Addendum to Deltamethrin Risk Characterization Document

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by

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ABBREVIATIONS AND ACRONYMS

ADD	absorbed daily dosage
AI	active ingredient
CAS No.	Chemical Abstracts Service Number
DFR	dislodgeable foliar residue
DPR	California Department of Pesticide Regulation
ENOEL	estimated no observed effect level
HTM	hand-to-mouth
M/L	mixer/loader
M/L/A	mixer/loader/applicator
MOE	Margin of Exposure
NOEL	no observed effect level
OTM	object-to-mouth
PHED	Pesticide Handler Exposure Database
PHI	preharvest interval
PISP	Pesticide Illness Surveillance Program
PPE	personal protective equipment
PUR	Pesticide Use Report
RCD	Risk Characterization Document
REI	restricted entry interval
STADD	short-term absorbed daily dosage
TC	transfer coefficient
UCL	upper confidence limit
U.S. EPA	U.S. Environmental Protection Agency
WHS	Worker Health and Safety Branch
WPS	Worker Protection Standard

ABSTRACT

Deltamethrin is a pyrethroid insecticide with multiple uses in both agricultural and non-agricultural settings. Several formulations of deltamethrin are registered for use in California, including those designed to be mixed with water before spraying, i.e. aqueous concentrates, emulsifiable concentrates, and liquid suspensions; and ready-to-use products in dust, granular, liquid, and impregnated material formulations. Deltamethrin concentrations in end-use products range 0.01 – 4.75%. The various formulation types are applied in numerous ways, including aerial and ground applications, hand-held equipment, and in ready-to-use packages such as shaker cans, spray bottles, and a flea collar.

A human exposure assessment for deltamethrin was finalized in 1996, and a Risk Characterization Document, identifying several scenarios with health concerns, was finalized in 2000. A Risk Management Directive was completed in 2004 and identified key exposures warranting mitigation, including those associated with broadcast residential applications and residential dust formulations. To provide current information for the risk mitigation effort, this Addendum to the Risk Characterization Document was prepared; it considers exposure scenarios associated with these uses and addresses new uses and new data. Deltamethrin is also a metabolite of another pyrethroid, tralomethrin. At the request of the primary registrant, U.S. EPA canceled all tralomethrin products effective December 15, 2014. In California, the only tralomethrin products are three insecticidal chalk products. With the cancellation of all uses, no additional risk assessment is being done for tralomethrin.

Exposure scenarios were identified from the uses listed on product labels. These were sorted into relatively high, moderate, and low priorities, by risk estimated as Margin of Exposure (MOE), which is calculated by dividing the no observed effect level of 0.1 mg/kg/day by estimated exposure. High-priority scenarios are defined as those in which MOE is less than or equal to 10, when rounded to one significant figure (i.e., MOE < 15). Scenarios with MOE $\geq$ 15 and $\leq$ 100 are classified as moderate priority. Scenarios with MOE above 100 are considered low priority. Exposure and risk estimates are given in this Addendum for the nineteen high-priority scenarios. Three highest priority scenarios, with MOE < 1, involve residential uses and dust applications, as indicated in the Risk Management Directive. Additionally, one scenario with MOE < 1, toddlers interacting with treated pets, relates to a use that was not registered in 2004.

Twelve of 44 occupational scenarios are high-priority, as listed below.

Agricultural handler scenarios: 7 of the 21 are high-priority:

- Mixer/loader (M/L) handling liquid in support of aerial application (MOE: 4)
- M/L handling liquids in support of high-acre aerial application (MOE: 1)
- High-acre aerial applicator applying liquids (MOE: 6)
- Flagger involved with high-acre aerial application of liquids (MOE: 11)
- M/L handling liquids in support of chemigation (MOE: 4)
- M/L handling liquids in support of high-acre groundboom applications (MOE: 7)
- Mixer/loader/applicator (M/L/A) using a high pressure handwand (MOE: 8)

Non-agricultural handler scenarios: 4 of the 16 are high-priority:

- Applicator spraying liquid into right-of-way (MOE: 5)
- Applicator using a paintbrush (MOE: 2)
- Applicator using a duster (MOE: < 1)
- M/L/A using a high pressure handwand (MOE: 8)

One of 7 representative occupational reentry scenarios is a high-priority scenario:

- Sweet corn hand harvesting (MOE: 7)

Seven of 16 residential scenarios are high-priority, as listed below.

Residential handler scenarios: 4 of the 10 are high-priority:

- Applicator hand-spreading granules (MOE: <1)
- Applicator of dusts (MOE: < 1)
- Applicator using a paintbrush (MOE: 6)
- Applicator putting a flea collar on a dog (MOE: 6)

Residential post-application scenarios: 3 of the 6 are high priority:

- Toddler on treated turf (MOE: 8)
- Adult with treated pet (MOE: 3)
- Toddler with treated pet (MOE: < 1)

INTRODUCTION

Deltamethrin is a pyrethroid insecticide with multiple uses in both agricultural and non-agricultural settings. It is toxic to insects by both dermal and oral exposure routes. The first deltamethrin products were registered in California in 1997. This Addendum to the Risk Characterization Document was prepared to provide current information for the risk mitigation effort.

Deltamethrin is also a metabolite of the pyrethroid insecticide tralomethrin. At the request of the primary registrant, U.S. EPA canceled all tralomethrin products effective December 15, 2014 (in California, the only tralomethrin products are three insecticidal chalk products). With the cancellation of all uses, no additional risk assessment is being done for tralomethrin.

REGULATORY STATUS AND RISK ASSESSMENTS

U.S. EPA

The United States Environmental Protection Agency (U.S. EPA) classifies deltamethrin as "not likely to be carcinogenic in humans, based on the absence of significant tumor increases in two adequate rodent carcinogenic studies" (Dotson *et al.*, 2010). The U.S. EPA classifies the acute oral toxicity of deltamethrin as Category II, the acute dermal toxicity as Category III, and the acute inhalation toxicity as Category II/III. In available animal studies, deltamethrin was not a dermal irritant or sensitizer, and it was classified as a minimal dermal irritant (Category III).

Deltamethrin was first registered with the U.S. EPA in 1996. Because it was registered after November 1, 1984, deltamethrin was not required to undergo U.S. EPA's reregistration process, and no Reregistration Eligibility Decision has been issued for deltamethrin. U.S. EPA initiated registration review for deltamethrin, as required every 15 years under the Food Quality Protection Act, on March 31, 2010. U.S. EPA anticipates finalizing its registration review in 2016 (U.S. EPA, 2010).

In association with registration review, U.S. EPA released its most recent risk assessments on deltamethrin (Dotson and Collantes, 2009; Dotson *et al*., 2010). In both assessments, the no observed effect level (NOEL) is 1 mg/kg/day, "based on decreased motor activity observed in an acute neurotoxicity study in rats" (Dotson and Collantes, 2009). As the critical endpoint was from an animal study, the target Margin of Exposure (MOE) was 100; an additional factor of 10 was applied for residential exposure scenarios involving children, for a target MOE of 1000. For dermal exposures, U.S. EPA applied a 1% dermal absorption factor derived from an *in vivo* study in rats with bifenthrin and an *in vitro* study with deltamethrin, bifenthrin, and cis-permethrin (Hughes and Edwards, 2010). Table 1 summarizes scenarios reaching U.S. EPA's level of concern (i.e., scenarios with MOEs below the target MOE).

