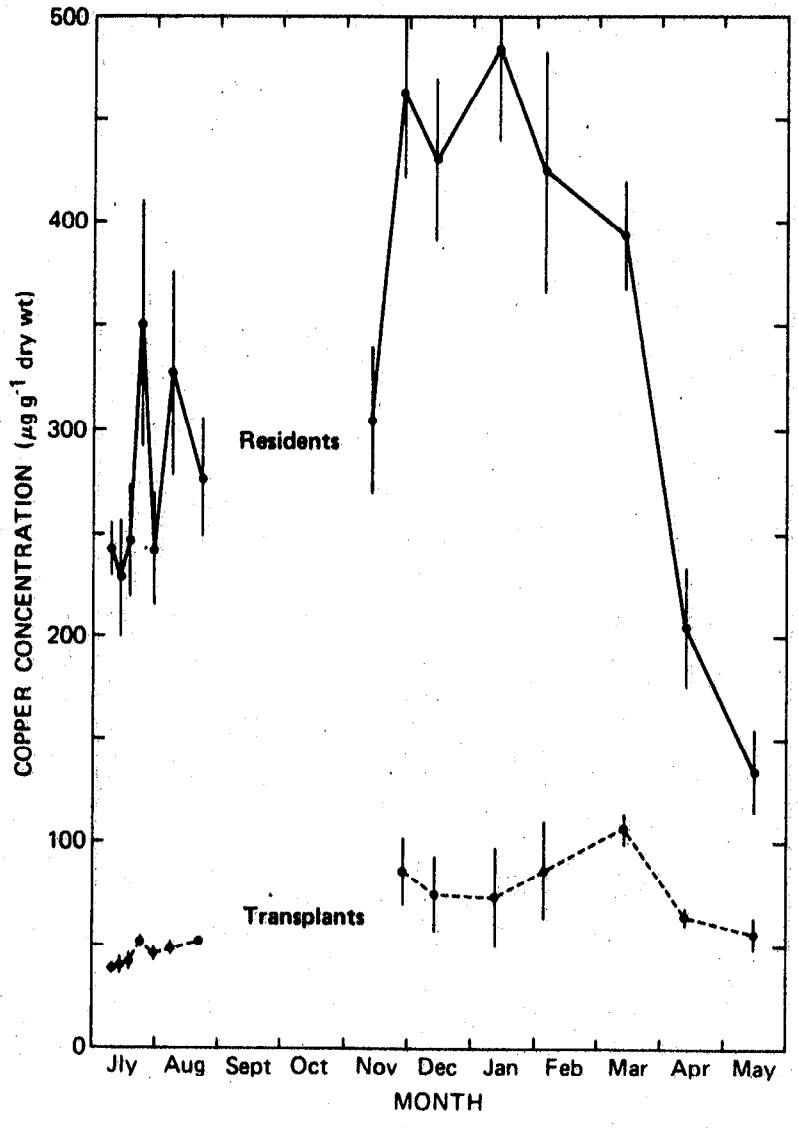


Table 5. The concentration of copper in *Mytilus edulis* tissues Southern California) (Young et al., 1979).

Site	Digestive gland (mg/kg dry wt)	Gonad (mg/kg dry wt)	Muscle tissue (mg/kg dry wt)	All other tissues (mg/kg dry wt)	Primary source of copper
Newport Harbor (Sta. I.) San Diego Bay	127 ±18	93±15	52±10	100±14	Large recreational vessel painting and repair facilities.
Coastal location (Sta. H.) San Diego Bay	16±1.0	9.6±0.2	5.7±0.3	11±0.6	
Royal Palms Beach, San Pedro Harbor	47±2.8	42±0.5	14±1.0	44±7.0	Submarine discharge of municipal wastewater from Los Angeles County Sanitation District
Coastal Stations, San Pedro Harbor	20±2.4	10±0.8	11±2.9	13±1.5	

McCain et al. (1992) studied the relationship between chemical pollution and associated fish diseases in San Diego Bay between 1984 and 1988. They reported that although the sediment concentrations of copper were significantly higher at sites within San Diego Bay (nearly 180 µg/g) compared to a nonurban Dana Point site (< 10 µg/g) located outside of the Bay, concentrations of copper from livers of white croakers and barred sand bass from San Diego and Dana Point did not differ significantly. The researchers observed this lack of a relationship between sediment and fish tissue concentrations consistent with the results of studies conducted along coastal waters in other parts of the United States.

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PART THREE — THE FATE OF TRIBUTYLTIN IN THE ENVIRONMENT

Pamela C. Wales

Introduction

Tributyltin (TBT) compounds are organic derivatives of tetravalent tin (Sn^{4+}) and have the general formula $(CH_3–CH_2–CH_2)_3$ Sn — R where R is a covalently linked anion or group. The nature of the covalently–linked anion or group influences the physical and chemical properties of the resulting TBT derivative, in particular its solubility in water and vapor pressure (IPCS, 1990). The commercially important tributyltin derivatives include TBT oxide, TBT benzoate, TBT methacrylate, TBT neodecanoate, and TBT fluoride (Table 6).

Table 6. Physical and chemical properties of some TBT derivatives .

	TBT oxide	TBT benzoate	TBT methacrylate	TBT neodecanoate	TBT fluoride
CAS number	56–35–9	4342–36–3	2155–70–6	28801–69–6	1983–10–4
Molecular formula:	$C_{24}H_{54}OSn_2$	$C_{19}H_{32}O_2Sn$	$C_{16}H_{32}O_2Sn$	$C_{22}H_{46}O_2Sn$	$C_{12}H_{27}FSn$
Molecular weight	596.2	411.2	375.2	461.4	309.1
Vapor pressure (Pa at 20°C)	1×10^{-3}	2×10^{-4}	3×10^{-2}	—	—
Density (20°C)	1.17–1.18	≈1.2	1.14	—	1.25
Solubility	750 mg/L @ pH 6.6 31,000 mg/L @ pH 8.1	—	—	—	—

Sources: IPCS, 1990; Lewis, Jr., 1992; U.S. EPA, 1987.

Environmental fate of tributyltin

Since the late 1970s, when the ecological and economic effects of TBT on an important commercial stock of oysters in Arcachon Bay, France became evident, several groups have studied the environmental persistence and fate of TBT in aquatic ecosystems. It soon became evident that this long-acting, effective antifouling biocide had a detrimental affect on non-target organisms. The threshold concentration for biological effects was determined to be low, at about 20 ng TBT per liter of seawater. Based on this information, in 1982 France became the first country to take regulatory action by banning the use of TBT paints on all pleasure craft of less than 25 m in length, in an attempt to protect French oyster culture farms. French oyster farms have estimated losses at around $147 million during the period from 1977 until 1983, one year following the ban of TBT hull paints by that government. Following further research, both the United States and the United Kingdom enacted similar control measures. Evidence that only a few nanograms of TBT per liter

of seawater elicited a morphological change in a marine snail resulted in a lowering of the environmental quality target levels to 2 ng TBT per liter in the United Kingdom (Alzieu, 1991; Mee and Fowler, 1991; Waite et al., 1991). Reports from several regions in the United States showing TBT concentrations that exceeded the toxic limits for several sensitive marine species led to regulatory and legislative action to restrict the use of TBT antifouling paints on craft less than 25 meters in length, to require the use of low-release–rate paints in authorized applications, and to remove TBT paints from retail sale (IPCS, 1990). California followed suit, adopting regulations in January 1988 that restricted the use of TBT paints to large vessels (> 25 m in length). California's Department of Fish and Game and Department of Pesticide Regulation have monitored TBT and dibutyltin levels in Lake Tahoe and San Diego Bay since 1987 to assess the effectiveness of use restrictions. Residues in the sediments and organisms in these areas have declined sharply, demonstrating that restrictions on use have reduced TBT levels in these aquatic environments (Menconi, 1994).

Although there is some disagreement between the results of the different studies, it is generally agreed that:

- Because of its low solubility in water, TBT preferentially leaves the aqueous phase and adsorbs onto suspended particles and the sediment, in the aquatic environment.
- Significant amounts of TBT are associated with sediments in estuaries.
- TBT is more persistent in sediments than in the water column.
- The main factors limiting the persistence of TBT in aquatic ecosystems are the photolysis of TBT in water and biological degradation in water and sediment.
- TBT degrades through a series of debutylation steps to dibutyltin (DBT) and monobutyltin (MBT).
- The highest levels of TBT in the aquatic environment are primarily associated with ship or boat maintenance areas, and secondarily effluent outfall areas.
- The fate of TBT varies in the aquatic environment: physical and chemical properties operating in one region may not be applicable to others.

Fate in water

Estuarine water

Estuarine environments are dynamic systems, characterized by high biological productivity, and fluctuations in salinity, amounts of suspended particulates, and ionic concentrations. These areas also tend to receive input from the development of harbors and marinas, the encroachment of urban areas, and run-off from urban and agricultural activities.

Several studies address the fate of tributyltin in an estuarine environment (Lee et al., 1989; Seligman et al., 1989; Stang and Seligman, 1987; Donard and Weber, 1985). The World Health Organization has summarized many other studies (IPCS, 1990). Generally, the fate of the tributyltin derivatives in the estuarine environment is closely associated with their low solubility in water and their lipophilic characteristics. When TBT is introduced into natural waters, partitioning occurs and TBT leaves the aqueous phase and preferentially adsorbs onto suspended particles. The degree of adsorption depends on the characteristics and amount of the suspended particles, the salinity and temperature of the water, and the presence of dissolved organic material.

The reported amount of TBT that is adsorbed onto suspended particles ranges from 10 to 95% and varies with the conditions present (IPCS, 1990). Data suggest that in salinities approaching that of seawater, TBT is more strongly adsorbed, while in less saline water, TBT adsorption is reduced.

Once adsorbed, degradation of TBT occurs by biological action. Lee et al. (1989) reported that microalgae (dinoflagellates and diatoms) play an important role in degradation of TBT in sunlit estuarine waters. They monitored the degradation of TBT in sunlight and in darkness, in natural estuarine water and estuarine water from which they had removed the biological components by filtration and/or poisoning with a 3% formalin solution. The authors reported that TBT degradation in unaltered estuarine water occurred faster in sunlight than in darkness, with half-lives ranging from 3–13 days. This is consistent with another report of half-lives in the marine environment ranging from 4–14 days (Seligman et al., 1989). However, Evans and Huggett (1991) reported a degradation half-life of two to three years, based on statistical modeling of data collected during an intensive monitoring program they conducted from 1986 to 1989 in two tidal creeks of the Chesapeake Bay. Lee et al. (1989) noted that TBT degradation did not occur in the water lacking biotic components. When unaltered estuarine water was supplemented with nitrates, the degradation half-life was reduced to one to two days, and was associated with the stimulation of algal growths.

Non-estuarine water

Stang and Goldberg (1989) reported the average rate of degradation of TBT in fresh water is about the same as that in marine water; however, Stallard et al. (1987) reported that fresh and brackish waters generally had a much lower DBT/TBT ratio (an indication of the degree of degradation) than did comparable seawater samples. They concluded from their studies that TBT degradation may occur at a slower rate in fresh water than in seawater. Other studies have suggested that the degradation processes that occur in fresh water are not so much affected by the differences between salt and fresh water, but by the various physical characteristics such as turbidity, circulation, tidal flushing, and nature of source of contaminants present in a given body of water (Stang and Goldberg, 1989; Huggett et al., 1986).

Fate in sediments and sludge

Fate in sediments

Many studies address the fate of TBT in marine and estuarine sediments (Dowson et al., 1993a; Dowson et al., 1993b; Stang et al., 1992; Kram et al., 1989; Krone et al., 1989; Seligman et al., 1989; Unger et al., 1988; Maguire et al., 1985; Maguire and Tkacz, 1985; Maguire, 1984; and Maguire et al., 1983). Most of these studies concern the degradation of TBT in sediments; some also address the bioavailability of sediment-bound TBT (Table 7).

Table 7. A summary of tributyltin degradation studies in aquatic sediments.

Half-life of degradation	Location of sediment	Additional comments	Reference
10 months	Toronto Harbor, Canada	Desorption half-life, sterile sediment	Maguire and Tkacz, 1985a
4 months	Toronto Harbor, Canada	Water-sediment mixture	Maguire and Tkacz, 1985b
23 weeks	San Diego Bay, CA		Stang and Seligman, 1986
0.9–5.2 years	Essex and Suffolk, U.K.	Estuarine and freshwater sediment cores	Dowson et al. 1993a
1–2.1 years	Essex and Suffolk, U.K.	Controlled lab conditions, surface sediments	Dowson et al. 1993b

TBT degradation is slower in sediment than in water, with half-lives in months instead of days.

Municipal wastewater and sewage sludge

One group has investigated the concentration and fate of TBT during sewage sludge treatment in Zurich, Switzerland (Fent et al., 1991). The authors found that municipal wastewater and sewage were contaminated by organotin compounds; raw sewage sludge contained TBT, DBT, and MBT residues ranging from 0.28–0.83 mg/kg. Like the situation in sediment, TBT in wastewater and sewage sludge is primarily adsorbed onto particulate matter. They monitored the fate of the organotin compounds at various conditions (aerobic, anaerobic, mesophilic, thermophilic) and found the degradation rate of TBT during sludge treatment to be low, regardless of the conditions. They concluded that the abundance of nutrient materials present in sewage sludge may interfere in the degradation of TBT.

Fate in aquatic organisms

Tributyltin has been called the most toxic substance ever intentionally introduced into the marine environment (Mee and Fowler, 1991; IPCS, 1990). It first entered the marine environment in the mid-1960s as an active ingredient in marine antifouling paints. TBT is one hundred to one thousand times more toxic to laboratory animals than the zinc and copper compounds it replaced (Lenihan et al., 1990; Stallard et al., 1987). During the decade following its introduction, sales of TBT increased as manufacturers and users recognized the cost effectiveness of its use. The environmental and economic impact of TBT did not become evident until the deformative and reproductive failures of *Crassostrea gigas* (an important commercial stock of oyster) were noted in Arcachon Bay, France during the late 1970s (Alzieu, 1991; Mee and Fowler, 1991).

Once in the marine environment, TBT can be taken up by marine organisms through exposure to TBT-contaminated water and sediments, or ingestion of TBT-contaminated food sources.

The mechanisms of the storage and the elimination of TBT by the organism depends upon that organism's ability to metabolize the compound (Lee, 1991). The World Health Organization (IPCS, 1990) and U.S. EPA (1987) have provided excellent summaries of the earlier efforts to understand the environmental fate of this compound.

Bioavailability and bioaccumulation

Several groups have studied the bioavailability and bioaccumulation of tributyltin in a variety of marine life. In general, they have found that:

- the behavior of TBT resembles that of other hydrophobic, nonpolar organic compounds in that it tends to accumulate differentially in the lipid-containing portions of tissues and cells with the highest concentrations in the viscera and gills (Lee, 1991; Laughlin, Jr. et al., 1986).
- even when exposed to low ambient concentrations of dissolved TBT, marine mussels will quickly and effectively accumulate TBT.
- although dibutyltin and tributyltin compounds are functionally similar, TBT is much more toxic in both acute and sublethal responses than DBT (Laughlin, Jr. and French, 1989).
- estuarine sediments represent a significant source of TBT contamination, particularly to bottom-feeding organisms in these environments.

Laughlin, Jr. et al. (1989) studied the accumulation of tributyltin by the blue mussel *(Mytilus edulis)* in the San Francisco Bay. They found that in the laboratory, marine mussels rapidly and efficiently accumulated TBT when exposed to ambient concentrations as low as 0.5 µg/L seawater. They reported that uptake also occurred, and at a much higher rate, when TBT was associated with the phytoplankton *Isochrysis galbana*, the major food source of the blue mussel. They found the highest concentrations of TBT in the gill tissue and viscera (4.5 µg TBT/g tissue after 47 days of exposure to TBT-contaminated water, and ≈5 µg TBT/g tissue following 30 days of exposure to contaminated *I. galbana*). Once TBT-exposed mussels were returned to the field, the half-life for depuration was reported to be 14 days.

Mytilus edulis was also the subject of research conducted by Short and Sharp (1989). They measured tissue concentrations of TBT in bay mussels collected from California, Washington and Alaska in 1986 and 1987 in an attempt to estimate the decline of environmental TBT that should have resulted from enacted legislation limiting the use of TBT-containing antifouling paints in those areas. They reported concentrations of TBT ranging from < 0.005 to 1.08 µg TBT/g tissue. The highest concentrations of TBT were associated with marinas or areas of high boat traffic, however, TBT was detected in mussels living in areas with little to no boat traffic. They concluded that sources of TBT pollution are not limited solely to marinas or areas of boat traffic, and significant decreases in the concentration of TBT in mussel tissues should result in less than one year following an appreciable reduction of the amount of TBT released into coastal waters.