Table 1. Scenarios Meeting U.S. Environmental Protection Agency Level of Concern for Deltamethrin

Scenario [a]	Exposure [b] (mg/kg/day)	Margin of Exposure (MOE) [c]
Child Post-Application		
Following Lawn Broadcast: Hand-to-Mouth	0.00194	515
Following Indoor Broadcast: Dermal	0.0014 – 0.0028	350 – 690
Following Indoor Broadcast: Hand-to-Mouth	0.0015 – 0.0044	230 – 670
Following Indoor Crack & Crevice: Dermal	0.0011 – 0.0023	430 – 870
Following Indoor Crack & Crevice: Hand-to-Mouth	0.0012 – 0.0036	280 – 830
Pet Collar: Dermal	0.042	24
Pet Collar: Oral	0.0224	45
Adult Post-Application		
Pet Collar: Dermal	0.027	37

[a] From Dotson *et al*. (2010), Attachment 5.
[b] Exposures are central tendency estimates.
[c] Margin of Exposure (MOE) is calculated by dividing critical no observed effect level (NOEL) of 1 mg/kg/day, based on decreased motor activity in rats, by exposure. Target MOE is 1000 for residential exposure scenarios involving children, otherwise the target MOE is 100. Ranges for child post-application exposure reflect variation in body weight and surface area assumed for children of different ages.

In addition to the chemical-specific risk assessment, U.S. EPA also assessed the cumulative effects of exposure to pyrethrins and pyrethroids, multiple chemicals sharing a common mechanism of toxicity with deltamethrin (U.S. EPA, 2011). The assessment concluded that, "cumulative estimated risks from existing pyrethrins/pyrethroid uses are not of concern."

California

The California Department of Pesticide Regulation (DPR) finalized its exposure assessment for deltamethrin in 1996 (Thongsinthusak, 1996). Dermal and oral absorption were estimated at 6.7% and 60%, respectively, based on a dermal absorption study in which deltamethrin was applied to rats and a pharmacokinetic study in which tralomethrin (which is "rapidly metabolized" to form deltamethrin) was administered to rats intraveneously and orally. Thongsinthusak (1996) used chemical-specific studies of aerial and groundboom handlers to estimate handler exposure. A single reentry scenario, cotton scouts, estimated exposure using foliar residues dislodged with hexane (Estesen *et al*., 1979), which is contrary to current practice (Edmiston *et al*., 2002). In residential settings, handler exposure estimates for pest control operators were derived from a chemical-specific study performed in Zagreb, Yugoslavia in 1980 (Kozar *et al*., 1981), and residential post-application exposures were based on a study of dislodgeable deltamethrin residues in carpet following a broadcast application (Maxey *et al*., 1995).

The Risk Characterization Document (RCD) for deltamethrin, identifying several scenarios with health concerns, was finalized in 2000 (Frank and Kellner, 2000). The NOEL for acute exposures was 0.1 mg/kg/day, based on "autonomic nervous system dysfunction (e.g., liquid feces, vomiting, and tremors)," which was "reported during the first week of a 13-week dog study" (Frank and Kellner, 2000). The study was reported by Chesterman (1977). Both DPR and U.S. EPA determined that the NOEL does not differ by exposure duration, and short-term exposures are potentially of the greatest concern. Table 2 summarizes scenarios assessed by DPR having MOEs below the target MOE.

Frank and Kellner (2000) also suggested that evidence of toxicity to dogs in the study of Chesterman (1977) could be seen at the low dose of 0.1 mg/kg/day, which might instead be considered a lowest observed effect level rather than a NOEL. To address that possibility, they calculated an estimated NOEL (ENOEL) of 0.01 mg/kg/day. However, consensus within DPR could be reached only on the NOEL, not the ENOEL. Frank and Kellner (2000) adjusted both the NOEL and ENOEL by the estimated 60% oral absorption.

A Risk Management Directive completed in 2004 identified key exposures warranting mitigation, including those associated with broadcast residential applications and residential dust formulations (Gosselin, 2004). To provide current information for the risk mitigation effort, this Addendum to the Risk Characterization Document was prepared; it considers exposure scenarios associated with these uses and addresses new uses and new data.

Table 2. Scenarios in the Risk Characterization Document Meeting California Department of Pesticide Regulation Level of Concern for Deltamethrin

Scenario [a]	Exposure [b] (mg/kg/day)	MOE from NOEL [c]	MOE from ENOEL [c]
Agricultural Applications			
Aerial Mixer-Loader	0.00168	36	4
Aerial Applicator	0.00114	53	5
Aerial Flagger	0.00009	670 [d]	67
Groundboom Mixer/Loader	0.00111	54	5
Groundboom Applicator	0.00014	430 [d]	43
Groundboom Mixer/Loader/Applicator	0.00125	48	5
Dust Loader/Applicator	0.00080	75	8
Cotton Scout [e]	0.00044	140 [d]	14
Residential Application			
Pest Control Operator (Mixer/Loader/Applicator)	0.06100	1	< 1
Post-Application, Infant	0.01417	4	< 1
Post-Application, Adult	0.00902	7	< 1

[a] From Frank and Kellner (2000). Target MOE is 100.
[b] Exposures are upper-bound estimates (i.e., mean + 2 SD (standard deviation) for mixer/loaders and applicators involved with aerial application; upper limit of range all others). Application rate assumed to be 0.03 pound deltamethrin per acre; Thongsinthusak (1996) also calculated exposure estimates for an application rate of 0.02 pound deltamethrin per acre, but those estimates are omitted from this table.
[c] Margin of Exposure (MOE) is calculated by dividing the critical no observed effect level (NOEL) of 0.06 mg/kg/day, or the estimated NOEL (ENOEL) of 0.006 mg/kg/day, by exposure. MOEs reported as integers. Both the NOEL and ENOEL are based on autonomic nervous system dysfunction in dogs, and both were adjusted by a 60% oral absorption. Target MOE is 100.
[d] MOE calculated with the NOEL exceeds the target MOE, although MOE calculated with ENOEL does not.
[e] Cotton scouts not wearing gloves; Thongsinthusak (1996) also estimated exposure for scouts wearing gloves, but those estimates are omitted from this table.

PHYSICOCHEMICAL PROPERTIES

Deltamethrin is a synonym for cyano(3-phenoxy-phenyl)methyl;2-(2,2dibromoethenyl)-2,2-dimethylcyclopropanecarboxylate. The molecular formula is $C_{22}H_{19}Br_2NO_3$; the molecular weight is 505.2; and the CAS No. is 52918-63-5. The structure is shown in Figure 1 and selected physical properties are listed in Table 3.

Figure 1. Deltamethrin Chemical Structure.

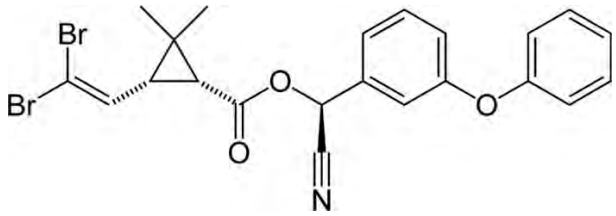


Table 3. Selected Physical and Chemical Properties of Deltamethrin

Property [a]	Value
Melting Point (°C)	90
Water Solubility (mg/liter, 25 °C)	< 0.002
Octanol/Water Partition Coefficient (log K_{ow})	6.20
Vapor Pressure (mm Hg, 25°C)	9.3×10^{-11}
Henry's Law Constant (atm-m^3/mole, 25°C)	4.99×10^{-6}

[a] From NLM (2012).

FORMULATIONS AND USES

Deltamethrin is available in California in several formulations. Formulation types include those designed to be mixed with water before spraying, including aqueous concentrates, emulsifiable concentrates, and liquid suspensions; and ready-to-use products in dust, granular, bait, liquid, and impregnated material formulations. Deltamethrin concentrations range 0.01 - 4.75%.

Currently in California there are 90 registered end-use products containing deltamethrin. Two additional registered products are for manufacturing use only and are outside the scope of this RCD Addendum because manufacturing uses are not regulated by DPR. The 90 products are summarized in Table 4. Of these, 73 are liquids; 12 are dusts; 3 are granular; one is a paint; and one is a flea collar. Fifteen of the aerosol spray mixtures also contain s-bioallethrin, imiprothrin, 1-octen-3-ol, or pyrethrins. Other active ingredients (AIs) are beyond the scope of this RCD Addendum, which focuses solely on deltamethrin.

Table 4. Deltamethrin Formulations and End-Use Products Registered in California

Formulation Type	Number of Products [a]	Deltamethrin Concentration Range (%)	Signal Word(s)
EC, LC, and SC [b]	14	0.32 – 4.75	Danger or Caution
Aerosol Spray Can [c]	19	0.01 – 0.06	Caution
Ready-to-Use Liquid [d]	40	0.02 – 0.03	Caution
Dust	12	0.05	Caution
Granular	3	0.1	Caution
Paint	1	0.075	Caution
Flea Collar	1	4	Caution
Total	90		

[a] Two products intended for manufacture use only were omitted.
[b] EC: emulsifiable concentrate. LC: liquid concentrate. SC: suspension concentrate. All three formulations are considered together in this exposure assessment, as all are mixed with water before application.
[c] Fourteen of these products are mixtures with pyrethrins (0.05 – 0.1% in 4 products), s-bioallethrin (0.02 – 0.1% in 7 products), imiprothrin (0.1% in 3 products), and 1-octen-3-ol (0.05% in 1 product).
[d] Products are either pre-packaged in trigger sprayers or hand pump-up sprayers, or designed to be poured into sprayers including trigger, pump-up, back pack, and hose-end.

PESTICIDE USE AND POUNDS SOLD

California requires reporting of all agricultural uses of pesticides, as well as other uses when pesticides are applied by a licensed applicator. These data are collected in the Pesticide Use Report (PUR) database (DPR, 2014a). Table 5 shows PUR data for top use sites for deltamethrin in 2008 – 2012, based on pounds applied. Structural pest control accounted for 74% – 99% of all use each year, for an average of 91% in the 5-year interval.

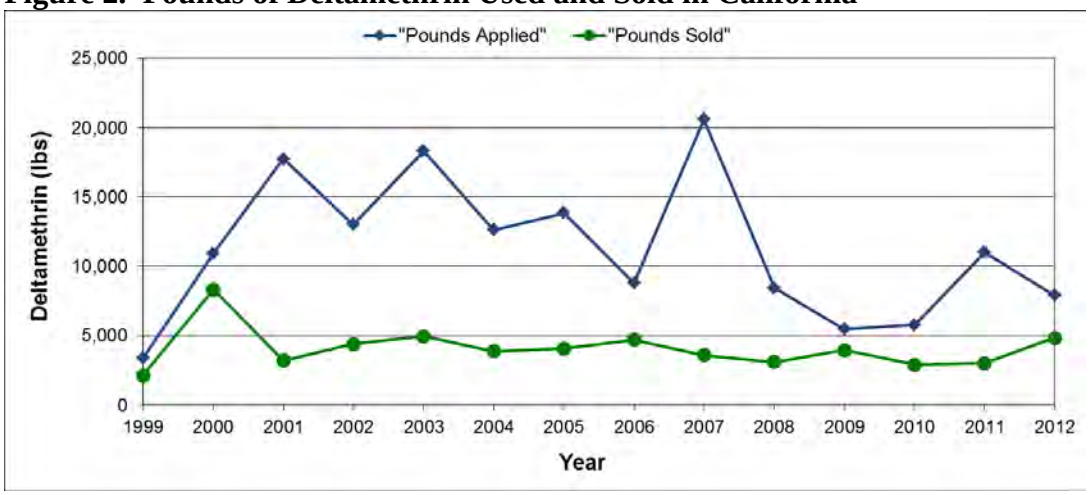
Table 5. Agricultural and Commercial Use of Deltamethrin for 2008- 2012

Use Site	Pounds Applied [a]					
	2008	2009	2010	2011	2012	5-year Average (% Total)
Structural Pest Control	7,276	4,010	5,123	10,899	7,776	7,017 (91.0)
Artichoke, Globe	589	444	336	5	1	275 (3.6)
Public Health	394	345	20	13	14	157 (2.0)
Landscape Maintenance	57	606	33	0	30	145 (1.9)
Nut Crops [b]	27	18	245	31	36	71 (0.9)
Total of listed crops	8,343	5,422	5,758	10,948	7,857	9,592
Total in PUR	8,413	5,467	5,769	11,010	7,899	9,801
Listed crops % of total	99.2%	99.2%	99.8%	99.4%	99.5%	97.9%

[a] From (DPR, 2010; 2011; 2012; 2013; 2014a). Arranged in descending order by 5-year average.
[b] Includes almonds, pistachios and walnuts.

However, examination of pounds deltamethrin sold in California suggests less variability than would be indicated by the changing annual totals shown in Table 5. California collects a fee for all pesticides sold in the state, including products sold for home use, and reports pounds of pesticides sold each year (DPR, 2014b). Figure 2 summarizes the total pounds used and sold reported to DPR each year.

Figure 2. Pounds of Deltamethrin Used and Sold in California



The PUR and pounds sold databases were intended for different purposes, and the data are not directly comparable (e.g., pesticides sold in one year may be used in a different year, and sales data include sales to distributors). Because reported use consistently exceeds reported pounds sold, selected records were examined to determine the source of the discrepancy. It was found that pounds sold were reported more reliably than pounds used.