Batley et al. (1989) measured the accumulation of tributyltin (as inorganic tin, Sn) by the Sydney rock oyster (*Saccostrea commercialis*) and the Pacific oyster (*C. gigas*) sampled from estuaries in New South Wales, Australia. They found tissue concentrations ranging from < 2 ng Sn/g in rock oysters from areas with no TBT exposure to 130 ng Sn/g in rock oysters exposed to high densities of boat traffic or poor tidal flushing. Shell deformities and reduced tissue weights were

associated with all samples exposed to water concentrations of TBT in excess of 10 ng Sn/L. Specimens of the Pacific oyster, growing alongside Sydney rock oysters, contained 2–3 times greater concentrations of TBT.

The impact of TBT and inorganic tin on species living in the estuaries and coastal regions of the United Kingdom (UK) was assessed by Langston et al. (1990). They noted that sediment-bound TBT exhibited a higher degree of bioavailability than dissolved TBT, especially among estuarine bottom-dwelling species, such as the clam, *Scobicularia plana*. They also reported that the presence of aqueous concentrations of inorganic tin (mostly as the relatively insoluble $SnO[OH_3]^-$) seemed to offset some of the deleterious effects of the organotin, and suggested that the bioavailability and environmental impact of tin, as for many other metals, are related to chemical speciation.

Lenihan et al. (1990) studied the changes in community patterns induced by tributyltin in the hard-bottom, or fouling, communities of San Diego Bay. They found a large difference in the characteristic species that comprised the communities dwelling in areas of few boats, as opposed to those dwelling in areas relatively free of boat and marina activities. Areas with much vessel activity were reportedly characterized by sepulid polychaete worms, filamentous algae, and a tunicate, *Ciona intestinalis*. In areas with little or no boat or marina activity, these groups were replaced by mussels, sponges, bryozoans, and other tunicates, reportedly those hard-bottom communities characteristic of natural reefs. The authors concluded that community patterns in back-bays with many boats could be caused by the contamination with TBT (from anti-fouling paints) coupled with poor flushing or water circulation.

Deposit-feeding bivalves from 25 estuaries in England and Wales consistently contained higher concentrations of organotin than did other coexisting benthic organisms, indicating that preferential uptake of organotins from sediments may be an important route for bioaccumulation in *S. plana* (Langston and Burt, 1991). The authors measured the concentrations of TBT, DBT, inorganic tin and total tin in water, sediments and deposit-feeding clams to compare the bioavailability of different forms of tin, and studied the kinetics of TBT accumulation and elimination in the clams. They found that TBT and DBT are rapidly bioaccumulated from sediments. The authors reported that within a few days, clams held in sediments containing 10 µg TBT/g accumulated tissue levels of 25–30 µg TBT/g, a level sufficiently toxic to result in the death of these clams within two weeks, while clams held just above the sediment surface in the same tanks without direct contact with sediment, had only accumulated < 5 µg TBT/g after 50 days. They concluded that the sediments rather than desorbed TBT were the major vector for bioaccumulation.

In studying the subsequent elimination of TBT from *S. plana*, Langston and Burt (1991) found initially that elimination was rapid in those clams previously exposed to 1.0 µg TBT/g, and somewhat slower for those clams exposed to lower concentrations. From laboratory studies, they calculated half-lives of 14.5 and 27.5 days for clams previously treated with 1.0 and 0.3 µg TBT/g, respectively. They reported a half-life of about 50 days for clams that were collected from contaminated estuaries and placed in tanks of TBT-water in the laboratory.

Acute and chronic toxicity

There are several studies that address the toxicity of tributyltin to marine life. In general, these studies show that:

- organotins lead to an altered biology/ecology of numerous species. Extreme gross morphological and physiological sexual anomalies have been documented in many estuarine and marine species.
- the NOEL for TBT in oysters may be as low as 2 ng/L of seawater;
- all of the characteristic effects associated with TBT poisoning are hormonally regulated: TBT and hormones share common metabolic pathways.

Laughlin, Jr. and French (1989) examined the toxicity responses by zoeae of the mud crab *Rhithropanopeus harrisii* to TBT and DBT in the laboratory. They found TBT to be 54 and 65 times more toxic than DBT for crabs collected from Sykes Creek, Florida and Petaluma River, California, respectively. They reported LC_{50} values for both TBT and DBT. These values varied depending on the species origin. LC_{50} values reported for California crab zoeae were 13.0 µg TBT/L and 0.807 mg DBT/L, and for the Florida crabs were 33.0 µg TBT/L and 1.66 mg DBT/L.

Langston et al. (1990) assessed the deleterious effects of TBT-contaminated water on the dogwhelk, *Nucella lapillus*, a marine gastropod, by correlating a sequence of TBT-induced reproductive abnormalities, termed imposex, with the concentration of TBT in the aqueous environment. These phenomena, first identified in the estuarine snail *Ilyanassa obsoleta*, involve the development of a penis, vas deferens, and nonfunctional oviduct by female gastropods (Smith, 1980). The degree to which development of these anomalous characteristics affects the organism varies with the individual species, and may eventually lead to sterilization and death for the individual and ultimately to the loss of whole populations. In the case of *N. lapillus*, treatment with TBT has been demonstrated to convert ovaries into sperm-producing testes (Gibbs et al., 1988). Langston et al. (1990) reported that the initiation of imposex occurred at seawater concentrations below 1 ng/L (measured às inorganic Sn) and complete sterilization occurred after prolonged exposure to 3 ng/L. They warned that population recovery would not be possible until seawater TBT concentrations fall below the level that does not sterilize all developing females (about 2 ng/L), a level that was adopted as an environmental quality target (EQT) by the UK.

Curtis and Barse (1990), while studying the imposex phenomenon in the estuarine snail *I. obsoleta* living in the estuarine habitats of southern Delaware, reported that the same conditions that generate imposex in the female also affect male sexuality in this species. Two observations led the authors to this conclusion: 1) healthy *I. obsoleta* males normally lose the penis following reproduction, however they tend to retain it where female imposex-inducing conditions (the presence of organotin molecules in the water) were strong; and 2) males parasitized by trematodes normally lose the penis, but do not under the conditions that cause imposex.

The effects of tributyltin contamination in oysters have been summarized by Alzieu (1991). Documented abnormalities in *C. gigas*, an oyster of commercial importance, include the formation of wafer-like chambers of the shell following the abnormal secretion of an interlamellar jelly, reproductive failures, and mortality. The no-effect level (NOEL) was determined to be 20 ng/L,

while exposure to TBT levels as low as 50 ng/L caused mortality after two days, although Alzieu et al. (1991) reported that levels as low as 2 ng/L can cause deformities. In comparison, the NOEL for copper chloride is nearly five hundred times higher, at 10 µg/L.

Stephenson (1991) assayed the affects of TBT toxicity on *C. gigas* oysters in 26 bays, estuaries, and near-shore locations in California, including marinas, sewage, and refinery discharge areas, abandoned harbors and off-shore areas, following observations in Coos Bay, Oregon and Morro Bay, California, where oyster-growing areas had either been abandoned or oysters living there manifested the chambering deformities characteristic of TBT toxicity. He reported that at TBT levels of 40 ng/L no oysters developed normally or were commercially viable. Even at 10 ng/L, deformities were noted in developing oysters. Stephenson did not evaluate development at TBT levels below 10 ng/L.

Salazar and Salazar (1991) conducted field transplant tests from 1987 to 1990 in San Diego Bay to assess effects of TBT contamination on mussel growth rates. They measured mean concentrations of TBT in seawater ranging from 2 to 530 ng/L with corresponding tissue concentrations between 0.1 to 3.2 µg/g. They reported that normal growth was dependent on seawater and tissue TBT concentrations, with the lowest growth rates occurring at the most contaminated sites. The NOEL concentration has been estimated at 0.5 µg/g, which corresponds to those oysters exposed to TBT concentrations of about 25 ng/L or less (Page and Widdows, 1990).

Lee (1991) summarized recent work on the metabolism of TBT by marine animals and described possible metabolic linkages to the observed effects of TBT toxicity. He relates that tributyltin, like many other toxic compounds, is hydrophobic and tends to accumulate in the lipid-rich portions of tissues and cells. Marine organisms eliminate hydrophobic compounds by metabolizing and transforming them to water-soluble polar molecules. Generally, the metabolic breakdown of toxic compounds reduces their persistence and toxicity by accelerating their elimination. In some cases, the metabolites are more toxic than their parent compounds.

Lee (1991) reports that the research concerning tributyltin has demonstrated that this polar hydrophobic substance enters animals via lipid membranes and is metabolized in two phases. The first phase involves the hydroxylation of TBT to four hydroxydibutyltin derivatives through the cytochrome P-450–dependent mono-oxygenase system. The second phase involves conjugation of the hydroxydibutyltin derivatives to sugar or sulfate molecules, and the subsequent rapid elimination of these highly polar conjugates from the body. According to Lee, vertebrates and a number of the decapod crustaceans have well-developed cytochrome P-450 systems. In these organisms, the P-450 system is usually involved in vitamin D synthesis and/or calcium metabolism. Molluscs, however, typically exhibit very low cytochrome P-450 and mono-oxygenase activity, and therefore, substantially reduced rates of TBT degradation, which results in the accumulation rather than the elimination of TBT. The evidence suggests that the accumulation of TBT results in a hormonal imbalance in molluscs (as hormones and toxic substances are known to share common metabolic pathways) and leads to the structural and functional abnormalities commonly associated with TBT toxicity in these animals.

Presence in the environment

Sources

Tributyltin compounds are contained in pesticides registered in California for use in antifoulant paints on boats, ships, and marine structures such as piers and docks; as wood preservatives, molluscicides, and disinfectants; and as biocides for use in cooling towers, pulp and paper mills, and textile mills. The oxide and neodecanoate derivatives of TBT are contained in pesticides registered as active ingredients for use as biocides in cooling towers (DPR, 1995).

Concentrations and distribution in marine, fresh, and estuarine waters

The highest levels of TBT in the marine environment are located near marinas, boat yards and drydocks, and points where effluent from cooling tower blowdown is released. Concentrations of TBT are affected by the degree of tidal flushing and turbidity present (Uhler et al., 1993; IPCS, 1990; Lenihan et al., 1990). In areas of shallow water, with little or poor circulation of tidal waters, TBT may accumulate in the water and ultimately the sediments (Valkirs et al., 1986).

San Francisco Bay Region

In 1986, Stallard et al. (1987) monitored the concentrations of butyltin compounds at over eighty sites along the California coast, including San Francisco Bay. They found concentrations of TBT in the San Francisco Bay area waters ranged from 4 ng/L (ppt) in Vallejo to 570 ng/L at the Antioch Yacht Club. Sediment-bound TBT concentrations ranged from none detected (in several locations) to 7.7 ng/g (ppb) in the Oakland Estuary at Jack London Marina. They measured the concentrations of DBT and MBT at each site, and reported that, in general, DBT and MBT were found in lesser concentrations than TBT, although exceptions were noted. They also surveyed the aquatic biota at each sampling site, recording the identity and relative number of each species present. They reported that there was a conspicuous absence of native organisms, especially molluscs, in areas where TBT concentrations (in either the sediment or water column) exceeded about 100 ppt.

Stallard et al. (1987) reported that higher concentrations of butyltins were found in marina waters than in either harbor or coastal waters, and that fresh and brackish waters generally had a much lower DBT/TBT ratio (an indication of the degree of degradation) that comparable seawater samples. They speculated that TBT degradation may occur at a slower rate in fresh water than in seawater.

Other locations in California

From 1983 to 1985, Valkirs et al. (1986) monitored the concentrations of several butyltin compounds (TBT, DBT, and MBT) and inorganic tin in water samples taken from ten sites within San Diego Bay. They found that concentrations of all organotin compounds increased over time, ranging from the MDL (< 0.01 µg/L) to 0.93 µg/L, and attributed their observations to increased boating activity and topography. The relatively narrow entrance channels to many portions of the San Diego Bay limit water circulation in these areas, and therefore affect the levels of contaminants released into these areas.

San Diego Bay was also the location for TBT stratification and variability studies conducted by Stang et al. (1989). They monitored concentrations of TBT in near-surface and near-bottom water over a 25-hour period at the entrance to Shelter Island yacht basin. They reported surface

water concentrations varying from 20–225 ng TBT/L and bottom water concentrations varying from < 1–77 ng TBT/L. The highest surface water concentrations were associated with ebbing tides, while the lowest were associated with flooding tides. The reported bottom water concentrations were nearly always lower than the surface water concentrations, and varied 180° out-of-phase with the surface water concentrations. The authors concluded that a vertical stratification of the water column occurred during ebbing tides and dissipated during the flooding tides. They indicated that TBT concentrations in natural waters are dynamic and are subject to the spatial and temporal changes characteristic of the particular site of interest.

Stang and Goldberg (1989) measured the butyltin concentrations at twenty-seven locations throughout California, primarily in river and lake marina waters. They reported measurable amounts of butyltin compounds in a majority of the freshwater samples collected. The highest concentrations were at the Discovery Bay Yacht Harbor (140 ng TBT/L) and at the San Joaquin Sailing Club (110 ng TBT/L), both of which berth vessels that travel downriver to marine areas. However, TBT was found in 19 other marinas in freshwater lakes with no boat access to marine waters, eleven of which contained environmentally significant levels of TBT (levels ≥ 10 ng TBT/L). The authors attributed the presence of TBT in freshwater to the unnecessary use of TBT-containing hull paints on boats harbored in these marinas. In studying the TBT/DBT ratio, they found them to be similar to those reported for marine water, and concluded that the factors that govern degradation in the marine environment also affect TBT degradation in the freshwater environment.

Valkirs et al. (1991) conducted prolonged monitoring of TBT concentrations in San Diego Bay from 1988 to 1990 to determine if legislative restrictions on the use of TBT-containing antifouling paints (effective January 1988) affected TBT concentrations in the Bay. They reported that surface water concentrations significantly decreased compared to previous studies they conducted (Valkirs et al., 1986). Tissue samples taken from *M. edulis* living in the monitored areas also showed a decrease in tissue concentrations of TBT; however, the authors report that sediment-bound concentrations of TBT did not reflect the decreases observed in the water column.

Other locations in the United States

Huggett et al. (1986) conducted a monitoring program for tributyltin concentration in the Southern Chesapeake Bay and Elizabeth River, both in Virginia. Chesapeake Bay was chosen for this study based on the increasingly large number of recreational, naval and commercial vessels moored within its waters. The Elizabeth River estuarine system was selected because of the high degree of industrialization along its banks. The authors reported that the data collected demonstrated that tributyltin concentrations vary to a large degree over time and space; concentrations an order of magnitude apart were found at the same location within the same week, while concentrations different by a magnitude of two were found in samples taken from different locations within the same marina at the same time. The authors warn that such variabilities must be considered when interpreting results from monitoring studies.

Evans and Huggett (1991) monitored the presence of tributyltin during a three-year program of weekly sampling at nine locations within two tidal creeks of the Chesapeake Bay. They statistically modeled the results of this intensive monitoring program, which began in July 1986 and

concluded in the summer of 1989. From their studies they calculated a degradation half-life for TBT of two to three years.

Contributions from urban effluent

Urban effluent has been identified as a potential source of TBT entering the estuarine and marine environment. The predominant source of TBT in urban effluent is discharge from cooling towers, or blow-down (Clean Bay Plan, 1994). Other sources of TBT in urban effluent may include exterior-grade wood preservatives for use on siding, decks, and outdoor furniture, or disinfectant and antimicrobial cleaners, toilet bowl cleaners, and antibacterial carpet and upholstery shampoos, all designed for hospital and institutional use (DPR, 1995).

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PART FOUR — ALTERNATIVES TO THE USE OF COPPER SULFATE FOR CONTROL OF ROOT INTRUSION IN SEWER LINES

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Introduction

Root intrusion in sewer lines can be a significant problem for municipalities (Ralph (Bus) Breese, pers. comm.; Farral Crawford, pers. comm.). However, surveys have shown that residential service laterals—the portion of the sewer line extending from houses and apartments to the main sewer lines that run along the street—are the source of most problems with sewer system root intrusion (Sullivan et al., 1977a; Sullivan et al., 1977b; Tobiason, 1990). Root intrusion into lateral service lines can be controlled by introducing copper sulfate purchased over the counter into residential drains (Brandenburg, 1994; Will, 1991). For this reason, this alternatives analysis will primarily focus on methods to control root intrusion in service laterals, although discussion of root control methods from the perspective of municipalities is included as well.