PHARMACOKINETICS AND TOXICITY

Dermal Absorption

Thongsinthusak (1996) evaluated a dermal penetration study conducted by Ampofo (1995) using male rats dosed with radiolabeled deltamethrin in a water vehicle. The study was well-conducted, with total recovery of the radiolabel ranging between 93.7% and 113%. Thongsinthusak (1996) estimated dermal absorption following a 10-hour exposure, by combining the amounts of radiolabel recovered from the carcass, blood, urine, feces, cage wash, and cage wipes, with an estimate of amount absorbed from bound skin residues. Bound skin residues are the amount remaining on treated skin after washing, some or all of which can later be absorbed. Using a model published by Thongsinthusak *et al.* (1999), the assumed portion of bound skin residue absorbed, based on excreted radiolabel, yielded an estimated dermal absorption of 6.7% (see Thongsinthusak (1996) for study and calculation details). However, DPR does not presently support the model used, and in this RCD Addendum the dermal absorption estimate instead incorporates the bound skin residue, in agreement with current DPR practice. At the lowest applied dose (1.23 $\mu g/cm^2$), the dermal absorption following a 10-hour exposure (to mimic a full workday followed by washing after a worker arrives home) is calculated by summing the percent of applied radiolabel from each of the following matrices: 0.01% (blood) + 0.11% (carcass) + 0.1% (cage washes and wipes) + 0.35% (urine and feces) + 10.7% (bound skin residue) = 11.27%, which rounds to 11.3%.

Oral Absorption

Thongsinthusak (1996) estimated 60% absorption of deltamethrin by the oral route, based on a pharmacokinetic study in which tralomethrin (which is "rapidly metabolized" to form deltamethrin) was administered to rats intraveneously and orally. Tanoue (1988) administered a single dose of 0.3 mg/kg of each of three differently radiolabeled ^{14}C-tralomethrin compounds (labeled at the acid, alcohol, and cyano carbons) in dimethylsulfoxide and corn oil vehicles, respectively.

Oral absorption was estimated as the ratio of percent radiolabel excreted in urine following oral and IV dosing (i.e., IV dosing is considered equivalent to 100% absorption). Percent absorbed was 63.5%, 60.8%, and 50.9%, for the acid-, alcohol-, and cyano-labeled compounds. Thongsinthusak (1996) rounded the average of the three percentages (58%) to assume 60% oral absorption.

However, the use of tralomethrin as a pharmacokinetic surrogate for deltamethrin is poorly supported by results in another part of the study by Tanoue (1988), which measured distribution of the radiolabel recovered from urine, feces, and carcass following oral doses of radiolabeled ^{14}C-deltamethrin and ^{14}C-tralomethrin. In deltamethrin, the radiolabel was located at the acid carbon. Distributions differed between the chemicals; for example, males

dosed with deltamethrin excreted an average total of 60.8% in urine and 37.7% in feces, while males dosed with tralomethrin excreted an average total of 43.9% in urine and 54.7% in feces.

Furthermore, Kim *et al.* (2007) reported that the gastrointestinal absorption, bioavailability, and neurotoxicity of deltamethrin varied by formulation. The oral-dose vehicle used by Tanoue (1988) was water-insoluble corn oil; however, the vehicle used by Chesterman (1977) in the toxicity study was the polyethylene glycol solvent PEG 200, which is miscible in water. In this RCD Addendum, the oral absorption estimate by Thongsinthusak (1996) was not used, and 100% oral absorption was assumed.

Inhalation Absorption

In the absence of inhalation absorption data, a default inhalation absorption value of 100% was used for calculations of doses absorbed via inhalation in accordance with DPR policy (Frank, 2008).

Toxicity

DPR's RCD for deltamethrin established two acute critical endpoints for evaluating risk, both based on autonomic nervous system dysfunction (e.g., liquid feces, vomiting, and tremors) in dogs (Chesterman, 1977), the species among those tested most sensitive to deltamethrin. Frank and Kellner (2000) described the derivation of the NOEL and ENOEL as follows:

> On the basis of autonomic nervous system dysfunction reported during the first week of a 13-week dog study (Chesterman, 1977) the lowest observed effect level (LOEL) for acute toxicity appeared to be 0.1 mg/kg/day (the lowest dose tested). This resulted in an estimated NOEL (i.e., ENOEL) of 0.01 mg/kg/day. The ENOEL was calculated by using the default approach of dividing the LOEL by an uncertainty factor of 10. In the process of DPR internal peer review, however, a consensus on the biological relevance of the effects reported at 0.1 mg/kg/day could not be established. Consequently, margins of exposure were calculated using both a NOEL of 0.1 mg/kg/day and a LOEL, with resultant estimated NOEL (i.e., ENOEL) of 0.01 mg/kg/day. Since oral absorption has been estimated to be 58%, (or approximately 60%) the acute NOEL of 0.1 mg/kg/day, was adjusted to 0.06 mg/kg/day, and the acute ENOEL of 0.01 mg/kg/day was adjusted to 0.006 mg/kg/day.

As explained above in the Oral Absorption section, the oral absorption factor is not well supported, and is not used in this RCD Addendum. Additionally, only the DPR consensus NOEL of 0.1 mg/kg/day is used to estimate risk.

ENVIRONMENTAL CONCENTRATIONS

Dislodgeable Foliar Residues

Dislodgeable foliar residue (DFR) is defined as the pesticide residue that can be removed from both sides of treated leaf surfaces using an aqueous surfactant, and is assumed to be the portion of an applied pesticide available for transfer to humans from leaf and other vegetative surfaces. Measurements of DFR can be used, along with an appropriate transfer coefficient

(TC), to estimate the amount of pesticide adhering to clothing and skin surfaces following entry into a previously treated field. The DFR is reported as residue per leaf area (µg/cm²).

Two studies DFR are available in the literature for deltamethrin. In the first, DFR was determined on cotton foliage in an Arizona field following an application of Decis® (Estesen *et al*., 1979). This study was used by Thongsinthusak (1996) to estimate exposure of cotton scouts. However, in this study DFR was dislodged by hexane, which may also extract residues from inside leaves (Iwata *et al*., 1977). The second DFR study also featured a non-standard dislodging solution, 2% sodium chloride (Mestres *et al.*, 1985). DFR was sampled following application of Decis® to French beans in a French greenhouse. To assure that only surface residues are measured, the residues should be dislodged from leaf surfaces with a detergent solution rather than an organic solvent (Iwata *et al.*, 1977; U.S. EPA, 1996). Dislodging with a saline solution might yield lower residues than a surfactant solution, and results cannot be used with TC derived from studies in which DFR was dislodged with a surfactant. In the absence of acceptable DFR data, default DFR for this RCD Addendum was estimated using a default of 20% of the application rate. This was calculated according to guidance in U.S. EPA (1999): DFR (µg/cm^2) = Rate (lb AI/acre) x [(11.2 µg/cm^2)/(1 lb AI/acre) conversion factor] x [percent (20 % assumed) of rate available as dislodgeable].