Control of root intrusion—copper sulfate and alternatives

Plant roots do not prefer waterlogged conditions. With few exceptions, roots generally seek and grow in environments high in humidity rather than in standing water where they die, deprived of oxygen (Sullivan et al., 1977a; Sullivan et al., 1977b). Sewer pipes are only partially filled with water at any given time and the air within them is warm and moist, an optimal environment for roots. Air, rather than water, is a limiting factor in root development. Roots do not break pipes to gain access to water, but rather flourish in moist soil near a seepage, penetrate the pipe at the seepage point, and then proliferate within the humid air in the pipe, ultimately causing a blockage (Brennan et al., 1989). Roots tend to enter points of sewer defects near the top or sides of the pipe, rather than at the bottom. Consequently, copper and other chemicals that are simply poured down toilets, cleanouts, or manholes in liquid form to control roots in sewer lines have a tendency to flow under the bulk of the root masses, doing little damage to roots unless the roots actually reach all the way down to the water line in the pipe (Sullivan et al., 1977a; Ralph (Bus) Breese, pers. comm.; Farral Crawford, pers. comm.). This method of chemical application for root control allows little control of actual concentration of the product or duration of exposure to roots in the pipe line. Adequate chemical concentration and contact time are critical to root control. Copper does not prevent regrowth of roots that it kills. Ahrens et al. (1970) demonstrated that even when using high concentrations of copper sulfate, root kill was incomplete and phytotoxicity to vegetation resulted. In addition, copper sulfate is toxic to microflora, including those that rot and decay killed roots as well as those that are necessary to the sewage treatment plant (Sullivan et al., 1977b; Mossar, 1991).

Alternatives to copper sulfate each have their own particular niche and value, as well as limitations in given situations (Table 8, page 56). Moreover, each site and situation has its own set of unique parameters. An attempt was made to identify the comparative costs of the various alternatives; however, meaningful comparisons of the feasibility of these alternatives should not be

based on cost. Soil type, sewer pipe material, line depth, line size, line condition, ease of access, tree species, tree age, root mass, proximity of roots to lines and availability of treatment options are just a few of the parameters that enter into the overall cost equation. Thus, one method is likely to be more suitable than another for that specific situation, notwithstanding cost. In addition, some alternatives are simply inappropriate and impractical for a given situation. The costs given are merely gross estimates and are in no way meant to reflect what the actual costs might be for a particular site. The costs described are merely intended to provide a relative comparison of alternatives, not an accurate cost estimate that will be applicable in all cases. The costs given, therefore, should not be construed as an objective basis for comparison of alternatives. On the contrary, durability and longevity of repair, duration of repair process, labor and equipment necessary as well as disruption of service and above-ground activity are probably far more realistic criteria by which to compare the feasibility of alternatives for a given situation. In addition, mention of trade names in this report in no way implies endorsement by DPR.

Short-Term Control Measures

Chemical alternatives

Toby's Foaming Root Killer D—Manufactured by Toby's Chemical Co. and marketed by General Chemical Company, Toby's Foaming Root Killer D contains 0.5% dichlobenil, and is a non-systemic herbicide specifically designed for the control of tree roots. The product foams on contact with water and fills the line with foam solution, including the air space above the water line, insuring good contact of the herbicide with roots growing into the pipeline from the top and sides of the pipe. To apply to 4-inch residential laterals, two pounds are added to the toilet bowl or cleanout, followed by quickly flushing with about five gallons of water.

Advantages: Dichlobenil is an effective root growth inhibitor and root killer. The foam formulation fills the line and makes good contact with roots that hang down from the top and sides of the pipe. The foaming feature makes the product especially useful for lines with low flows since it does not require blocking of a line and filling it up with liquid to ensure adequate contact with roots. Unlike copper sulfate, dichlobenil does not destroy root-decomposing microflora or microflora important to treatment plants. Dichlobenil is an effective root inhibitor even at sublethal concentrations (Sullivan et al., 1977b). It has good residual activity, repressing root growth for 13 years. It is readily available in bulk quantities and can be applied without need of a contractor, special license, or special application equipment. The foam product distributes well through pipes even in hilly topography. It provides longer term control than cutting the roots. There is no service disruption, excavation, or flow diversion necessary. In some parts of the country, it can also be dusted into sewers by licensed contractors to insure higher concentrations of herbicide come into contact with the exposed roots.

Disadvantages: The foam eventually drips and drains away, taking a good deal of chemical with it. Much of the chemical is wasted on filling empty line without contacting any roots, although this is not the case with the sewer-dusting type of application. Dichlobenil provides only temporary control of root intrusion. Roots will eventually grow back and require subsequent action if the pipe condition and environment are left unchanged.

Costs: Depending on the quantity ordered, 2-pound containers range from $16 to $18 per pound. Larger quantities can be as little as $8 to $9 per pound. There are no other costs. No contractor, license, or any specialized equipment is required. Based on label-recommended dosages, the cost for one residential lateral treatment would be about that of a 2-pound container for the entire lateral. Thus, if the lateral line is around 20 feet long, the cost would be approximately $1 per foot. For larger lines of municipalities, based on label-recommended dosages, the cost would be slightly more than $1.20 per foot for an 8-inch line.

Sanafoam™ Vaporooter® II and Foamcoat™ Vaporooter®—Manufactured by Airrigation Engineering, Sanafoam Vaporooter II is 24.25% metam-sodium and 1.95% dichlobenil. Foamcoat Vaporooter is 28.4% metam-sodium and 1.73% dichlobenil. Both products are applied as a foam produced by a piece of equipment called a Foamaker available from the chemical manufacturer. The purpose of the foam is to ensure good contact of the herbicide with roots growing into the pipeline from the top and the sides of the pipe. Sanafoam Vaporooter II is used to fill the line with foam, whereas Foamcoat Vaporooter is designed to coat the inside of the line with approximately a 2-inch layer of foam rather than fill all the airspace. Foamcoat Vaporooter is designed to be more economical for use in large diameter pipelines so that good contact with intruding roots is achieved without having to fill up a relatively large diameter pipeline with foam. For homeowners, Sanafoam Vaporooter II is applied by a contractor.

Advantages: The chemicals are efficacious, provide residual activity for one to three years, and are well distributed within the pipe, providing good contact with roots penetrating from the tops and sides of the pipe. Use of these products provides longer term control than cutting. There is no service disruption, excavation, or flow diversion necessary. The foam product distributes well through pipes even in hilly topography. After repeated treatments to kill regrowing roots, residual control may last for up to five years (Farral Crawford, pers. comm.; Michael Parks, pers. comm.). Because the Sanafoam application equipment comes in a range of size and prices, contractors and municipalities can purchase equipment that fits their particular budget and needs. The price of the equipment includes training and certification of the operating personnel by the manufacturer.

Disadvantages: This method requires either contractor application, or purchase of application equipment (Foamaker®). City of Sacramento personnel believe that for long-term effectiveness it should be used in conjunction with root cutting to clean out killed roots. Using this method of control, the municipality of Rockville, Illinois chemically killed roots without cutting or cleaning and experienced problems with dead roots falling off, accumulating at connections of laterals and mains, and collecting debris (Sutton, 1984). Although this material inhibits root regrowth much longer than cutting, it provides only temporary control of root intrusion. Roots will eventually grow back and require subsequent action as long as the pipeline environment remains unchanged. One municipality interviewed had used this material in the past but stopped because they experienced problems with phytotoxicity to trees, turf, and shrubs. Others said they do not prefer this method because they want to avoid the liability of handling or using metam-sodium (Dan McKenna, pers. comm.). Metam-sodium is toxic to microflora necessary to treatment plants. The product does not work as well during the drier months in California when pipeline flows are lower (Farral Crawford, pers. comm.). If a municipality goes to the expense to invest in the application

equipment, it still may not be able to afford the personnel costs associated with application. The equipment and crew must be able to work quickly and efficiently to make this method cost-effective (Farral Crawford, pers. comm.).

Costs: Typically, herbicide foam treatments costs range from about $1.00 per foot (Claudia Norton, pers. comm.) to $2.50 per foot (Tobiason, 1990). Contractors frequently perform a root cutting/line cleaning before treatment. If the equipment is already owned, then the material cost for Sanafoam Vaporooter II is about 33¢ per foot for an 8-inch line (one gallon costs $52 and makes 400 gallons of foam that will fill 160 linear feet of 8-inch diameter pipe). The cost of the chemical varies with the quantity purchased. The initial investment in the Foamaker can range from $9,000 to $29,000 depending on the size and versatility of the machine chosen. The cost of the equipment includes the cost of training and certification of the operating personnel by the manufacturer. According to Airrigation Engineering Co. representatives, such equipment should last for ten years with good maintenance (Barbara Tiernan, pers. comm.). Personnel from the City of Chico (Chris Boza, pers. comm.; Michael Parks, pers. comm.) feel that Sanafoam Vaporooter II gives them three to five year control in lines of up to 14 inches. They estimate their cost of treatment is somewhere around $9–$12 per linear foot, taking into consideration the expense of the equipment and labor.

There are a number of other chemical root-control products on the market that are currently registered in California containing little or no copper. However, no users of these products could be located, nor was cost per foot information available. The following products are included in this category.

- ***Angus Hot Rod with 2,6-D***® is a compound that contains 56% sodium hydroxide and 0.5% dichlobenil. The label allows municipal users.
- ***Rooto***® is a product that contains 85.69% sodium hydroxide and 0.3% copper sulfate.
- ***Root Out***™ is a product that contains 2.1% dichlobenil.

Physical and Mechanical Alternatives

Root cutting—One of the most widely used methods of protecting sewers from root intrusion is by cutting or clearing by using a rotating blade or other device inserted in the line. Root cutting and line clearing provides the quickest, most immediate relief for root-clogged systems. Clear lines usually last for a few months without any further action. There are a number of devices designed to cut, mulch, or blast roots out of a line. For homeowners, private contractors such as Roto-rooter® can do the job, or they can rent a cutting device and do the work themselves. Municipalities have several devices to clear lines of roots. Listed below are three such devices that are specifically designed to cut roots in sewers.

- ***Ohio Root Cutter***®—This is essentially a circular, double-edged, coarse-toothed saw blade that saws the roots off while spinning at about 1,000 rpm. It is necessary when roots are more than one half centimeter in diameter. According to those in the industry, few municipalities are still using the Ohio Cutter because it tends to be somewhat labor intensive and dangerous, frequently causing back injury. The cutting blades need to be replaced relatively often (sometimes several times per week, or even per day), at a cost of about $20 each.

• ***Chain Flailer***—The chain flailer is lighter, easier to use, and safer than the Ohio Cutter, and tends to mulch the entire mass of exposed roots rather than just cutting them off and leaving stubs in the pipe. Sacramento and San Luis Obispo counties have used the chain flailer satisfactorily. They use special hardened chain from Sweden of a critical size. The flailer chains may need to be replaced frequently. New replacement chains run about $20 (Ralph (Bus) Breese, pers. comm.). In general, the chains have about 1,000 hours of usefulness.

• ***Hydro Jetcut***—The Hydrojet Cutter is a remote controlled pipe-cleaning system that uses a high pressure water jet system and closed circuit-television. It features a body and head that can rotate 360 degrees. It is more appropriate for small jobs, such as a single root-intruded joint or treatment of service laterals, rather than entire sewer lines. It can take out small rootlets, but isn't very effective against larger roots. It cuts relatively slowly, and requires a long time to set up (James Ovady, pers. comm.).

Advantages: Root cutting and line clearing provide the quickest, most immediate relief for root- clogged systems, and are chemical-free.

Disadvantages: Cutting is only a short-term, temporary solution, as the roots immediately begin to grow back, becoming larger and more vigorous than before (Rolf and Stål, 1994; Sullivan et al., 1977b; Sutton, 1984). Root cutting equipment can not always be used effectively if lines are badly misaligned, in lines in which laterals protrude into mains, or if lines run very deep. The logistical and space requirements of the equipment can be a problem if access is not convenient. Occasionally crews have problems getting cutting equipment to the sewer entrance site when manhole access is not located in or near a street (for example in backyards). Removal and disposal of root material from the line after cutting can sometimes be a problem as well. A sewer in poor condition can actually be damaged by cutting or flailing equipment (Sullivan and Ewing, 1985; James Ovady, pers. comm.). Some pipe materials are inappropriate for certain pieces of equipment. For example, the chain flailer can be used without problems in concrete pipes but can damage other types of pipes such as those made from clay (James Ovady, pers. comm.). The Ohio cutter and similar heavy equipment can sometimes be a safety problem, particularly for back injuries, resulting in workers' compensation claims (Ralph (Bus) Breese, pers. comm.). In addition, root cutting equipment requires a significant capital investment. The initial cost to purchase a chain flailer, for example, is about $16,500 (James Ovady, pers. comm.). But in addition to the initial purchase, there are costs associated with maintenance, replacement parts, and the well-trained labor needed to operate it.

Relative Costs: For the homeowner, Roto-rooter-type companies do the job at a cost of about $50–$70 per hour (Will, 1991). The homeowner can rent a cutting device for about $50 to $60 per day (e.g., $55 at River City Rentals, Sacramento). For municipalities, it costs roughly $500 (including labor, maintenance, and new parts) to do a typical root cutting/clearing with an Ohio cutter for a block-long sewer line, a job requiring about three hours' work. The same job using other equipment may cost more or less, depending on numerous factors such as the crew size, accessibility to the entrance, the line size and depth, removal and disposal of material from manholes and distance to disposal site, the need and degree of traffic control necessary, the availability of water, the structural condition and material of the sewer, the degree of root

intrusion, and weather conditions. For comparison, the chain flailer takes about one-half hour to do the same job at about one-fourth the cost as the Ohio Root Cutter (Ralph (Bus) Breese, pers. comm.). Rodding or jetting lines clear of small roots costs roughly $1.00 per foot (Tobiason, 1990).

Installation of Y-Cleanouts—Some municipalities that require homeowners to assume responsibility for the condition of their own lateral service lines have encouraged homeowners to install Y-shaped cleanouts near the street easement to ensure ready access for future root intrusion control by cutting or other action. To encourage this, homeowners in some areas have been offered future root-cutting maintenance of their laterals by the municipality at no charge (Ron Morrow, pers. comm.). In some municipalities street-access cleanouts are required for all new construction (Sutton, 1984).

Advantages: The main advantage of Y-cleanouts is ease of access for mitigation of root intrusion with cutting equipment or other means. This provides for immediate relief of future root problems by cutting, if nothing else.

Disadvantages: Y-cleanout installation involves high up-front costs to the homeowner. It provides for only temporary relief, and potentially sets up a municipality for a substantial amount of future, labor-intensive cutting work. Root problems will get worse if cutting is the only approach, regardless of the convenience of access.

Costs: A typical cost for installation of a Y-cleanout by a local contractor was estimated by one city expert at about $800 per lateral (Ron Morrow, pers. comm.). However, amortized over time, such costs might be considered relatively reasonable by the homeowner.

Long-term Control Measures

Excavation and Replacement of Line—Excavation of a defective line and replacement with a new one is the most long-term solution, and in some cases the only certain remedy to a faulty sewer line (Brennan et al., 1989). This is particularly true for replacement with ABS or PVC (solvent-welded) type pipe that has fewer, and more water-tight joints than the commonly used clay pipe. Excavation and replacement of old deteriorated lines usually involves heavy equipment and is fairly labor intensive, as well as disruptive to traffic and other above-ground activities. Several options exist for replacement materials. For example, among other materials, municipalities can opt for more jointed, vitrified clay pipe (VCP), cast iron pipe, or plastic solvent-welded pipe such as PVC or ABS pipe. The City of Chico is replacing more and more defective sewer lines with ABS and PVC solvent welded pipe in particularly troublesome root intrusion areas since this repair lasts much longer (Chris Boza, pers. comm.). After a line has been cut, cleaned, and Vaporooter-treated several times and the pipe line continues to be a trouble spot, the City of Sacramento frequently replaces or relines the troublesome line (Farral Crawford, pers. comm.).

Advantages: Replacement provides the most long-lasting repair. Correctly installed solvent-welded pipe, in particular, features few joints and is not vulnerable to root intrusion since root- attracting leaks are unlikely (Uni-Bell PVC Pipe Assoc., 1991; Randy Becker, pers. comm.). The life expectancy of a new plastic pipe line is likely to be greater than a repaired VCP line. Ten to thirty years (or better) of relief from root intrusion is possible, depending on the pipe material used and

the quality of installation (Tobiason, 1990; Randy Becker, pers. comm.; Claudia Norton, pers. comm.).

Disadvantages: Potentially high up-front costs, the inconveniences associated with excavation (disruption of service, traffic diversion), and longer time for repair than trenchless repair methods are major tradeoffs for the long-term benefit of excavation and replacement with a new line.

Costs: The greatest portion of the cost of line replacement is for excavation. Chris Boza (pers. comm.) estimates that in Chico it costs roughly $30 per foot just to open a trench without doing any work to the line itself. The Sacramento County Water Quality District (SCWQD) estimates a cost of about $120 per foot for excavation and replacement of a 10-inch-diameter line with lateral connections (Hassey et al., 1991). It should be noted that costs for excavation and replacement can vary greatly from site to site. For example, to replace typical residential laterals in Orange County it can cost from $2,000 and higher (Ron Morrow, pers. comm.). In the San Francisco Bay Area the same repair can range from $1,500 to $3,500 for 4-inch laterals, that tend to be shallower than main sewer lines (Will, 1991). However, when amortized over the expected ten to 30 years of relatively maintenance-free lines, such costs become much more affordable, in the range of $50 to $120 per year.

Trenchless Replacement of Lines—Some systems can provide for replacement pipe of the same diameter or even a larger diameter in the same space without excavation. One such system is the Miller Xpandit® trenchless system that uses a splitting head that breaks and displaces the old pipe, and pulls a new high density polyethylene thermoplastic pipe (HDPE) into place behind it.

Advantages: There is no reduction in pipe diameter as is the case with pipe liners. With this pipe replacement system, it is possible not only to replace a pipe line with one of the same size, it is actually possible to replace a pipe with a new line that has up to 50% greater cross-sectional area. The Miller Xpandit trenchless system can be used to replace pipes from about four to 20 inches in diameter (Collins Orton, pers. comm.).

Disadvantages: The system is relatively expensive, and requires an excavation pit at one or both ends of the pipeline being replaced to accommodate the winching equipment and the new sections of pipe being pulled into place. Reconnection of laterals may also be labor intensive and expensive.

Costs: The Xpandit system of pipe replacement runs about $60 to $100 per foot, depending upon several factors, including the number and length of lines being replaced, and whether lateral connections are involved. A recent job in Washington involving the replacement of about 10,000 feet of various sized lines cost about $75 per foot (Collins Orton, pers. comm.).

Cured In-Place Pipe (CIPP)—Inversion lining or Cured In-place Pipe behaves as a flexible conduit in a rigid pipe. Currently, the best known CIPP product is Insituform®. A 1993 Amoco Chemical Company advertisement in the industry periodical Trenchless Technology made the statement that over 10 million feet of Insituform pipe has been installed in the United States.

Felt tubes that are impregnated with a resin are manufactured to precisely fit a specific size of pipe. One end of the Insituform sleeve is attached to the end of an inversion tube at the entrance to the existing pipe. Pressurized cold water forces the sleeve into the old pipe, turning it inside out as it goes. The new Insitutube walls that are resin-impregnated, are pressed firmly into continuous

contact with the walls of the old pipe. The smooth side of the Insitutube sleeve becomes the interior of the new pipe. After the insitutube is inverted all the way through the old pipe, the water is heated and the hot water cures the resin, changing the pliable insitutube into a hardened, seamless, jointless, pipe-within-a-pipe (referred to at that point as Insitupipe™). When Insituform is used for sewer mains, reconnecting service laterals can be accomplished by a remote-controlled, television-monitored cutter that cuts out the lateral connections where the CIPP liner is distinctly dimpled. It can cut as many as 65 lateral connections in a day (Anonymous, 1994a). Insituform requires about 12 hours to cure. Because it is a trenchless repair procedure, many businesses choose Insituform for sewers that run under buildings and structures (Olson, 1986).

Advantages: There is little disturbance to people and property, and there is relatively little down-time for the sewer system. There is little or no excavation involved, making this method of sewer repair much faster than excavation and replacement. It can be done in hours to days instead of days to weeks. This is especially true for deeply placed lines that would require considerably more excavation. The new pipe has good strength, durability, and longevity. Insituform liners are flexible and can repeatedly go around corners and 90-degree bends. Insituform provides a seamless and jointless pipe line which means there are no joints to open or leak, thus preventing the attraction of tree roots. The smooth walls on the new pipe provide low-flow resistance and increased flow volume, compared to unlined clay pipe (Utz, 1983). Insituform is resistant to a wide variety of chemicals, so it does not quickly degrade or deteriorate from chemicals. Even Insituform-lined sewers that carry high-strength industrial/chemical waste hold up well (Olson, 1986). In fact, different kinds of resins can be used depending on the type of sewage effluent, e.g., in industrial vs. suburban areas. The flexibility of Insituform eliminates the need for large pits through which to load inflexible pipe liners. Insituform comes in a wide range of sizes. It can reline 4-inch service laterals up to 120-inch pipelines (Anonymous, 1994b). Because Insituform is a trenchless repair method it avoids a significant amount of injury to the root systems of valuable trees by avoiding excavation (Utz, 1983). Where legal or physical access to a site is a problem, Insituform is of great benefit (Olson, 1986). The new pipe material can also be patched, welded, or bored making any future repairs much easier (Farral Crawford, pers. comm.).

Disadvantages: Before relining, the old pipe must first be thoroughly cleaned. Safety may be a concern during installation, since hot water or steam under pressure used for curing can be hazardous, particularly considering the height at which the hot water must be drawn and discharged into the inversion tube. The resulting pipe is smaller in diameter than the original pipe. Sometimes it is difficult to get trucks and the necessary equipment near the entrance site to pipelines when the entrance is not conveniently located in the street.

Costs: Costs may be relatively high, compared to some other repair methods. Costs may also vary from job to job depending on a number of variables. For example, the EPA Certification 91-24 Handbook (July 1991 edition) lists the cost for Insituform-lining of a 10-inch line at $80 per foot, but SCWQD reported that the actual cost for a 10-inch line on a project without any laterals was $140 per foot (Hassey et al., 1991). On the other hand, on a Nashville project, 4,400 linear feet of 8-inch clay pipe was relined for $44.50 per foot (Bible and Hinte, 1993). In Northern California, a typical four-inch residential lateral relining could run about $2,500, or about $60 per

foot (Claudia Norton, pers. comm.). As another example, Insituform Midsouth Co. completed a repair using this method, that included cleaning, television monitoring, and relining of 63 service laterals, each about 20 feet long, for $1,475 per service line, or roughly $74 per foot (Bible and Hinte, 1993). Although the method is currently somewhat expensive, it is the opinion of some in the industry that if the patent for this technology expires, more companies might offer this technology, that could result in a reduction of the cost of this method of repair.

Fold and Form PVC Pipe—Fold and Form PVC is a polyvinyl chloride pipe material that is soft and flexible at ambient temperature, but is cured to a hard state with hot water or steam after being pulled or pushed through an existing pipeline. The PVC lines the walls of the existing damaged pipeline. One of the best known fold and form PVC pipe products is Nupipe®. It is transported in a softened condition, then pulled into the old pipeline through a heat containment chamber. A rounding device then conforms the softened material to the walls of the old pipeline, and pushes any water out ahead of the pipe-rounding device. The pipe is then allowed to cool and harden. Recently the service laterals of residents of the City of Willits, California, as well as a number of larger city sewer lines, were lined with Nupipe (Claudia Norton, pers. comm.).

Advantages: Installation of Nupipe is a quick, trenchless operation that can reline a 100- to 200-foot line in two to four hours. A lack of joints and seams halts seepage and attraction of roots. Flow is maintained or improved as a result of the lack of joints, the smooth inner PVC surface, and the smooth transition at existing offsets and deflections. The new pipe is flush against the old deteriorated pipe, maintaining structural strength.

Disadvantages: Unlike Insituform, Nupipe will not work in 90° bends because it is pulled by a winch through a heat containment tube. A good pre-cleaning of the pipe is necessary. Some spot repair may be necessary first before lining, depending on the degree of damage to and general condition of pipe line (misaligned, crushed pipe will not accommodate the liner very well). There may be additional costs associated with preliminary evaluation of the line for straightness and defects. The resulting pipe is smaller in diameter than the original pipe. Nupipe is only available in four to 12 inch size pipe, as opposed to four to 120 inch for Insituform.

Costs: The cost to reline a typical service lateral with Nupipe is about $2,000, or about $30 to $60 per foot (Claudia Norton, pers. comm.). The cost for larger diameter pipes is about $20 to $40 per foot, depending upon how much line is being done (Claudia Norton, pers. comm.). Other economic factors to consider include the size and weight of liners (the thicker and heavier the liner needed, the more expensive to make, ship, and handle), the type and amount of pre-cleaning procedures necessary (effort and equipment required), the degree of damage and general condition of pipe line (misaligned or crushed), the costs associated with proving the line for straightness and defects, the number of service laterals that will need to be cut and reconnected, the amount and type of spot repairs necessary before lining, and any traffic control or diversion.

Chemical Grouting—Chemical grouting and sealing is done to stop the seepage of water from sewer lines that attracts tree roots. There are a number of different grouting systems and a number of different grouts available on the market with different curing or hardening times, strengths, and textures to suit different situations. Chemical grouting involves the use of a television camera

and robotic device that can locate problem areas, prepare surfaces, and apply grout to seal defects one at a time by remote control. Grout packing devices generally have two inflatable ends that, when inflated, seal off the defect from the rest of the line, permitting the gel packer to fill the void with the gel-grout material. The grout is forced into the joint and/or the cavity that may also exist to some degree outside the line. The newly grouted repair is air pressure-tested on the spot. The herbicide dichlobenil is sometimes added to grout to inhibit future root intrusion. The Gelco Company, for example, frequently adds the dichlobenil product Casoron herbicide to its grout (Claudia Norton, pers. comm.). For maximum effectiveness, a thorough precleaning of the line to be grouted is necessary. Grouts have typically been acrylamide gels mixed with diatomaceous earth, although now acrylics and urethane grouts are being used as well, depending on the soil type and other site variables. However, due to environmental and health concerns acrylamide gels may be on the way out (Berry and Magill, 1992; Claudia Norton, pers. comm.). According to Claudia Norton, formerly of the Gelco Company, a common practice is to grout all of the joints in a line if one is bad, rather than to grout only the joints with obvious, visible defects.

Advantages: Grouting can be done using a television camera and grout packer to seal pipe joints and pipe defects in pipes 4 inches and larger. The equipment inspects and seals in one operation. Dichlobenil can be added to the grout giving added effectiveness and residual protection against future root intrusion.

Disadvantages: Lines must be thoroughly cleaned before television camera inspection and grouting. Although basically cost-effective in the short term, grouting thus far has been somewhat inconsistent in long-term dependability. Grouting is impractical for use with lines that are badly deteriorated, badly misaligned, or have large voids. It works well for repairing leaky joints, providing the line is reasonably straight and in good structural condition, but is not particularly effective for repairing structural breaks in the lines. If structural damage is present it may be necessary to do some excavation and spot repairs first. Adequate curing and bonding has sometimes been a problem, particularly in wet environments, that may result in the need for return visits to the site for additional follow-up repairs (Berry and Magill, 1992; Hassey et al., 1991). It is very difficult to adequately grout repair defects and joints near lateral connections with mains since there isn't an effective way to seal off one end of the defect area so that pumping pressure can be applied. It is also ineffective for cracks or defects that extend longer than the grout packing device. Grouting does not work well for joints with more than just a slight amount of displacement due to the inability to apply pressure to the grout. Since grout repair jobs are frequently put out to bid, it is always possible that low-bid contractors may do an inadequate packing job, necessitating follow-up visits and repairs (Claudia Norton, pers. comm.). In a 1986 EPA report, a multifaceted approach to repairing the sewer lines of Hagerstown, Maryland is described in which four methods of repair were used, including grouting. Although all four methods successfully reduced the amount of mainline seepage to ground water in the short run, a number of sections that received grouting treatments began to deteriorate shortly thereafter (within two to three years), so plans were made to reline them with Insituform (Olson, 1986). Sacramento County also experienced mixed results from a grouting and sealing procedure done by a contractor as part of an on-site demonstration project (Hassey et al., 1991). In addition, robot breakdowns do occur, causing down-time and

delays due to repairs and parts replacement during the job (Hassey et al., 1991). In some cases the weight of the umbilical cord to the robotic device can be a limitation, and the robot's motor drive may be inadequate to pull the device very far into a line, in which case it must be winched manually (Hassey et al., 1991). The future availability of acrylamide gels is questionable, and none of the newer urethane and acrylic grouts and other substitutes for the acrylamide grouts have been completely satisfactory (Berry and Magill, 1992). Residuals in empty grout containers have been classified as hazardous, creating storage and disposal problems. Consequently, grouting costs have risen (Berry and Magill, 1992). Without herbicide additives, grout alone may not adequately stop root intrusion (Tobiason, 1990).

Costs: Grouting can be done for about $8 to $10 per foot (done over a 5,000 line foot stretch of 8″ pipeline) by a contractor. A grout-repaired pipe line could conceivably then last from five to 40 years, depending on the quality of installation (Claudia Norton, pers. comm.). The actual cost of a Sika robotic system repair of a 10-inch line on a job in Sacramento County was $70 per foot (Hassey et al., 1991). The cost to purchase the equipment is approximately $600,000 with a life expectancy of five years. Thus, it would require roughly a $120,000 per year investment over the useful life of the robotic system equipment. Estimated operating cost is another $208,280 per year, or about $105 per hour (based on 2,000 hours of use per year) (Hassey et al., 1991). Other economic factors to consider in grouting include the type and expense of grout (type determined by soil type); the type and amount of pre-cleaning procedures necessary (manpower and equipment required); the degree of prior damage to or general condition of the pipe line (misaligned or shifted pipe will take more effort and time if it can be grout repaired); the size of voids and flaws (length of cracks); and the amount and type of spot repair necessary before grouting (excavation included).

Sealing—Sealants are applied to imperfections in the pipe via gravity and hydrostatic pressure (by maintaining a high column of liquid) in a two-solution, two-phase process. A well-documented sealing product/system that can be used for both 4-inch service laterals and larger municipal lines is the Sanipor System. When the two solutions mix, the stabilizers within each react and a strongly polymerized polysilicic acid gel results. Soil particles and sand grains are bonded to form a cohesive concrete-like mass that solidly encapsulates the defective area and is impermeable to water.

Advantages: There is no need for television inspection, since the sealant temporarily fills the line and is forced into any cracks or defects that may be present. Using this method the entire line is sealed rather than just one defect at a time (Claudia Norton, pers. comm.).

Disadvantages: Since there is no way to see the actual size of the defects and voids outside the lines without excavation, there may be large undetected cavities surrounding the pipes such as might occur from leaking water washing away soil. Such defects or holes can result in a rather large and unexpected volume of material being used, resulting in an unanticipated increased cost for materials (Claudia Norton, pers. comm.).

Costs: Approximately $25-30 per foot (Claudia Norton, pers. comm.).

Point Repair—Sections of pipe are point repaired when they are too damaged for repair by less complete rehabilitation procedures. The process usually involves the trenchless repair of a

damaged section of pipe that generally doesn't exceed 15 feet in length. It frequently involves repair of a leaking joint or faulty service connection, but differs from other pipe-repair operations that involve entire manhole-to-manhole lengths. Most systems available involve the application of either some type of grouting system, a cured in-place pipe sleeve, or an epoxy-based spray. The systems differ the most from one another in the method of application. Some use robotic devices, others use a winched-into place sleeve piece, and others may use a combination of methods. Some repair methods are only designed to repair larger pipe lines, but some repair methods are appropriate for 4-inch residential service laterals as well (and are identified as such below). There's a number of point repair methods currently available, and technology is rapidly changing. Following is a partial list of some examples of such systems (Thomas, 1994):

- ***Performance Liner***® (LMK Enterprises) is a seamless tube of custom length and thickness of cured in-place liner pipe (CIPP). It is appropriate for the repair of 4-inch pipe. It is installed by the inversion liner method, with the exception that it is cured at ambient temperatures rather than with hot water or steam, as Insituform. It is available in lengths from five to 100 feet for repairing 4-inch lines. It is a quick, clean, trenchless repair that places a seamless new pipe section in a damaged one, and is done by licensed contractors.
- ***Amkrete***® (Amkrete Company) is a cured-in-place process involving the injection of epoxy resin into faulty areas and defects from 12 to 44 inches long in pipelines with diameters from 4 to 24 inches.
- ***Eco-liner Pipe Repair***® (American Pipeline Supply Co.) is a replacement system to repair 2- to 12-foot long sections of 6- to 15-inch diameter pipes by installation of a new epoxy-reinforced fiberglass pipe within the existing line.
- ***Econoliner***® (Avanti International) is a CIPP repair for sections of 6- to 30-inch diameter pipes of any material as short as three feet long.
- ***Form-A-Pipe***® (American Logiball) is a CIPP repair that involves the installation of a fiberglass-impregnated mat inside broken sections of pipe.
- ***Link Pipe Grouting Sleeve***® (Link Pipe Co.) is a stainless steel sleeve that is grouted into place.
- ***Magnaliner***® (I.S. Inspection Services) is a composite resin liner for rerounding collapsed pipe sections six inches in diameter and larger. This system can repair sections one to 80 feet long. The literature indicates the installation cost is less than 50% of a repair involving excavation.
- ***Sika Robotics***® (Sika Robotics, Inc.) is a self-contained repair system involving a color television camera, computer software-controlled robot, and a two-part epoxy resin. It is designed to repair pipes from 6 inches to 33 inches in diameter.
- ***Ka-Te System***® (Ka-Te USA) is a robotic point repair system that epoxy-seals/repairs defects such as faulty protruding lateral connections (it grinds them down flush before sealing), offset joints, holes, or cracks.