The maximum application rate of deltamethrin on sweet corn is 0.028 lb AI/acre. The default DFR is calculated as follows: [(0.028 lb AI/acre) x (11.2 µg/cm^2)/(1 lb AI/acre)] x 0.20 µg/cm^2 = 0.0627 µg/cm^2.

Air

No ambient air or application site monitoring has been conducted in association with agricultural or other outdoor uses of deltamethrin in California. Limited monitoring of indoor air following structural applications of deltamethrin has been reported in studies published in the open literature (Mestres *et al.*, 1985; Berger-Preiss *et al*., 1997; Ramesh and Vijayalakshmi, 2001). Mestres *et al.* (1985) measured airborne deltamethrin in a 1,300-m^3 greenhouse in which French beans were treated with Decis®; at the end of the application, the concentration in the center of the room was 5.2 µg/m^3, and 30 minutes later the concentration was 0.008 µg/m^3. Following crack and crevice treatment of 60-m^3 rooms with an aqueous formulation of deltamethrin totaling 230 – 350 mg per room, Berger-Preiss *et al*. (1997) measured deltamethrin vapor concentrations of 0.0015 – 0.0020 µg/m^3, and suspended particle concentrations of 2.4 – 3.3 µg/m^3. Ramesh and Vijayalakshmi (2001) sprayed an unspecified amount of a deltamethrin aerosol product in a single room, then measured air concentrations at three locations in the room at several time points. Fifteen minutes following the application, the highest concentration was measured near the ceiling at 118 µg/m^3. Fifteen minutes later, the concentration had decreased to 21 µg/m^3; an hour post-application the concentration was 6 µg/m^3. Concentrations measured in the center of the room or near the floor were lower than those near the ceiling.

None of these studies related application rates to concentrations, and these data cannot be used to estimate exposure; however, they suggest that indoor sprays result in airborne concentrations that quickly decrease under the conditions tested.

Water

With a reported water solubility of < 0.002 mg/liter at 25°C (NLM, 2012), deltamethrin has a relatively low potential to reach ground water. Deltamethrin has been detected in surface water and sediment in California. Zhang (2010) summarized monitoring data for deltamethrin in surface water in Californian urban areas between 1993 and 2010. Deltamethrin was detected in 163 of 880 samples analyzed during that time, for a detection frequency of 18.5%. Reported concentrations ranged 0.0002 µg/liter to 0.3957 µg/liter (Zhang, 2010). Deltamethrin was not detected in the 40 samples collected from receiving waters; 161 detections were in the 822 storm drain effluent samples and the other two samples were collected in water treatment plants. Zhang (2010) also reported on deltamethrin concentrations in sediments collected from urban areas. Of the 247 samples collected 1993 and 2010, deltamethrin was detected in 88. Reported concentrations ranged 1.1 µg/g to 78 µg/g (Zhang, 2010).

REPORTED ILLNESSES

DPR's Worker Health and Safety Branch (WHS) includes a Pesticide Illness Surveillance Program (PISP). PISP maintains a database of all reports of illness and injury potentially related to pesticide exposure in California. The PISP database contains information about the nature of the pesticide exposure and the subsequent illness or injury (WHS, 2007).

Sixty-nine illness cases involving deltamethrin were reported during the years 1992 through 2011 (DPR, 2014c). The symptoms most often reported included tingling, dizziness, nausea, and shortness of breath.

Deltamethrin was the sole implicated pesticide in 22 cases, including three cases in 1993 and 1994 in which children ingested insecticidal chalk products that were not registered in California. A single case of apparently intentional ingestion was reported in 2010. Two cases in 2011 involved mishandling of spray bottles. The remaining sixteen deltamethrin-only cases involved structural pest control; in fourteen of these, people remaining in areas during applications or entering treated areas became ill. The other three cases involved structural pest control operators, one of whom was sprayed in the face while removing his backpack sprayer; the other found a leak in the pesticide tank on his truck.

In 57 cases, deltamethrin was implicated along with one to eleven additional compounds, any or all of which may have contributed to symptoms. In 36 cases, people staying in areas during applications or entering treated areas became ill. Seven cases involved residential users who became ill after spraying their living quarters. Two cases involved structural pest control operators who became ill while working with pesticides including deltamethrin, and another case involved a building worker who became ill while cleaning in a treated area. In two other cases, children accessed aerosol cans; one sprayed himself in the face and the other sprayed an infant sibling. Finally, one illness occurred in an agricultural setting, when a fieldworker became ill while pruning treated nursery trees.

LABEL PRECAUTIONS AND CALIFORNIA REQUIREMENTS

Label Precautions

With the exception of the two EC products intended for agricultural use, labels carry few precautionary statements. The two EC products containing 4.75% deltamethrin have the signal word of Danger; all other products have the signal word Caution.

Label precautions include measures to protect people and the environment. Pesticide handlers are legally required to use personal protective equipment (PPE) and engineering controls listed on the label. Labels for products used in production agriculture contain requirements for PPE that are enforceable under the Worker Protection Standard (WPS) and Title 3, Division 6 of the California Code of Regulations. Deltamethrin exposure estimates assume that handlers wear the clothing and PPE listed on product labels.

Products for Use in Agriculture

Four products carry agricultural use requirements on their labels. Two of these labels, for Battalion™ 0.2 EC and Decis® 0.2 EC, contain the following information:

> Precautionary Statement: DANGER
> Hazards to Humans & Domestic Animals: May be fatal if swallowed. Corrosive. Causes irreversible eye damage and skin burns. Do not get in eyes, on skin, or on clothing. Harmful if absorbed through the skin or inhaled. Avoid breathing spray mist. Wear protective clothing, gloves, eyewear (goggles, face shield or safety glasses) as indicated under Personal Protective Equipment. Prolonged or frequently repeated skin contact may cause allergic reactions in some individuals. Wash thoroughly with soap and water after handling and before eating, drinking, chewing gum, or using tobacco.
>
> PPE: Some materials that are chemical-resistant to this product are listed below. If you want more options, follow the instructions for category G on an EPA chemical resistance category selection chart.
>
> Handlers who may be exposed to the dilute through application or other tasks must wear:
> - Coveralls over short-sleeved shirt and short pants,
> - Chemical-resistant gloves such as barrier laminate or Viton®,
> - Chemical-resistant footwear plus socks,
> - Protective eyewear
> - Chemical-resistant headgear for overhead exposure, and
> - Chemical-resistant apron when mixing or loading, or cleaning equipment
>
> Handlers who may be exposed to the concentrate through mixing, loading, application, or other tasks must wear:
> - Coveralls over long-sleeved shirt and long pants,
> - Chemical-resistant gloves such as barrier laminate or Viton®,
> - Chemical-resistant footwear plus socks,
> - Protective eyewear
> - Chemical-resistant headgear for overhead exposure, and

- Chemical-resistant apron when mixing or loading, or cleaning equipment

When handlers use closed systems, enclosed cabs, or aircraft in a manner that meets the requirements listed in the Worker Protection Standard (WPS) for agricultural pesticides [Title 40, Code of Federal Regulations, Section 170.240(d)(4-6)], the handler PPE requirements may be reduced or modified as specified in the WPS.