Advantages: A quick, clean, trenchless spot repair offers considerable savings over excavation and replacement of an entire line. Usually such point repair systems provide good durability of repair. An EPA study showed that lack of deterioration was a plus for point repair (Olson, 1986).

Disadvantages: Some systems may be labor intensive. Some excavation of a line may be necessary for certain point repairs. Point repair methods are strictly for spot repairs. If a line has numerous leaks, it may be more cost effective to simply renovate the entire pipeline with CIPP, fold-and-form PVC pipe, or a sealant system. Licensing may be required for use of patented materials or equipment, requiring the use of a contractor, potentially increasing costs. With some systems the diameter of the pipe may be reduced. That may be a disadvantage, particularly with smaller diameter pipe.

Costs: Cost comparisons for the various point repair systems were given by Thomas (1994). Robotics cost in the range of $500 to $2,000. Stainless steel sleeves cost from $2,000 to $3,000. Sectional patch repairs range from $2,500 to $4,500. Excavation repairs are highly variable, from $2,500 to $15,000. In the City of Sacramento, one particular spot repair of a 30-inch main line with an 18-inch long repair piece cost $3,000 ($2,000 per foot), but that was considered relatively inexpensive by city staff, considering the major excavation and replacement work that did not have to be done, together with the labor and time savings as well as the reduced disruption of service and traffic (Farral Crawford, pers. comm.). As an example of a residential 4-inch pipe line point repair, the cost for a contractor to repair a 4-inch pipe line with the Performance Liner might run roughly from $50 to $100 per foot, depending upon the site variables (LMK Enterprises 1995).

Slip Lining—Slip lining is the insertion of smaller diameter rigid liner pipe into an existing pipe. A slip liner is pushed or pulled into an old pipe from an excavated pit that is large enough to maneuver the rigid liners into the existing pipe. A slip liner is usually made of plastic or fiberglass. Two systems are approved for slip lining in the United States. One method is the Spirolite System (made by Chevron Chemical Co.) that is a high-density polyethylene (HDPE) thermoplastic pipe. This type of liner has a bell and spigot joint design. HDPE is suitable for lining pipe lines up to 48 inches in diameter. The second method is referred to as Centrifugally Cast Fiberglass Reinforced Polyester Pipe (FRP) (manufactured by Hobas USA, Inc.) that also features a bell and spigot joint design. Pipe diameters larger than 48 inches necessitate liner walls that are thickened for strength. However, this thickening of the HDPE liner restricts flow. For those larger diameter lines, the FRP pipe is preferable because it provides the necessary strength without excessively thick walls (Anonymous, 1994b). Generally some type of grout or other hardening agent must be placed between the liner and the existing pipe to maintain structural strength (Claudia Norton, pers. comm.).

Advantages: Slightly flexible PVC type pipe allows long lengths of sewer to be relined in a no-dig, trenchless repair. The resultant line has fewer, water-tight solvent-welded joints.

Disadvantages: Slip lining doesn't work well where the line isn't relatively straight. It is also not advantageous where a lot of service connections are present along the lines since they all have to be precisely located, excavated, cut, and reconnected. Workers in the city of Vancouver found that locating the connection points was a major problem on a slip lining repair project (Baker, 1980). Service laterals must be treated as spot repairs requiring excavation. Unlike CIPP inversion liners where lateral connections are more easily recognized because they are somewhat dimpled at connection points, lateral connection points must be very precisely located and cut when slip lining.

This may involve excavation at each lateral connection point. Residential 4-inch lines are too narrow for slip lining (Will, 1991). Slip lining requires much more time than Insituform installation (Olson, 1986). Because of the lack of flexibility of the pipe liners, slip lining requires a large pit at the end of at least one end of the pipe to be lined. Slip liner pipes are typically available in 20-foot lengths, regardless of diameter, so these entrance pits are always required. There is also a limit to the length of the line being slip lined due to friction from the new pipe being pulled through. Slip lining doesn't surmount major changes in sewer line alignment, nor does it work well for sewer lines with projecting service laterals. The sealing of liners at manholes is a specialty job requiring special expertise and sealant (Sullivan et al., 1977a). Flow capacity and geometric requirements may preclude a reduced diameter pipe, and changes in pipe size are not easily adjusted for. According to Los Angeles City sewer designer Calvin Jin, large diameter slip line pipes (e.g., 48 inches) do not bend well enough to accommodate horizontal bends in lines. For this and for 90 degree turns, large pits must be excavated to accommodate custom-fitted pieces to navigate the turns (Anonymous, 1994b). HDPE is also buoyant, adding to its difficulty to install (Anonymous, 1994b). The space between the slip line and the original pipe must be addressed as well, since the liner is not as structurally rigid as the original pipe. Some type of grout or rigid filler must be applied around the liner for strength and stability.

Costs: There are a large number of economic factors that affect the cost of slip lining, such as the size and weight of the rigid liners. Thicker, heavier pipe is more expensive to make, ship, and handle. Some of the factors that must be taken into consideration include (1) the type and amount of pre-cleaning procedures (manpower and equipment required) necessary; (2) the degree of damage to and general condition of pipe line (misaligned or shifted pipe will take more effort and time, if possible to do at all); (3) the cost of proving the line for straightness and proper alignment to determine the practicality of using slip liners at all; (4) the depth of the main line, that determines the size of pit necessary, including restoration and repair of the pit area, and indirectly, the size of equipment and crew needed; (5) the number of service laterals and their depth that affect job cost since they may all have to be excavated and cut; (6) the amount and type of spot repair necessary before slip lining; (7) the amount of time of traffic control or diversion; (8) and the amount of grout or filler material needed to fill annular space between the new slip line and the old sewer pipe including in and around lateral service lines (to prevent movement, increase strength and stability, and prevent infiltration or leakage). Because of the large number of variable cost factors, it is very difficult to standardize the cost of slip lining (Claudia Norton, pers. comm.). Sullivan and Ewing (1985) provide a list of 48 separate and variable economic factors to consider in estimating a slip lining job. In general, the relative costs for slip lining are somewhat less than fold-and-form PVC and somewhat more than grouting, which might place it very roughly at about $20 to $40 per foot (Claudia Norton, pers. comm.), however these costs could vary substantially depending on a number of factors.

Preventive Control Measures

Tree Removal—Homeowners who are plagued with sewer root problems frequently want to resort to tree removal, particularly at a municipality's expense, because it is perceived that this will

finally put an end to the problem. Sacramento's City Arborist performs over 300 root damage evaluations each year, usually related to hardscape damage, that is, damage to walkways, driveways, streets, and curbs made of concrete, asphalt, or other hard materials. All city arborists interviewed stated that tree removal is a last resort and generally not done merely because of root intrusion into service laterals. On the contrary, municipalities go to great lengths to preserve trees. In addition, tree and shrub root systems are tremendously large and fibrous and extend for distances well beyond their above-ground parts. Just removing one plant does not guarantee that the same niche will not be exploited by the root system of another tree or shrub in the area, and immediately or eventually cause more root intrusion.

Advantages: In rare cases, tree removal may be the most appropriate long-term resolution of a chronically severe root intrusion problem.

Disadvantages: Tree removal is an expensive and, unfortunately, temporary procedure since the roots of other plants can move in to occupy the same niche if the leaky line is not repaired or replaced (Brennan et al., 1989). According to several municipality-employed professional arborists, rarely, if ever, is tree removal justified on the basis of root intrusion. The high cost of removal, the loss of economic value to municipal or private property, the loss of shade and energy conservation (Ken DeYoung, pers. comm.), and the unlikelihood of the problem being permanently resolved despite the removal, are all reasons against tree removal to solve the root intrusion problem. In addition, unless the stump of the removed tree is thoroughly killed, the roots of some species will continue to grow even after the tree is removed (Tobiason, 1990).

Costs: According to professional arborists, the cost of the actual tree removal itself can easily exceed $1,000 depending upon the complexity of the removal, the proximity of vulnerable targets (such as structures, other trees, and utility lines) to falling limbs, and the amount of time and caution necessary to do the job safely. For example, tree removal with replacement of the root-damaged portion of the sewer line in the City of San Francisco can run $5,000, according to city personnel. In addition, the economic, energy, aesthetic, and other losses to a property may outweigh the perceived economic benefits of tree removal. The dollar value reduction to the property value alone could place the loss of a typical front yard tree with an 18-inch diameter trunk at several thousand dollars (Fitzpatrick and Verkade, 1990).

Tree Species Selection and Site Planing with Utilities in Mind—Selection of trees for specific criteria such as non-invasive roots or correctly proportioned tree to lot size, can go a long way to prevention of future root intrusion problems. Certain species are recognized by arborists as having notoriously invasive roots in landscapes including willow, poplar, eucalyptus, mulberry, liquidambar, elm, ash, magnolia, black acacia, carob, both species of pepper trees, and *Ficus*, and should naturally be avoided in areas of close proximity to sewer lines, particularly service laterals. Instead, species that are known for less invasive root systems should be considered to prevent potential root intrusion problems in the future. Some agencies and municipalities whose services are at risk to tree root intrusion have professional arborists on staff to help with preventive site planning decisions as well as to trouble shoot existing problems involving tree root intrusion. Pacific Gas and Electric, for example, uses a copyrighted software product of its own called TreeFinder

that helps in the selection of tree species based on specific criteria, including root invasiveness (Steve Cieslewicz, pers. comm.).

Advantages: Prevention and avoidance of a problem altogether is usually cost-effective.

Disadvantages: There are no disadvantages to avoiding a problem in the first place via careful planning. However, not all homeowners or landscape architects are knowledgeable about the various horticultural characteristics of tree species, including root behavior. Probably few are aware of resources for tree selection information or have ready access to good information on species selection criteria. In addition, the out-of-sight- out-of-mind aspect probably factors in also, as homeowners and municipal site planners may not be cognizant of the precise location of utility and other lines, and consequently are not aware when they plant trees or shrubs with invasive roots in close proximity to their service laterals (Steve Cieslewicz, pers. comm.).

Costs: Potentially hundreds to thousands of dollars in corrective efforts may be saved by avoiding the use of a known troublesome species, and by avoiding planting in a location that is in close proximity to service lines. Most communities have information sources such as libraries, nurseries, and cooperative extension offices that can provide information and advice pertaining to tree selection. Some communities have enacted ordinances barring certain tree species in future planting and on rare occasions have even ordered removal of existing stands, thus potentially avoiding the costs of repairs or replacement (Tobiason, 1990).

Root Barriers—Root barriers are principally used to protect hardscapes such as sidewalks and curbs from the destructive forces of growing, enlarging tree roots. Experiments by University of California Cooperative Extension personnel indicate that root barriers have the ability to significantly reduce the damage potential of tree roots (Steinmaus, 1994). Although a DPR survey located few persons who have actually had experience using root barriers specifically to protect sewer lines, most reported success in protecting hardscapes. Theoretically, root barriers should protect sewer lines as effectively as they protect hardscapes, either by blocking roots in a linear manner (e.g., along a trench) or with the flexible barriers via wrapping the pipes. Root barriers work best as a preventive measure when trees are first planted. When working with the root systems of well-established, mature trees, some selective, directional root pruning is recommended to assure best results with the barriers (Joe Borden, pers. comm.; Mark Beaudoin, pers. comm.). There are a number of different materials used as root barriers. Three examples of root barriers that have relatively wide industry use are the ***Deep Root Barrier®***, the ***Biobarrier Root Control System®***, and ***copper wire cloth*** (manufactured by the Howard Copper Wire Cloth Company).

Deep Root Barrier is a ribbed, solid plastic barrier that is intended to physically block and redirect roots. These barriers come in three different forms. With one form, flexible 2-foot interlocking panels can be used to surround a root system or to isolate it via a linear wall from areas to be protected from invasive roots. A second type is also used in linear applications, and consists of rigid, interlocking 2-foot wide panels. A third type is a pre-formed round planter designed for trees that will be relatively small at maturity (12-inch trunk caliper or smaller). Linear barriers come in heights of 12 inches up to 48 inches, and the round pre-formed barrier is 18 inches in height. The Biobarrier Root Control System consists of a spun-bound polypropylene cloth mesh in which beads of the nonsystemic herbicide, trifluralin, are incorporated. This is designed to

inhibit root growth near the surface of the mesh barrier by establishing an in-soil vapor zone of trifluralin approximately two inches wide on each side of the fabric. Root growth is inhibited in this region because the trifluralin stops cell division of the root tips (Tracy Whittaker, pers. comm.). The herbicide used in the Biobarrier is not systemic, thus it is not phytotoxic to above ground parts (Tracy Whittaker, 1994). "Surround installation" of Biobarrier for the protection of sewer lines and septic systems is described by the promotional literature and the Technical Application Manual for Biobarrier (Remay, Inc., 1994). Unfortunately, no one who had used Biobarrier in this manner could be located. However, the Carmichael Recreation and Park District used Biobarrier in a surround application by wrapping it around flood-control drainage pipes that were installed as replacements for previous drainage lines that had been crushed and severely displaced by roots of some *Liquidambar* trees. The trees were considered too important to remove since they serve in the summer shading of non-air conditioned buildings. After three years, they have had no signs of any problems with the tree roots damaging the Biobarrier-wrapped, replacement pipeline (Ken DeYoung, pers. comm.).

Copper wire cloth (manufactured by the Howard Copper Wire Cloth Company) controls roots by permitting initial penetration by rootlets through the copper mesh, but it eventually prunes them off by constriction and girdling as they enlarge.

Another root barrier method involves the use of machine-compacted soil as a root barrier. The purpose of this type of barrier is to withhold the aeration requirements of roots, and thus prevent their entry into the compacted area of soil.

Advantages: Avoiding root intrusion by effectively blocking off invasive roots from sewer lines may be an effective measure with potentially hundreds to thousands of dollars in savings by making corrective efforts and repairs unnecessary. Particularly in the case of newly planted trees, root barriers may be effective in redirecting or restricting directional root growth, and prevent them from becoming a threat to the sewer lines.

Disadvantages: Not all root barriers work equally well in all soils, on all sites, or for all tree species. Careful attention must be given to installation, as roots can go over, under, around, or through improperly installed barriers. Some root barriers permit free movement of air, water, and nutrients. Others, such as those made of solid plastic do not, and if installed improperly, can stress a tree and lead to tree health problems. Likewise, soil compaction is likely to stress all plant life in the compacted zone. This is a better approach for hardscape protection, where nothing is intended to grow. If a tree already has exposed surface roots, Biobarrier cannot be used since it cannot be effective if exposed to air. Nobody can say for sure at this point how long the effect of any of the root barriers last after installation, since they haven't been widely used for very long. Some municipalities do not like the potential liability of using barriers with an herbicide, and prefer not to use those types (Dan McKenna, pers. comm.). Root pruning, while being beneficial and making root barriers more effective, can be labor intensive and may involve a significant amount of excavation (Mark Beaudoin, pers. comm.; Joe Borden, pers. comm.). In addition, to correctly prune the roots of mature trees requires considerable arboricultural training, and would probably necessitate the expense of the contracted services of a professional arborist. In some cases the confines of

hardscapes and the presence of utility lines or underground cables in and around roots can make installation and use of barriers impractical (Dan McKenna, pers. comm.).

Costs: In San Jose, using soil compaction as a barrier costs a minimum of $12 per square foot due to the specialized equipment involved. The labor for mechanical trenching to retrofit-install a barrier to an established tree's root zone may be expensive, depending on the site conditions, the difficulty in trenching through the soil, the amount of root pruning necessary, the depth of the soil and roots, and the size and type of the barrier to install, among other factors. Trenching and installation of copper wire cloth to protect a vulnerable section of sewer line San Francisco, for example, can run as high as $700–$1,000 (Dan McKenna, pers. comm.). Biobarrier costs approximately $1.00 per square foot. Deep Root plastic barriers cost approximately $3.58 per linear foot for an 18-inch deep barrier (it comes in two-foot long connecting panels). Copper wire cloth is about $3.00 per linear foot, or about $1.00 per square foot (it comes in rolls measuring three by 100 feet). In addition, the services of a highly skilled certified professional arborist may run $50 to $75 per hour for consultation alone, without any labor for root pruning, or other work (Roger Poulsen, pers. comm.).

Table 8. A summary of copper sulfate alternatives. Cost estimates are not comparative, as each site and method has its own set of restrictions and variables that affect overall costs.

Municipal Alternatives

Category	*Product or practice*	*Duration*	*Major limitations*	*Approximate cost*
Chemical	Toby's Foaming Root Killer D®	Short term	Temporary measure	$1.00–$1.20 per foot
Chemical	Sanafoam® Vaporooter® II	Short term	Temporary; need equipment	$.35 per foot + equipment cost
Mechanical cutting	Root cutters, flailers, rodders	Short term	Temporary; need equipment	$0.25–$1.00 per foot + equipment cost
Construction	Y-cleanout installation	Short term	Expensive, temporary measure	up to $800 per site
Replacement	Excavation and replacement	Long term	Expensive, disruptive	$120–$500 per foot
Trenchless replacement	Pipe bursting and replacement	Long term	Expensive; excavation pits	$60–$100 per foot
Trenchless replacement	Slip lining	Long term	Diameter reduction, excavation pits	$20–$40 per foot
Liners	Cured in-place liners	Long term	Diameter reduction	$80–$140 per foot
Liners	Fold and form PVC	Long term	Straight lines only	$20–$40 per foot
Grouting and sealing	Chemical grout	Long term	Variable results	$8–$70 per foot
Grouting and sealing	Sealant	Long term	Large voids a problem	$25–$30 per foot
Point repair	Liners, grouts, and combinations	Long term	Few repairs per line only	$500–$15,000 per site
Tree removal	Tree removal	Short to long term	Expensive, temporary, tree loss	$1,000–$5,000 per site
Prevention	Species and site planing	Long term	Limited information distribution	$0–undetermined (for consultant)
Prevention	Root barriers	Long term	Installation quality critical	Up to $1,000 per site

Residential Alternatives

Category	*Product or practice*	*Duration*	*Major limitations*	*Approximate cost*
Chemical	Toby's Foaming Root Killer D®	Short term	Temporary measure	$1.00–$1.20 per foot
Chemical	Sanafoam® Vaporooter® II	Short term	Temporary; need contractor	$1.00 per foot + cutting costs
Mechanical cutting	Root cutting	Short term	Temporary; contractor or rental	$50–$140 per site
Construction	Y-cleanout installation	Short term	Temporary; expensive	up to $800 per site
Replacement	Excavation and replacement	Long term	Expensive and disruptive	$2,000– $100,000 per site
Liners	Cured in-place liners	Long term	Diameter reduction	$60–$80 per foot
Liners	Fold and form PVC	Long term	Straight lines only	$30–$60 per foot
Grouting and sealing	Chemical grout	Long term	Variable results	$8–$10 per foot
Grouting and sealing	Sealant	Long term	Large voids a problem	$25–$30 per foot
Point repair	Liners, grouts, and combinations	Long term	Few repairs per line only	$50–$100 per foot
Tree removal	Tree removal	Short to long term	Expensive, temporary, tree loss	$1,000–$5,000 per site
Prevention	Species and site planing	Long term	Limited information distribution	$0–undetermined (for consultant)
Prevention	Root barriers	Long term	Installation quality critical	Up to $1,000 per site

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PART FIVE — ALTERNATIVES TO THE USE OF TRIBUTYLTIN FOR THE CONTROL OF MICROORGANISMS IN COOLING WATER SYSTEMS

Adolf L. Braun and R. Patrick Akers

Introduction

In 1992, the California Regional Water Quality Control Board, San Francisco Bay Region adopted a shallow-water effluent limitation for tributyltin of 5 parts per trillion (ppt) (= 0.005 µg/L) for the San Francisco Bay. During 1992 and 1993, samples from discharges of the Palo Alto Regional Water Quality Control Plant (RWQCP) exceeded the effluent limit of tributyltin. RWQCP staff searched for various tributyltin sources, and found that tributyltin in the discharge of some cooling water systems was the most obvious source in their service area (RWQCP, 1993; RWQCP, 1994). (Tributyltin is one of several active ingredients used to kill microorganisms in cooling towers.) Staff calculated that only one gallon of 2 percent tributyltin solution discharged to the sewer and treated with other waste water at the RWQCP would contaminate more than 2.4 billion gallons of the effluent to a level exceeding the 5 ppt tributyltin effluent limitation. This means that even very small discharges (on the order of one hundred milliliters) of tributyltin-containing products could put the city of Palo Alto in violation of their discharge permit, which would force the San Francisco Bay Area Regional Water Quality Control Board to impose fines of up to $25,000 per day for non-compliance.

Cooling water systems

There are three types of cooling water systems: once-through, closed loop/chill, and open recirculating. The once-through system wastes water; because of water conservation efforts new installations are prohibited and existing systems are being phased out (RWQCP, 1994). In a once-through system, constantly replenished water is discharged as waste after it cool heated ventilation water. The closed loop/chill water system does not discharge the water except for maintenance, which may occur yearly. Water circulates continuously as in a car radiator, absorbing heat and transfering it elsewhere. The recirculating water is not exposed to sunlight, so algal growth is not a problem. The open-recirculating system or evaporative cooling system is the most commonly used for commercial air conditioning and industrial cooling systems. This system consists of pumps, a heat exchanger, and a cooling tower. Water absorbs heat and releases it through evaporation occurring in the cooling tower. Because it is an open system, the recirculating water is more prone to collect silt, dirt, and microbiological contamination than the closed loop/chill water system. Algae grow in the water in response to exposure to sunlight. In addition, water is lost due to evaporation which changes the basic chemistry of the water. Salts, minerals and metals in the cooling tower water become concentrated as the water evaporates during use. A portion of this water (blowdown) is frequently drained and replaced with fresh water.

The quality of water circulating through the cooling system (particularly open-recirculating systems) can influence the efficiency of the system, the degree of maintenance required, and the useful life of the system components. Heat exchangers and cooling towers are susceptible to

microbiological contamination and fouling from suspended solids other than mineral salt (scale) deposits. The water flow in these sites is very low, providing an ideal environment for microorganisms to grow (Lutey, 1991). Bacteria, algae, and other microorganisms grow readily in cooling towers. They can form an insulating coating on heat transfer surfaces, restrict fluid flow, promote corrosion, and attack organic structural components such as wood (ASHRAE, 1992). Eighty to 90 percent of open-recirculating cooling water system failures are directly or indirectly related to problems caused by microorganisms. A general rule of thumb is that a 0.01 inch layer of biological slime, often referred to as biofilm or biomass, will cause a 10 percent decrease in the efficiency of the cooling system (Glen Heikkinen, pers. comm.). Biological slime can build up within four to eight hours on heat transfer surfaces (Lutey, 1991). If the causal organisms are not controlled with microorganism-killing biocides, the cooling system may have to be shut down for cleaning. If the system is essential to a sensitive environment such as a hospital, shutting it down may be extremely costly.

Proper maintenance of cooling water systems by monitoring of biocide levels and microbial populations is more practical and economical than allowing the system to get out of control (Glen Heikkinen, pers. comm.). Biocides containing tributyltin or other active ingredients are used to control microorganisms in cooling water systems. The use of an oxidation-reduction probe (ORP) allows for the convenient measurement of biocide levels, some of which kill through oxidation reactions.

Tributyltin compounds do not degrade easily and can persist in the environment (see Part Three). In addition, tin, especially in its organic form, is toxic to aquatic organisms, accumulates in fish, and, if consumed, transfers to humans (Berman et al., 1991).

The purpose of this section is to identify and assess potential alternative to tributyltin for the control of microorganisms in cooling water systems. Part of this assessment includes their cost (Table 10).

Biocides Used for Cooling Water Systems

Methods for obtaining information on biocides

The Department of Pesticide Regulation maintains information on active and inert ingredients of each pesticidal product registered in California. A computer program was used to identify all currently registered products that active ingredients used as biocides in cooling water systems (Tables 9 and 10).

Information on these biocides was also gathered from face-to-face interviews with employees of various companies providing water treatment services to cooling water installations and from published literature.

Use and methods of feeding biocides in cooling water systems

Both broad- and narrow-spectrum biocides are used in cooling water systems. The use of broad-spectrum biocides ensures adequate contact time for target microorganisms, necessary because they are not always killed by immediate contact with most organic non-metallic microbiocides (Lutey, 1991). Alternating treatments with different biocides—the broad-spectrum oxidizing biocides and the (primarily) more specific non-oxidizing compounds—and blends of

biocides generally give the most effective results and prevent resistant microorganisms from becoming dominant (Glen Heikkinen, pers. comm.; Lutey, 1991). However, due to the limitations of oxidizing biocides, such as their corrosive characteristics, non-oxidizing biocides are more widely used to control microorganisms in cooling water systems (Lutey, 1991). Other chemicals such as copper are routinely added in small amounts to protect metal components.

The manner in which these biocides are fed to a system is important. For instance, overfeeding may increase treatment costs, corrosion of metals, and foaming. There are three methods to feed biocides regularly for the control of microorganisms in water cooling systems:

1) **Continuous feed method.** Currently this application method is becoming more common, as automated biocidal feeders, chemical feed pumps, and test kits to monitor the level of the biocides become more available. A low but effective concentration of the biocides is fed continuously to keep bacterial populations from entering into a rapid (logarithmic) growth phase (Lutey, 1991; Buckman Laboratories, 1982). This method ensures uniform treatment and makes service of the cooling water system easy. Another benefit of this method is that it saves water and biocides (Louis Ruiz, pers. comm.), and warns operators when problems develop (Glen Heikkinen, pers. comm.).

2) **Intermittent feed method.** With this method, biocides are also fed into cooling towers by chemical metering pumps, but these are generally timer-controlled so that they activate at given intervals and operate for a predetermined period of time to deliver the amount of biocide required. This feed system accurately meters the desired treatment dose on a consistently controlled basis, so that the bacterial population never achieves a logarithmic reproductive rate (Lutey, 1991; Buckman Laboratories, 1982). Good control of the microorganisms can be maintained at low biocide concentrations, thereby reducing the potential for corrosion due to overdosing. Both the intermittent and continuous feed methods are used to maintain clean recirculating cooling water systems. Because of its accuracy, the intermittent feed method is preferred over continuous feed for large recirculating cooling water systems (Buckman Laboratories, 1982). This feed method also introduces a higher concentration of biocide into the system, so a more effective concentration is likely to enter the system.

3) **Slug feed method.** When the cooling water system is fouled with an overgrowth of microorganisms, high concentrations (shock dosages) of biocides are added manually at regular intervals. Depending on microbiological growth, degree of external contamination of the cooling water system, and the amount of suspended solids in the circulating water, shock doses are made once or twice per week until control is achieved and the cooling system can return to routine maintenance (Lutey, 1991; Buckman Laboratories, 1982). This method is considered the most effective feed method to clean a fouled system (Buckman Laboratories, 1982). Limitations include the possibility of overfeeding (Lutey, 1991) and worker exposure from feeding the biocide manually (Louis Ruiz, pers. comm.).

Organotin compounds in cooling water systems

Bis-tributyltin is the most common organotin biocide (Buckman Laboratories, 1982). There are currently 12 tributyltin-containing products registered for recirculating cooling water systems (Table 9).

Tributyltin compounds are non-oxidizing biocides that are most effective against fungi, specifically the wood-rotting fungi (Buckman Laboratories, 1982; Glen Heikkinen, Jim Lagunich, Bob Cunningham, pers. comms.). They are moderately effective against bacteria and algae (Richard Cannon, pers. comm.). Tributyltin compounds inhibit the growth of microorganisms by permeating their cell walls and disrupting enzymatic activities (John Davies, pers. comm.). They are very effective when the water has a pH range of 6.5 and 9.0, but have a slow biocidal activity. They require a contact time of 6–8 hours (Lutey, 1991; Jim Rauh, pers. comm.). Their long residence time makes them attractive biocides for use in open- and closed-recirculating cooling water systems. Tributyltin compounds are considered biostats, inhibiting the growth or reproduction of microorganisms, and are only used to prevent plugging and fouling problems in towers made of wood. They have no odor and are not difficult or particularly dangerous to handle (Richard Cannon, pers. comm.). High silt levels and cellulose fibers can inactivate these compounds (Lutey, 1991; John Davies, pers. comm.). Tributyltin compounds are not easily degradable and thus have long-lasting residual effects (Bob Cunningham, pers. comm.). They can persist in the environment for a long time (Lutey, 1991).

Tributyltin compounds are often mixed with quaternary ammonium compounds to enhance their dispersibility and to provide some synergistic effects (Lutey, 1991; Buckman Laboratories, 1982; Bob Cunningham, William Dignin, and Jim Lagunich, pers. comms.). In addition, tributyltin compounds reduce foaming of the quaternary ammonium compounds (William Dignin, pers. comm.). These mixtures are commonly used in open- and closed-recirculating cooling water systems.

Table 9. Tributyltin-containing products registered in California for use in recirculating cooling water systems.

Product name	Manufacturer	Percent active ingredient
Dearcide 717	W. R. Grace & Co.	2.25
Formulation HS-69D	H & S Chemicals Division	2.25
Formulation HS-138D	H & S Chemicals Division	4.50
Garratt-Callahan Formula 34-A	Garratt-Callahan Co.	2.50
Nalco 2532 Microorganism Control Chemical	Nalco Chemical Company	2.50
Nalco 7328 Microorganism Control Chemical	Nalco Chemical Company	2.50
Nalco Visco 3951	Nalco Chemical Company	2.50
Sanatox 2219	San Joaquin Chemicals, Inc.	5.00
Skasol Microbiocide No. 8	Skasol Incorporated	0.51
TEI-4	CH2O, Inc.	2.25
West C-106	Water & Energy Systems Technology, Inc.	5.00
West C-113 Algicide	Water & Energy Systems Technology, Inc.	5.00

Alternative Control Methods

Synthetic chemical options or practices which, like tributyltin, are used as biocides in cooling water systems are identified in this section. These alternatives are classified as either oxidizers and non-oxidizers.

Oxidizers

Halogen donors

Chlorine and chlorine-generating compounds require the cooling tower water to have a pH between 6.0 to 7.5 (Lutey, 1991). The following chemicals can be classified under this group of compounds:

• ***Chlorine*** (e.g., Olin Chlorine®) added to cooling water as a gas hydrolyzes to hypochlorous acid, the biocidal agent. Maximum formation of hypochlorous acid occurs when the water being treated has a pH of 6.0 (Lutey, 1991). At a pH of 8.5, only 8 percent of the chlorine gas is converted to hypochlorous acid, thus requiring higher dosages of chlorine to control microorganisms effectively (Bob Cunningham, pers. comm.). Many present-day cooling water treatment programs operate with the cooling water pH in the range of 8.0 to 8.5 or higher. Thus, chlorine is less effective than other biocides that are less affected by these higher pH values. Chlorine is an inexpensive, reliable broad-spectrum compound, requiring a one-hour contact time. This compound is inactivated by water with a pH higher than 9.0, sunlight, aeration, hydrogen sulfide, and ammonia (Lutey, 1991; John Davies, pers. comm.). Chlorine is potentially corrosive when the water has a pH lower than 6.0, and it can adversely affect wood. Chlorine application equipment is expensive and requires extensive maintenance. Chlorine gas is dangerous to handle (Lutey, 1991; Buckman Laboratories, 1982). Its use is limited due to environmental regulatory restrictions on the discharge of chloramines and halomethanes (Lutey, 1991).

• ***Calcium and sodium hypochlorite*** (e.g., Sanatox 2243® and Nalco 7345®, respectively) are salts of hypochlorous acid, the biocidal agent. They are broad-spectrum biocides and are effective against all bacteria, fungi, and algae (Lutey, 1991). They act by oxidizing proteins, interfering with respiration and metabolism, and destroying cell walls. They are most effective when the pH of the water is between 6.5 and 7.5, requiring a short (one hour) contact time at this pH range. Hypochlorite salts are easier to handle than chlorine gas, but have the same limitations. They are also more expensive than chlorine gas (Lutey, 1991; Buckman Laboratories, 1982; John Davies, pers. comm.). They are often alternated with polymeric quaternary ammonium compounds (Richard Cannon, pers. comm.).

• ***Solid organo-chlorinated-hydantoins*** are effective against all types of bacteria, fungi, and algae. They oxidize proteins, interfere with respiration and metabolism of microorganisms, and destroy cell walls. They are most effective when the pH of the water is in the range of 8.0 and 9.0, which is a common pH range in cooling towers with present maintenance practices. A one-hour contact time is required for effectiveness (John Davis and Jim Rauh, pers. comms.). In many instances these compounds do not have the limitations that are encountered with gaseous and liquid biocides. Generally, they are not strong oxidizing compounds. Chlorine is slowly released. Consequently, contaminating organic material and high pH affect their efficacy less than chlorine gas or the hypochlorites. They are inactivated when the pH of the water is 10.0, or in the presence

of hydrogen sulfide and ammonia (John Davis, pers. comm.). Their widespread use is mainly limited by cost and the difficulty of controlling the rate they dissolve in water. Examples of active ingredients for this group of compounds are 1,3-dichloro-5-ethyl-5-methyl hydantoin (e.g., Dearcide 735®) and 1,3-dichloro-5,5-dimethyl hydantoin (e.g., Nalco 7346®).

• The ***triazinetriones*** are similar in their characteristics to the chlorinated-hydantoins, except they are more soluble in water and can provide higher concentrations of chlorine more quickly (Bob Cunningham, pers. comm.). Examples of active ingredients for this group of compounds are sodium dichloro-S-triazinetrione (e.g., A-109 Microbiocide®), sodium dichloro-S-triazinetrione dihydrate (e.g., Betz Entec 362®), and trichloro-S-triazinetrione (e.g., Sanatox 2247®).