Do not enter or allow worker entry into treated areas during the restricted-entry interval (REl) of 12 hours. PPE required for early entry to treated areas that is permitted under the Worker Protection Standard and that involves contact with anything that has been treated, such as plants, soil, or water is coveralls over short-sleeve shirt and short-pants, chemical-resistant footwear plus socks, chemical-resistant gloves such as barrier laminate or Viton®, protective eyewear, and chemical-resistant headgear if overhead exposure.

The other two products with agricultural-use instructions, DeltaGard® GC Granular Insecticide and DeltaGard® GC 5 SC Insecticide, carry the signal word CAUTION and require handlers to wear long-sleeved shirt and long pants, waterproof gloves, and shoes plus socks. The REI is 12 hours for these products as well.

Residential-Use and Commercial-Use Products

These product labels all carry the signal word CAUTION. No PPE or REI are specified on the labels. Exposure estimates for commercial and residential handlers do not assume that protective clothing (including long-sleeved shirt and long pants) is worn or that PPE is used.

California Requirements

The product labels contain most of the requirements of the California regulations. However, Title 3 of the California Code of Regulations, Section 6738(b) requires that protective eyewear be worn during most mixing, loading and application activities.

EXPOSURE SCENARIOS

An exposure scenario describes a situation where people may contact pesticides or pesticide residues, and in which the nature of the exposure as well as its magnitude (apart from variability among individuals and occasions) is relatively homogeneous. Several types of exposure scenarios are associated with use of deltamethrin. This RCD Addendum is intended to address all exposure scenarios, with exposure estimates provided for the highest-priority scenarios having the highest exposure potential. Scenarios are prioritized according to risk as estimated by the Margin of Exposure (MOE), which is calculated by dividing the no observed effect level of 0.1 mg/kg/day by exposure. High-priority scenarios are defined as those in which MOE $\leq$ 10 (i.e., an order of magnitude or more below the target MOE of 100). However, the resolution of each MOE estimate is limited due to uncertainties in exposure and toxicity estimates, making the distinction between values such as 9 and 11 difficult. For this reason, scenarios are considered high-priority if the MOE is less than or equal to 10, when rounded to one significant figure (i.e., MOE < 15). Scenarios with MOE $\geq$ 15 and $\leq$ 100 are classified as moderate priority. Scenarios with MOE above 100 are considered low priority.

Of 60 occupational and residential scenarios, nineteen were high-priority, including 12 occupational and seven residential scenarios.

Occupational Handler

Occupational activities are categorized into agricultural (involved in production agriculture) and non-agricultural handlers. Occupational agricultural handler activities include mixer/loader (M/L), applicator, mixer/loader/applicator (M/L/A), loader/applicator (L/A), and flagger. Agricultural handler scenarios are listed in Table 6. Of the 21 scenarios listed, 7 are high-priority.

Table 6. Agricultural Handler Scenarios for Deltamethrin

Activity [a]	Scenario Priority [b]	
	Liquid [c]	Granular [d]
Aerial M/L	**H** (high-acre = **H**)	
Aerial Applicator	M (high-acre = **H**)	
Flagger	M (high-acre = **H**)	
Airblast M/L	M	
Airblast Applicator	L	
Airblast M/L/A	M	
Groundboom M/L	M (high-acre = **H**)	
Groundboom Applicator	L (high-acre = M)	
Groundboom M/L/A	M	
Chemigation M/L	**H**	
Low Pressure Handwand M/L/A	L	
Backpack M/L/A	M	
High Pressure Handwand M/L/A	**H**	
Broadcast Spreader Loader		M
Broadcast Spreader Applicator		L
Push-Type Spreader L/A		L

[a] Based on product labels approved by the California Department of Pesticide Regulation. No agricultural uses of other formulations are allowed. L/A is loader/applicator. M/L is mixer/loader. M/L/A is mixer/loader/applicator.
[b] Scenario priority identified as follows: H = high. M = moderate. L = low. See text for definition of priorities. High-priority scenarios are bolded.
[c] Includes emulsifiable concentrate and suspension concentrate, which are diluted before use.
[d] Granular products are not mixed with water before use, but are applied in solid form.

Occupational non-agricultural handlers, who are not involved in production agriculture, may use deltamethrin products on driveways or walkways, for turf and landscape maintenance, or they can apply deltamethrin in and around structures such as residential and office buildings. Some product labels allow use in airplane cargo areas, on ships, or in sewers. Non-agricultural handler scenarios are listed in Table 7. Four of the 16 scenarios listed are high-priority.

Table 7. Non-Agricultural Occupational Handler Scenarios for Deltamethrin

Activity [a]	Scenario Priority [b]			
	Liquid [c]	Granular [d]	Dust [d]	Ready-to-Use Liquid
Groundboom M/L	M			
Groundboom Applicator	L			
Groundboom M/L/A	M			
Right-of-Way M/L	L			
Right-of-Way Sprayer	**H**			
Low Pressure Handwand M/L/A	L			
Backpack M/L/A	M			
High Pressure Handwand M/L/A	**H**			
Broadcast Spreader Loader		M		
Broadcast Spreader Applicator		L		
Push-Type Spreader L/A		L		
Handheld Duster			**H**	
Aerosol Can Applicator				L
Paintbrush Applicator				**H**
Hose End Sprayer M/L/A				L
Trigger Spray Applicator				L

[a] Based on product labels registered by the California Department of Pesticide Regulation. L/A is loader/applicator. M/L is mixer/loader. M/L/A is mixer/loader/applicator.
[b] Scenario priority identified as follows: H = high. M = moderate. L = low. See text for definition of priorities. High-priority scenarios are bolded.
[c] Includes emulsifiable concentrate, liquid concentrate and suspension concentrate, all of which are diluted before use.
[d] Granular and dust products are not mixed with water before use, but are applied in solid form.

Occupational Post-Application

Agricultural Reentry Scenarios (Activities in Production Agriculture)

Agricultural reentry exposure scenarios considered in this exposure assessment are listed in Appendix 1. For crops treated with deltamethrin, typical reentry activities include scouting, thinning, pruning, weeding, transplanting, staking/tying, swathing, and harvesting. Crops listed on deltamethrin product labels registered in California include field crops such as canola, cotton, sorghum, and sweet, field and popcorn; cucurbits (cucumbers, melons, etc.); fruiting vegetables (eggplant, tomato, etc.); root, corm, and tuber vegetables (artichoke, garlic, potato, etc.); pome fruit (apple, pear, etc.); ornamentals; sod; and tree nuts. Non-crop sites include turfgrass. Use sites are listed in Appendix 1, along with reentry activities expected to occur in each. Also, the maximum application rate allowed for each use site, and the preharvest interval (PHI; for assessing occupational exposure during harvest) for each crop, are given in Appendix 1. Reentry activities other than harvesting were assessed at the expiration of the REI, which is 12 hours.