Bromine-generating compounds

• The ***bromine-substituted hydantoins*** or solid organo-bromine compounds have many of the same characteristics, advantages, and limitations as the chlorinated hydantoins. The most commonly used active ingredient within this group of compounds is 1-bromo-3-chloro-5,5-dimethyl-hydantoin (BCDMH) (e.g., Sanatox 2080®). This compound is very effective against bacteria, but less effective against algae and fungi. It is formulated as tablets that dissolve slowly in water. This biocide is not as pH sensitive as chlorine. It is most effective when the pH of the treated water is in the range of 6.0 to 9.0, which is a typical range found in cooling towers. In open-recirculating cooling water systems, BCDMH is alternately used with polymeric quaternary ammonium compounds. Because BCDMH is an oxidizer, it can contribute to corrosion and diminish the effectiveness of some corrosion inhibitors (Richard Cannon and William Dignin, pers. comms.). (Corrosion destroys the metal components of the cooling system; inhibition of corrosion is an important part of water system management, along with microbial and scale control.) BCDMH is considered one of many viable alternatives to tributyltin compounds (Richard Cannon, and Ellis Atwater, pers. comms.).

• ***Sodium bromide*** (e.g., Skasol MB-B) is formulated as a liquid or solid product and must be activated with sodium hypochlorite, which releases hypobromous acid, the actual biocidal agent. This product is an effective biocide for bacterial and algal control and is efficacious over a wider pH range than chlorine and the chlorine-generating compounds. For instance, at pH 8.3, which is characteristic for many cooling towers, less than 13 percent of active hypochlorous acid is available as a biocide. On the other hand, over 70 percent of hypobromous acid remains at this pH (Midland Research Laboratories). Sodium bromide is becoming more accepted as an alternative to chlorination, despite its higher oxidation potential (Lutey, 1991; Bob Cunningham, pers. comm.).

Non-halogen donors

• ***Chlorine dioxide*** (e.g., Dura Klor®) is a gas that does not convert to hypochlorous acid in water as chlorine does. It remains as dissolved chlorine dioxide in solution (Buckman Laboratories, 1982). This microbiocide is an excellent bactericide and algicide. It is more effective at higher water pH ranges than chlorine. Consequently, chlorine dioxide is more effective than chlorine gas and sodium hypochlorite in present-day cooling water treatment programs. Sodium dichloride does not react with ammonia, so it does not lose its effectiveness, unlike the halogenated hydantoins (Jim Rauh, pers. comm.). Chlorine dioxide is unstable and explosive and thus is

produced on-site and fed directly into the system (Chambers, 1962). Sodium chlorite, one of the precursors commonly used to generate chlorine dioxide, can also be explosive. Although techniques for safely handling the precursors have been developed, these techniques add to the cost and complexity of the system. This makes chlorine dioxide more expensive than most of the chlorine generators (Lutey, 1991; Ken Swanson, pers. comm.). Chlorine dioxide is a strong oxidizer and can be potentially very corrosive (Chambers, 1962; Bob Cunningham, pers. comm.).

• ***Ozone***, a gas, is a strong but unstable biocide. It is usually fed continuously or intermittently to the water added to the cooling tower to prevent contamination of a clean system (Buckman Laboratories, 1982). When used at concentrations of 20 to 40 ppb, this gas is an excellent bactericide, but a poor algicide. Ozone is also very effective against fungi at concentrations of 40 to 50 ppb, but at these levels, ozone begins to leave solution (outgas). Dissolved in water, it does not pollute the environment and is harmless to aquatic organisms after decomposition to oxygen. Ozone in air is extremely corrosive to nearly everything, including wood and metals (Ken Swanson and Ellis Atwater, pers. comms.). Ozone dissolved in water does not seem to cause corrosion as other oxidizers do (Ken Swanson, pers. comm.). Like chlorine, ozone is affected by the pH of the water (Lutey, 1991), but does not increase inorganic salt content and is a more powerful biocide. Water temperatures of 110°F or higher will inactivate ozone (Puckorius, 1993). Ozone has to be generated on-site with ozone generators, using high voltage. This requires a large initial investment in generation equipment needed for an ozone application system (Lutey, 1991). The ozone generation system should run efficiently to keep electrical costs down. Although ozone is a very effective microbiocide, its use in cooling water systems is limited to small units or to specific areas within a larger system because of the high cost to generate the needed ozone (Ken Swanson, pers. comm.). Also, its residence time in water is short, so it is difficult to generate enough ozone at a single point to provide effective concentrations to every part of a large system.

Non-oxidizers

Examples of the most commonly used compounds in this group are:

Organo-bromine compounds are most effective against bacteria and fungi, but are weak algicides (Lutey, 1991; Friend et al., 1980). They act extremely rapidly—used under situations when the bacterial population is out of control—requiring a contact time of only half an hour. These compounds interfere with cell respiration. Organo-bromines are effective when the pH of the water is in the range of 6.0 and 9.0. High temperature, sunlight and sulfide ions will inactivate them (Lutey, 1991; John Davis, pers. comm.). They are less hazardous to handle than the isothiazoline compounds. An example of this group of compounds is 2,2-dibromo-3-nitrilopropionamide (DBNPA), the active ingredient of Antimicrobial 7413®. DBNPA is considered another viable alternative to tributyltin compounds for use in recirculating cooling water treatment programs (Larry Grab, pers. comm.).

Triazines are another group of biocides. Effective against algae, they are used only when algae cannot be controlled by other biocides, most often where cooling towers are exposed to sunlight (Glen Heikkinen, pers. comm.). These compounds are reasonably safe and easy to handle. Examples of active ingredients for this group of compounds are hexahydro-1,3,5-tris(2-hydroxyethyl)-S-triazine (e.g., Duracool 6451®) and terbuthylazine (e.g., Nalco 2834®).

Isothiazoline compounds are generally a mixture of two isothiazoline chemicals. For instance, 2-methyl-4-isothiazoline-3-one and 5-chloro-2-methyl-4-isothiazolin-3-one are the active ingredients of Dearcide 702®. Isothiazoline compounds are used as broad-spectrum biocides in open- and closed-recirculating cooling water systems. These biocides are most effective when the pH of the water is in the range of 6.5 and 9.0 (John Davies and Ron Derbyshire, pers. comms.). They are most effective against bacteria and moderately effective against algae and fungi. They inhibit respiration and food transport through their cell walls. They can be used as slug treatments or continuously fed (Ken Swanson and William Dignin, pers. comms.). At recommended label rates, these compounds act relatively slowly, requiring a contact time of six hours, and do not affect components of the cooling water system (John Davies, Ken Swanson, and Bob Cunningham, pers. comms.). Fouled systems can be more economically treated by combining isothiazolines with a penetrant/biodispersant, which reduces the amount of biocide needed (Lutey, 1991). Isothiazolines are inactivated in the presence of sulfite and sulfide compounds (John Davies and Bob Cunningham, pers. comms.). They should be carefully handled because they can cause severe dermal effects. For this reason, automated feeding systems are recommended (Lutey, 1991; Ron Derbyshire, pers. comm.). They are considered viable options to tributyltin (Ellis Atwater, William Dignin, and Larry Grab, pers. comms.), but do contain traces of copper as a stabilizer. Copper, like tributyltin, is also problematic for some POTWs trying to meet their effluent limitation. Less of these products are currently used as biocides in cooling water systems and some manufacturers are preparing to replace the copper with iron to stabilize the compounds. Viable options to the isothiazoline and tributyltin compounds are DBNPA and glutaraldehyde (Glen Heikkinen, Richard Cannon, Larry Grab, and William Dignin, pers. comms.).

Quaternary ammonium salts are commonly known as quats. They are the largest class of non-oxidizing biocides (Lutey, 1991; Ward, n.d.). The quats are most effective against bacteria and algae when the pH of the water is in the range of 7.5 and 9.0. They are not effective biocides against fungi regardless of the pH of the water. Like organotin compounds and glutaraldehyde, they act very slowly, requiring a contact time of six to eight hours. Their mode is attack of phospholipids in the cell membrane and blocking of normal cell wall activity. The quats are classified as biostats and considered another viable option to tributyltin compounds. Like organotin compounds, the quats are inactivated by high silt levels and cellulose fibers (Lutey, 1991; John Davies, pers. comm.). Their efficacy is generally affected by high chloride concentrations (Lutey, 1991), dirt, and calcium salts (William Dignin, pers. comm.). The quats may create foaming problems even when used at recommended rates, and this is a major limitation of their use (Lutey, 1991).

There are at least eleven different quat compounds, most of them variants of alkyl ammonium chlorides, for example alkyl (58% C14, 28% C16, 14% C12) dimethylbenzyl ammonium chloride (e.g., Sanatox 2201®). Dodecylguanidine hydrochloride (e.g., Betz Entec 349®) is another quat. Polymeric quaternary ammonium compounds or poly-quats are among the most widely used of the quat compounds. The poly-quats are effective broad-spectrum biocides when the pH of the treated water is in the range of 7.5 to 9.0 (Shair et al.,. 1978). They are effective against algae, bacteria, and have some fungicidal activity (Lutey, 1991; Jim Rauh, pers. comm.). The major poly-quat is poly[oxyethylene (dimethyliminio) ethylene-(dimethyliminio) ethylene

dichloride] (e.g., Midland 605®) (Buckman Laboratories, 1982). Sometimes also known as a water-soluble cationic polymer, this poly-quat is more of a biostat than a biocide, but it is effective at maintaining control in a cooling system once a desired level of cleanliness has been achieved. This compound must be alternated with another biocide, usually an oxidizer such as chlorine. The compound is safe to handle and is also used in pools and spas (Richard Cannon and Jack Walker, pers. comms.). Suspended solids in the water may inhibit its efficacy (Lutey, 1991).

Biocide formulations used in cooling water systems to control microorganisms often contain two or more different active ingredients. These blends not only provide broader and possibly synergistic activity against target microorganisms, but may also help prevent resistance. For example, quats are frequently combined with tributyltin because tributyltins help suppress the foaming problems of the quats, and the quats help increase the solubility of the tributyltins, which otherwise have a tendency to come out of solution (Lutey, 1991; Buckman Laboratories, 1982). Due to increasing costs for the development of new active ingredients, current research is focused on the development of these synergistic blends (Lutey, 1991).

Organo-sulfur compounds are commonly used in cooling water treatment programs. They include active ingredients, such as methylene bisthiocyanate (e.g., Dearcide 709®), potassium N-methyldithiocarbamate (e.g., Skasol MB-X®), and both sodium (e.g., Formula 37®) and potassium dimethyldithiocarbamate (e.g., Midland 638®) (Buckman Laboratories, 1982). The organo-sulfur compounds are formulated as a liquid or powder (William Dignin and Jim Lagunich, pers. comms.). They do not foam (William Dignin, pers. comm.) and are generally applied alone or in combination with other biocides (Lutey, 1991). These compounds are most effective against bacteria and less effective against fungi and algae. The pH of the treated water should be in the range of 7.5 and 9.5. Their mode of action is chelation of essential metallic ions, which interrupts the metabolic processes of microorganisms. Low pH of the treated water and the presence of heavy metals, such as iron, inactivate these compounds (Lutey, 1991; John Davies, pers. comm.). They act slowly, requiring a contact (exposure) time of 8 hours (John Davies and Jim Rauh, pers. comms.). An exception is methylene bisthiocyanate, which requires a contact time of about two hours (Lutey, 1991). Methylene bisthiocyanate hydrolyzes (degrades) rapidly at a water pH above 8.0, losing its efficacy (Lutey, 1991; Ward). Thus, cooling water systems operating in the alkaline range require higher concentrations or more frequent applications of this biocide (Ward, n.d.). Methylene bisthiocyanate is not easy to handle and feed. It does not dissolve in water readily as the carbamates (see *organo-sulfur compounds* above) (Lutey, 1991). Methylene bisthiocyanate mixed with 2-(thiocyanomethylthio)benzothiazole (discussed below) is considered a viable alternative to tributyltin because the two act synergistically, resulting in a very rapid kill of the microorganisms present in the cooling water system (Jim Lagunich and Jim Rauh, pers. comms.).

Glutaraldehyde (e.g, Nalco 8396®) is a broad-spectrum biocide and is effective against all bacteria, fungi, and algae. It is most effective when the pH of the water is higher than 6.0 (John Davies and William Dignin, pers. comms.). Its mode of action is reaction with and crosslinking amino groups of proteins in the cell nucleus. It acts relatively slowly, requiring a contact time of 6 to 8 hours (John Davies, pers. comm.). Glutaraldehyde does not foam (William Dignin, pers. comm.) and rapidly degrades to carbon dioxide and water (Richard Cannon, pers. comm.). Biocides based on liquid formulations of glutaraldehyde are widely used in situations where

bacteria are troublesome, including those associated with microbiologically influenced corrosion. They are one of several commonly used biocides in open- and closed-recirculation cooling water systems (Glen Heikkinen and Ellis Atwater, pers. comms.; Lutey, 1991) and are considered viable options to tributyltin compounds (William Dignin and Larry Grab, pers. comms.). Their disposal in cooling water treatments is not a problem, because they break down to carbon dioxide and water (Lutey, 1991). Glutaraldehyde is inactivated by ammonia or primary amines at concentrations higher than 200 ppm (John Davies and Larry Grab, pers. comms.). It has an unpleasant odor and can cause blindness if splashed in the eyes (Richard Cannon, pers. comm.).

Organic thiocyano-azole compounds are generally used to control severe microbiological problems, such as plugging, fouling and microbiologically influenced corrosion. An example is 2-(thiocyanomethylthio)benzothiazole (TCMTB) (e.g., West C-118®). It is an effective fungicide primarily used to protect wooden cooling tower structures from wood-rotting fungi (Lutey, 1991; Mayur et al., 1991; Buckman Laboratories, 1982). It also effectively controls bacteria that cause microbiologically influenced corrosion (Lutey, 1991). TCMTB does not cause foaming, but is hazardous to handle. Since it is formulated as a solvent-based liquid, care must be taken to choose handling and pumping equipment that can tolerate the solvent. High levels of sulfides, when present in the treated water, will inactivate this biocide (Jim Luganich, pers. comm.). When used in a routine microorganism control program, TCMTB is usually mixed with methylene bisthiocyanate (Lutey, 1991; Jim Luganich, pers. comm.).

Cost comparisons for tributyltin alternatives

Costs of products used for cooling towers were obtained through a series of steps.

1) The recommended range of treatment dosages and frequencies were determined from the label.

2) The type of use of the product was determined. In most cases, a product can be used two ways: a) to clean an especially dirty or fouled system, and b) to maintain a system once it is acceptably clean. Cleaning a fouled system generally employs a pulse of disinfectant at an elevated concentration for a relatively short time and is done only infrequently. Maintenance generally employs a lower concentration, released at regular, relatively frequent intervals. Usually the timing and dosages of the maintenance regime is explicitly stated on the label, while only the dosage of the cleaning regime is explicitly stated, and the timing is left to the discretion of the operator on an as-needed basis. In most well-managed, non-industrial cooling water systems, cleaning should be necessary only once or twice per year. We allowed for one cleaning dosage per month. In practice, a cleaning episode might require several doses, but our estimates should still allow for a relatively high rate of cleaning, perhaps two to four times per year. Labels usually provide a range for all dosages and frequencies.

3) Costs were standardized to a one-month period and 1,000 gallons of system capacity.

4) A range of costs per pound of the product was determined by contacting a dealer.

5) Monthly maintenance cost was taken as the product of dosage, frequency, and cost per pound of the product. The lower bound of the cost range was the product of the lower bound of each term, and the upper bound was similarly calculated using the upper bound of each term.

6) Since we allowed for one cleanup dosage per month, cleanup cost was the product of dosage and cost per pound. Again, lower and upper bounds were calculated.

7) Overall monthly costs were calculated by summing the maintenance and cleanup costs, again summing across lower bounds to obtain the overall lower bound, and summing across upper bounds to obtain the overall upper bound.

Table 10. Cost comparison of alternatives to tributyltin for cooling water systems.

Product name[1]	Active ingredient, percent	Cost of material[2]	Total cost per month
➥ *Chlorine-generating compounds*			
Nalco 2590	65.0% calcium hypochorite	$5.64–$5.85/lb	$6.35–$6.57
Nalco Acti-Plus 2818 (= Nalco 7345)	8.3% sodium hypochorite	$1.86–$3.32/lb	$11.80–$42.14
Skasol MB-H	12.5% sodium hypochorite	$1.05–$4.72/lb	$3.28–$39.27
• *Solid organo-chlorinated hydantoins*			
Nalco 7346	1-bromo-3-chloro-5,5-dimethyl hydantoin, 60.0%; 27.4%[a]; 10.6%[b]	$5.26–$5.53/lb	$5.79–$129.96
a) 1,3-dichloro-5,5-dimethyl hydantoin; b) 1,3-dichloro-5-ethyl-5-methyl hydantoin			
• *Triazinetriones*			
7419 Microbiocide (AWT)	34%[a]	$4.06–$4.35/lb	$7.11–$15.21
A-109 Microbiocide (ASE)	34%[b]	$4.07–$4.52/lb	$7.13–$15.82
A-809 Microbiocide (ATC)	34%[b]	$3.47/lb	$6.08–$12.15
Betz Entec 362	99.5%[b]	$7.91/lb	$4.75–$90.97
ChemTreat C-2185	98.8%[c]	$9.50/lb	$1.81–$3.33
Dearcide 716 (DD)	25%[c]	$3.72/lb	$8.14–$16.29
G-C Formula 36	25%[b]	$2.75–$3.80/lb	$4.82–$6.65

a) sodium dichloro-S-triazinetrione; b) sodium dichloro-S-triazinetrione dihydrate; c) trichloro-S-triazinetrione

➥ *Bromine-generating compounds*

Nalco 7346 (see *solid organo-chlorinated hydantoins* above)

7215 Microbiocide (AWT)	92.5%★	$8.25/lb	$5.78–$47.03
7215 Microbiocide (ATC)	92.5%★	$8.23/lb	$5.78–$46.91
7215 Microbiocide (ASE)	92.5%★	$10.53–$11.40/lb	$7.38–$64.98
Chemcide 935 (CWT)	92.5%★	$9.07/lb	$6.35–$251.65
ChemTreat C-2189 Tablets	92.5%★	$8.92/lb or $0.39/tablet	$6.24–$50.84
G-C Formula 314-T	92.5%★	$6.00–$9.35/lb or $0.26–$0.41/tablet	$4.20–$53.30
Sanatox 2060 (SJC)	93.5%★	$6.80–$7.30/lb	$44.76–$41.61
Sanatox 2080 (SJC)	92.5%★	$6.80–$7.30/lb	$44.76–$41.61

★ 1-bromo-3-chloro-5,5-dimethylhydantoin

G-C Formula 318	40.0% sodium bromide	$1.55/lb	$0.01–$7.98
Nalco Acti-Brom 1338	42.8% sodium bromide	$1.45/lb	$0.02–$6.89
Nalco Acti-Brom 7342	42.8% sodium bromide	$1.54–$3.34/lb	$0.02–$15.74

➥ *Organobromine compounds*

7413 Antimicrobial (ATC)	5.0%✣	$5.89/lb	$4.58–$634.18
7413 Antimicrobial (ASE)	5.0%✣	$6.91–$7.05/lb	$5.38–$759.07
Betz Entec 345 A	5.0%✣	$5.17/lb	$4.19–$584.99
Antimicrobial DB-5 (CPL)	5.0%✣	$3.05/lb	$2.37–$328.39
ChemTreat CL-207	5.0%✣	$5.45/lb	$4.20–$577.81
Dearcide 723 (DD)	20.0%✣	$7.36–$7.46/lb	$2.35–$204.55
Dearcide 734 (DD)	40.0%✣	$42.19/lb or $18.60/tablet	$55.80
Nalco 2510	20.0%✣	$11.88–$12.33/lb	$2.71–$9.94

✣ 2,2-dibromo-3-nitrilopropionamide

➥ *Triazines*

Nalco 2834	4.0%✲	$6.66–$7.56/lb	$15.59–$17.69
Nalco 7336	4.0%✲	$4.27/lb	$10.02

✲ terbuthylazine: 2-(tert-butylamino)-4-chloro-6-(ethylamino)-S-triazine

➥ ***Isothiazoline compounds***

Ancocide 4070 (ACC)	1.2%[a]; 3.5%[b]	$3.32/lb	$9.09–$55.31
7423 Microbiocide (ASE)	1.2%[a]; 0.4%[b]	$4.86–$5.16/lb	$13.41–$86.48
Betz Entec 368 (Betz Entec)	1.2%[a]; 0.4%[b]	$3.72/lb	$10.27–$62.35
ChemTreat C-2155	4.3%[a]; 1.3%[b]	$3.89/2-oz bag	$31.12–$155.60
ChemTreat CL-2150	1.2%[a]; 0.4%[b]	$3.40–$3.70/lb	$9.38–$62.01
Dearcide 702 (DD)	1.2%[a]; 0.4%[b]	$3.70–$3.80/lb	$32.41–$63.69
G-C Formula 313	4.3%[a]; 1.3%[b]	$1.78–$2.23/lb	$32.08–$200.40
G-C Formula 315	1.2%[a]; 0.4%[b]	$3.65–$5.15/lb	$10.08–$86.32
Nalco 2810	4.3%[a]; 1.3%[b]	$9.05–$11.60/packet	$72.40–$464.00
Nalco 7330	1.2%[a]; 0.4%[b]	$4.43–$4.94/lb	$38.81–$82.79

a) 5-chloro-2-methyl-4-isothiazolin-3-one; b) 2-methyl-4-isothiazolin-3-one

➥ ***Quaternary ammonium salts*** — **Quats**

Betz Entec 349	10.0%[a]; methylene bis (thiocyanate), 5.0%	$7.24–$7.50/lb	$8.69–$63.75
Dearcide 737 (see *glutaraldehydes* above)			
G-C Formula 30-A	7%[b]	$1.50–$2.20/lb	$7.98–$23.39
G-C Formula 35	25%[c]; isopropyl alcohol, 10%	$3.25–$4.55/lb	$6.77–$14.19
Nalco 8396 (see *glutaraldehydes* above)			
Sanatox 2201 (SJC)	10%[b]	$18.70/gal	$18.40–$70.86
Sanatox 2203 (SJC)	20%[b]	$21.00/gal	$10.01–$37.73

a) dodecylguanidine hydrochloride; b) alkyl dimethyl benzyl ammonium chloride; c) dodecyl dimethyl ammonium chloride

➥ ***Quaternary ammonium salts*** — **Polyquats**

7416 Microbiocide (AWT)	15%✣	$3.50–$3.59/lb	$2.32–$38.52
7618 (ATC)	5%✣	$3.05/lb	$6.24–$99.58
A-806 Algaecide (ATC)	15%✣	$3.46/lb	$2.32–$37.20
7618 Microbiocide (ASE)	5%✣	$3.20-$5.16/lb	$6.52–$168.53
A-106 Microbiocide (ASE)	15%✣	$3.64–$3.75/lb	$2.44–$40.30
Algae Control Ed Liquid (CPL)	15%✣	$2.10–$2.40/lb	$1.41–$25.73
Dearcide 722 (DD)	15%✣	$2.75–$2.89/lb	$1.84–$30.69
G-C Formula 32	18%✣	$3.30–$4.55/lb	$1.82–$40.31
Nalco 2594	20%✣	$4.36–$5.80/lb	$1.31–$45.84
Skasol MB-5	15%✣	$3.63–$14.53/lb	$2.46–$155.60
WC 620	10%✣	$2.98–$3.83/lb	$3.02–$62.28
WC 625	15%✣	$3.32–$3.89/lb	$2.23–$41.70
WC 630	30%✣	$4.25–$4.89/lb	$2.34–$25.82

✣ poly[oxyethylene (dimethyliminio) ethylene(dimethyliminio)ethylene dichloride]

➥ *Organo-sulfur compounds*

7212 Microbiocide (ATC)	25.0%[a]	$3.33/lb	$4.42–$26.17
7212 Microbiocide (ASE)	25.0%[a]	$3.22–$3.52/lb	$4.27–$27.67
Betz Entec 349 (see *quats* above)			
Chemcide 942 (see *organic thiocyano-azole compounds* below)			
Chemcide 946 (see *organic thiocyano-azole compounds* below)			
Chemicide 965 (CWT)	20.0%[a]	$2.60/lb	$4.24–$25.30
ChemTreat CL-216	15.0%[b]; 15.0%[f]	$2.45–$5.30/lb	$6.42–$34.76
Dearcide 709 (DD)	9.3%[d]	$6.47–$6.51/lb	$9.70–$19.53
Dearcide 714 (DD)	15.0%[b]; 15.0%[f]	$2.34–$2.48/lb	$6.13–$16.22
9927 Microbiocide (Eco)	3.7%[e]; 5.1%[c]	$1.52–$2.05/lb	$2.16–$60.80
G-C Formula 31-A	4.5%[b]; 4.5%[f]	$1.55–$2.25/lb	$12.25–$28.58
G-C Formula 37	15.0%[b]; 15. %[f]	$2.75–$3.80/lb	$7.56–$16.98
G-C Formula 38-A	7.4%[e]; 10.2%[c]	$3.45–$4.80/lb	$1.11–$23.04
G-C Formula 39	50.0%[a]	$3.60–$5.05/lb	$1.76–$36.92
G-C Formula 317	40.0%[b]; 40.0%[f]	$0.40–$0.54/lb ($0.10–$0.14/bag)	$0.60–$1.08
Skasol MB-X	7.4%[e]; 10.2%[c]	$3.47–$8.74/lb	$2.49–$129.23
Antifoulant C-101 (WTC)	3.7%[e]; 5.1%[c]	$13.05–$16.66/gal	$2.11–$56.13
WC 600	7.4%[e] 10.2%[c]	$3.64–$4.25/lb	$2.61–$62.85

a) potassium dimethyldithiocarbamate; b) sodium dimethyldithiocarbamate; c) potassium N-methyldithiocarbamate; d) methylene bisthiocyanate; e) disodium cyanodithiomidocarbonate; f) disodium ethylene-1,2-bisdithiocarbamate (nabam)

➥ *Gluteraldehyde*

7420 Microbiocide (AWT)	15.0% gluteraldehyde	$4.22–$4.54/lb	$36.08–$88.43
7420 Microbiocide (ATC)	15.0% gluteraldehyde	$4.39/lb	$37.53–$85.44
7420 Microbiocide (ASE.)	15.0% gluteraldehyde	$5.43–$5.73/lb	$46.43–$111.56
7421 Microbiocide (ASE)	45.0% gluteraldehyde	$10.83–$11.26/lb	$30.08–$72.96
Betz Entec 445	45.0% gluteraldehyde	$8.34–$10.23/lb	$23.44–$67.00
GA-15 Microbiocide (CPL)	15.0% gluteraldehyde	$2.51/lb	$21.46–$48.90
ChemTreat CL-2111	45.0% gluteraldehyde	$7.10/lb	$19.45–$45.15
Dearcide 733 (DD)	45.0% gluteraldehyde	$5.78–$5.96/lb	$16.01–$38.57
Dearcide 737 (DD)	42.5% gluteraldehyde; alkyl dimethyl benzyl ammonium chloride, 7.5%	$8.02–$8.12/lb	$19.89–$47.26
G-C Formula 312	45.0% gluteraldehyde	$5.45–$7.60/lb	$15.75–$51.38
Nalco 7338	45.0% gluteraldehyde	$5.16–$8.81/lb	$14.15–$56.29
Nalco 8396	14.0% gluteraldehyde; alkyl dimethyl benzyl ammonium chloride, 2.5%	$3.45–$4.71/lb	$2.62–$8.41
Microbiocide No. 4 (Ska)	15.0% gluteraldehyde	$5.01–$5.32/lb	$42.96–$103.89

➥ ***Organic thiocyano-azole compounds***			
Chemcide 942 (CWT)	methylene bis(thiocyanate), 2.5%; 2.5%✹	$7.50/lb	$3.38–$74.33
Chemicide 946 (CWT)	methylene bis(thiocyanate) 10%; 10.0%✹	$15.53/lb	$1.90–$42.40

✹ 2-(thiocyanomethylthio)benzothiazole (TCMTB)

[1] *Abbreviations for manufacturers of alternatives to tributyltin:* **ACC** = Anderson Chemical Company, Inc.; **ASE** = Aqua Serv Engineers, Inc.; **ATC** = AquaTreat Chemicals, Inc.; **AWT** = American Water Technology; **Betz** = Betz Entec; **ChemTreat** = ChemTreat, Inc.; **CPL** = Chem Pro Laboratory, Inc.; **CWT** = Chemco Water Technology; **DD** = Dearborn Division—W.R. Grace & Co.; **Eco** = Ecolab, Inc., Water Care Services; **G-C** = Garratt-Callahan Chemical Co.; **Nalco** = Nalco Chemical Co.; **SJC** = San Joaquin Chemicals, Inc.; **Ska** = Skasol, Inc.; **WC** = WC Chemical Engineering; **WTC** = Water-Tech Chemical Specialties, Inc.

[2] Total cost of material per month was calculated using estimates for monthly maintenance and a one-day cleanup pulse per month. To request a copy of cost descriptions of tributyltin alternatives, please write to:

Cost Comparison of Tributyltin Alternatives
Department of Pesticide Regulation
Environmental Monitoring and Pest Management
1020 N Street, Room 161
Sacramento, CA 95814–5624

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PART SIX — OPTIONS FOR CONTROLLING COPPER AND TRIBUTYLTIN-CONTAINING COMPOUNDS

A. W. Fabre

The Department of Pesticide Regulation (DPR) is committed to establishing a high-priority program to address the problem of excessive copper and tributyltin found in the effluent of Publicly Owned Treatment Works (POTWs) in the San Francisco Bay Area (Bay Area). A contributing source of these metals is associated with the use of pesticide products containing copper and tributyltin as active ingredients. DPR has identified administrative options that could be used to address this problem.

Voluntary Program

A cooperative outreach (voluntary) program has been used by several Bay Area POTWs in an effort to change pest control practices of residents, small businesses, and municipalities.

Advantage

- Educates users of copper and tributyltin pesticides and encourages them to switch to alternative compounds.

Disadvantages

- Involves added costs to local agencies.
- Requires coordination among users in municipalities in the Bay Area to obtain compliance.
- Requires coordination of municipalities within the boundaries of POTWs to obtain compliance.

Regulatory Program

DPR can use one of three regulatory options to address the problem of excessive copper and tributyltin discharges resulting from pesticide use in the Bay Area. These options include 1) cancellation of copper and tributyltin pesticide products, 2) designation of copper and tributyltin pesticides as restricted materials, and 3) prohibition of the sale and use of copper and tributyltin pesticides. Each option would reduce discharges to waterbodies in California attributable to copper and tributyltin. However, users would have to change their management practices for controlling roots in sewers and microorganisms in cooling water systems.

Option 1—Cancellation of copper- and tributyltin-containing products

A comprehensive prohibition of copper and tributyltin pesticides would result in their total elimination throughout California, including uses as fungicides and algicides.

Advantage

- Reduces the possibility of accidentally using canceled products.

Disadvantages

- Provides a solution that does not focus on the Bay Area. Inconveniences users outside of the Bay Area who do not contribute to discharges into the Bay.
- Fails to recognize that these materials are used throughout California for a wide range of agricultural and industrial uses and generally do not contribute to adverse aquatic effects.

Option 2—Restricted material status for copper- and tributyltin-containing products

Designation as a restricted material is the most complex option for addressing the problem of excessive copper and tributyltin discharges from POTWs in the Bay Area. The permitting procedure for restricted materials is intended to regulate pesticides that are used agriculturally. Many of the current uses of copper and tributyltin pesticides are not agricultural; therefore, the mechanisms appropriate for agricultural use pesticides may not apply to this situation.

Advantages

- Allows inspection of applications by county agricultural commissioners, facilitates notification of intent to apply restricted materials, and requires reporting of all pesticide applications of restricted materials, which would increase workload for users and county offices.
- Provides a way to monitor compliance with additional use requirements specified by regulations.

Disadvantages

- Allows sale of restricted materials only by licensed pesticide dealers, who are required to maintain sales records.
- Allows application of restricted materials only by certified applicators or by individuals under the direct supervision of certified applicators.
- Allows possession and application of restricted materials under permit issued by the county agricultural commissioner.
- Increases costs for retailers, pesticide dealers, pesticide applicators, local agencies, and users.

Option 3—Restrictions on sale and use

Statutory authority is provided by the Food and Agricultural Code for the prohibition and regulation of environmentally harmful materials (§ 14102). For example, DPR has adopted regulations governing the release rate of tributyltin from antifouling paints and coatings. Option 3 would prohibit the sale and use of copper- and tributyltin-containing products used for root control and cooling tower biocides in the counties of (1) San Francisco, (2) Santa Clara, (3) San Mateo, (4) Alameda, (5) Contra Costa, (6) Solano, (7) Napa, (8) Marin, and (9) Sonoma.

Advantages

- Tailors the prohibition of sale and use in the Bay Area for copper used to control roots in sewers and tributyltin used to control microorganisms in cooling water systems.
- Limits sale and use prohibition to copper- and tributyltin-containing products that have label instructions for use in sewers or cooling water systems.

Disadvantage

- Requires county agricultural commissioners of the nine affected Bay Area counties to redirect their efforts to monitor sales of copper- and tributyltin-containing products used in sewers or cooling water systems.