For agricultural reentry scenarios, representative scenarios were determined by first grouping application sites, then by selecting activities within each group that would be anticipated to

have the highest potential for exposure. Details of crop grouping and selection of representative scenarios are in Appendix 2.

Table 8 summarizes representative occupational reentry scenarios for deltamethrin. The last column in Table 8 lists priority of the representative scenario; one of the seven scenarios listed is high-priority. Scenarios grouped under a representative scenario are not all expected to have identical exposures; however, the representative scenario is anticipated to involve exposures similar to or greater than all scenarios covered by it. In other words, representative scenarios might overestimate exposure for other scenarios, but should not underestimate exposure.

Table 8. Representative Occupational Reentry Scenarios for Deltamethrin

Crop [a]	Activity [b]	Priority [c]
Apple	Thinning (REI)	M
Artichoke	Hand Harvest (PHI: 1)	L
Corn	**Hand Harvest (PHI: 1)**	**H**
Cucumber	Scouting (REI)	M
Potato	Scouting (REI)	M
Turf	Maintenance (PHI: 0)	L
Tomato	Staking/Tying (REI)	L

[a] Representative crops from Table A2-1 in Appendix 2.
[b] PHI: preharvest interval; number of days. REI: restricted entry interval; REI is 12 hours (i.e., on Day 0).
[c] Scenario priority identified as follows: H = high. M = moderate. L = low. See text for definition of priorities. High-priority scenarios are bolded.

Non-Agricultural Occupational Reentry Scenarios

Non-crop occupational use sites include fire ant mounds, rights-of-way, and ornamental and residential turf. Reentry activities in treated turf include landscape and golf maintenance activities such as mowing and weeding, and installation of sod. All of these reentry activities are included in turf reentry, which is a low-priority exposure scenario (see Table 8).

Residential Handler

Residential handler activities include M/L/A applying liquid formulations using low pressure handwands, backpack sprayers, or hose end sprayers; applicators and L/A applying granular formulations using shaker cans or push-type spreader; applicators applying dust from shaker cans to lawn and garden; and applicators applying ready-to-use liquids with trigger sprayers. Residential handler scenarios are summarized in Table 9. Four of the ten scenarios are high-priority.

Table 9. Residential Handler Scenarios for Deltamethrin

Activity [a]	Scenario Priority by Formulation Type [b]				
	Liquid [c]	Granular [d]	Dust [d]	Ready-to-Use Liquid	Impregnated Material
Backpack M/L/A	L				
Low Pressure Handwand M/L/A	L				
Hose End Sprayer M/L/A	L				
Push-type Spreader L/A		L			
Hand Spread Granular Applicator		**H**			
Dust Applicator			**H**		
Trigger Sprayer Applicator				L	
Aerosol Can				L	
Paintbrush Applicator				**H**	
Flea Collar Applicator					**H**

[a] Based on product labels registered by the California Department of Pesticide Regulation. L/A is loader/applicator. M/L/A is mixer/loader/applicator.
[b] Scenario priority identified as follows: H = high. M = moderate. L = low. See text for definition of priorities. High-priority scenarios are bolded.
[c] Includes liquid concentrate and suspension concentrate, which are diluted before use.
[d] Granular and dust products are not mixed with water before use, but are applied in solid form.

Residential Post-Application

Residential reentry exposures include reentry onto treated carpet or turf (e.g., lawns or golf courses), as well as petting and otherwise contacting pets wearing flea collars. Scenarios are summarized in Table 10. Three of the six scenarios are high-priority.

Table 10. Residential Reentry Scenarios for Deltamethrin

Scenario [a]	Priority [b]	
	Adult	Child
Reentry on Treated Carpet	L	M
Reentry on Treated Turf	M	**H**
Post-Application Flea Collar	**H**	**H**

[a] Based on uses listed on product labels registered by the California Department of Pesticide Regulation.
[b] Scenario priority identified as follows: H = high. M = moderate. L = low. See text for definition of priorities. High-priority scenarios are bolded.

Ambient Air, Bystander, Indoor Air, and Swimmer

Ambient air monitoring conducted in California suggests that airborne pesticide exposures to the public are possible in areas that are far from application sites. No outdoor ambient air monitoring has been conducted for deltamethrin; however, it has a relatively low volatility (vapor pressure = 9.3×10^{-11} mm Hg) and low application rate (0.03 lb AI/acre or lower). As a result ambient air is considered a low-priority scenario.

Bystanders include individuals, working or not, who are not directly involved with a pesticide application but who may be exposed to airborne pesticide during or after the application, by drift or volatilized pesticide. Bystanders might be exposed to deltamethrin if they are adjacent to fields, orchards, or structures that are being treated or have recently been treated. Because of the low application rate and low volatility of deltamethrin, bystander exposure is considered a low-priority scenario.

Indoor air concentrations measured following structural applications of deltamethrin suggest that these concentrations that quickly decrease under the conditions tested. Exposures of residential handlers include exposure to airborne residues during application. Because of the rapid dissipation of residues, exposure to indoor air following applications is considered a low-priority scenario.

Pesticide residues in surface waters such as lakes, rivers, and canals, may result in exposure for swimmers. Although deltamethrin residues have been detected in surface waters in California, reported concentrations were less than 1 µg/liter and swimming in contaminated surface water is considered a low-priority scenario.

EXPOSURE AND RISK ASSESSMENT

This RCD Addendum provides short-term exposure estimates for high-priority scenarios. For short-term exposures, WHS estimates the highest exposure an individual may realistically experience in association with legal uses. In order to estimate this "upper bound" of daily exposure, WHS generally uses the estimated population 95th percentile of daily exposure (Frank, 2009a).

Occupational Handler Exposure and Risk

When available, exposure monitoring studies with surrogate chemicals, involving appropriate handling tasks, conducted in an appropriate way and having acceptable quality assurance were used to estimate exposure. Study details are summarized in review memos (Beauvais, 2006; Beauvais, 2011a; Beauvais, 2011b). When such studies were unavailable, exposure estimates were based on the Pesticide Handler Exposure Database (PHED, 1995). PHED was developed by the U.S. EPA, Health Canada and the American Crop Protection Association to provide non-chemical-specific (generic) pesticide handler exposure estimates for specific handler scenarios. It combines exposure data from multiple field monitoring studies using several different AIs. Appendix 3 summarizes exposure rates and assumptions used to estimate exposures for the high-priority scenarios based on PHED (Beauvais *et al*., 2007).

Agricultural Handlers

Table 11 summarizes exposure rates and short-term exposure estimates for high-priority agricultural handler scenarios involving liquid formulations of deltamethrin. Exposure estimates were adjusted as needed with default protection factors for additional PPE. Handlers were assumed to wear the clothing specified on the product label: long-sleeved shirt and pants, chemical-resistant gloves, and shoes and socks. Chemical-resistant aprons are required when mixing, loading, and cleaning spills or equipment. As there is no requirement

for closed system mixing/loading, open pour mixing/loading was assumed. Similarly, product labels do not require applicators to be in enclosed cabs or cockpits; thus, open cab was assumed for groundboom and airblast, and open cockpit was assumed for aerial applications.

Table 11. Deltamethrin Exposure and Risk Estimates for High-Priority Agricultural Handler Exposure Scenarios

Scenario [a]	# [b]	Short-Term Exposure Rate (µg/lb AI handled)		STADD [c] (mg/kg/day)			MOE [d]
		Dermal	Inhalation	Dermal	Inhalation	Total	
Aerial (Liquids) [e]							
Mixer/Loader	5	1,446	7.34	0.0270	0.00121	0.0282	4
High-Acre Aerial (Liquids) [f]							
Mixer/Loader	5	1,446	0.734	0.0924	0.00415	0.0966	1
Applicator	17	236.2	2.12	0.0151	0.00120	0.0163	6
Flagger	7	133.02	0.680	0.00850	0.000385	0.00889	11
High-Acre Groundboom [g]							
Mixer/Loader	5	1,446	0.734	0.0140	0.000629	0.0146	7
Chemigation [e]							
Mixer/Loader	5	1,446	0.734	0.0270	0.00121	0.0282	4
High-Pressure Handwand [h]							
Mixer/Loader/Applicator	21	26,470	565	0.0111	0.00210	0.0132	8

[a] All scenarios were based on data from the Pesticide Handlers Exposure Database (PHED, 1995). Exposure rates and exposure estimates were rounded to three significant figures; dermal exposure rates may have four significant figures as a result of adding together hand and non-hand dermal exposures (see Appendix 3 for details).
[b] Scenario numbers from Beauvais *et al.* (2007). See Appendix 3 for summaries of scenarios and exposure rates. Handlers were assumed to wear long-sleeved shirt, long pants, shoes, socks, and chemical-resistant gloves as specified on product labels. Mixer/loaders were assumed to wear chemical-resistant apron.
[c] Short-Term Absorbed Daily Dosage (STADD) is an upper-bound estimate. Calculation:
STADD = [(short-term exposure) x (absorption) x (acres treated/day) x (application rate)]/(70 kg body weight).
Calculation assumptions include: dermal absorption = 11.3% (Ampofo, 1995); body weight = 70 kg (Thongsinthusak *et al.*, 1993); inhalation rate 16.7 liters/min (Andrews and Patterson, 2000); and inhalation absorption = 100% (Frank, 2008).
[d] Margin of Exposure (MOE) calculated by dividing no observed effect level of 0.1 mg/kg/day by total STADD.
[e] STADD estimates assumed 350 acres (142 ha) treated/day (U.S. EPA, 2001), and a maximum application rate of 0.033 lbs AI/acre (0.037 kg AI/ha), maximum rate on tree nuts.
[f] STADD estimates assumed 1,200 acres (486 ha) treated/day (U.S. EPA, 2001), and a maximum application rate of 0.033 lbs AI/acre (0.037 kg AI/ha), maximum rate on tree nuts.
[g] STADD estimates assumed 1,200 acres (486 ha) treated/day (U.S. EPA, 2001), and a maximum application rate of 0.030 lbs AI/acre (0.034 kg AI/ha), maximum rate on cotton.
[h] STADD estimates handling of 1,000 gal/day (3,800 liters/day; U.S. EPA, 2001), containing 0.00026 lb AI/gal (0.000031 kg AI/liter), maximum rate on ornamentals.

Non-Agricultural Handlers

Table 12 summarizes short-term exposure and risk estimates for high-priority non-agricultural handler scenarios. One scenario in Table 12 was also in Table 11, M/L/A using high-pressure handwand to apply deltamethrin liquid products to ornamentals. When ornamentals grown in greenhouses or outdoors are treated, it is considered an agricultural scenario. The non-

agricultural scenario involves landscape maintenance with spraying of ornamentals. The same application rate and other assumptions in both cases gives the same exposure estimates.

Table 12. Deltamethrin Exposure and Risk Estimates for High-Priority Non-Agricultural Handler Exposure Scenarios

Scenario [a]	# [b]	Short-Term Exposure Rate (µg/lb AI handled)		STADD [c] (mg/kg/day)			MOE [d]
		Dermal	Inhalation	Dermal	Inhalation	Total	
Right-of-Way [e]							
Applicator	16	48,803	12.3	0.0205	0.0000457	0.0205	5
High-Pressure Handwand [e]							
Mixer/Loader/Applicator	21	26,470	565	0.0111	0.00210	0.0132	8
Hand-Held Duster [f]							
Applicator	- -	1,390,000	8,100	0.112	0.00579	0.118	< 1
Paintbrush [g]							
Applicator	28	820,300	729	0.0414	0.000326	0.0418	2

[a] All scenarios were based on data from the Pesticide Handlers Exposure Database (PHED, 1995). Exposure rates and exposure estimates were rounded to three significant figures; dermal exposure rates may have four significant figures as a result of adding together hand and non-hand dermal exposures (see Appendix 3 for details).
[b] Scenario numbers from Beauvais *et al.* (2007). See Appendix 3 for summaries of scenarios and exposure rates. Handlers were assumed not to wear gloves, and may wear short-sleeved shirt, shorts, as no protective clothing or equipment is specified on product labels. However, PHED scenarios have limited data for handlers wearing shorts and t-shirt, and estimates are based on handlers wearing long-sleeved shirt and long pants. Only the hand-held duster applicator exposure estimate is based on handlers wearing shorts and t-shirt.
[c] Short-Term Absorbed Daily Dosage (STADD) is an upper-bound estimate. Calculation:
STADD = [(short-term exposure) x (absorption) x (acres treated/day) x (application rate)]/(70 kg body weight).
Calculation assumptions include: dermal absorption = 11.3% (Ampofo, 1995); body weight = 70 kg (Thongsinthusak *et al.*, 1993); inhalation rate 16.7 liters/min (Andrews and Patterson, 2000); and inhalation absorption = 100% (Frank, 2008).
[d] Margin of Exposure (MOE) calculated by dividing no observed effect level of 0.1 mg/kg/day by total STADD.
[e] STADD estimates handling of 1,000 gal/day (3,800 liters/day; U.S. EPA, 2001), containing 0.00026 lb AI/gal (0.000031 kg AI/liter), maximum rate on ornamentals.
[f] Estimates were based on data from Merricks (1997), as summarized by Beauvais (2011a). STADD estimates assumed handling of 0.05 lb deltamethrin/day, the amount in a 1-lb package (dusts contain 0.05% deltamethrin).
[g] STADD estimates assumed handling of 5 gallons paint/day (U.S. EPA, 2001).

Occupational Post-Application Exposure and Risk

Representative exposure scenarios for reentry workers were selected as described in Appendix 2. Only one of the representative scenarios has high priority, hand-harvesting of sweet corn. Exposure and risk estimates for that scenario are given in Table 13. The short-term exposure was estimated at the expiration of the pre-harvest interval (PHI) of 1 day, and assumed that workers would not wear protective clothing or equipment.

The absorbed daily dosage (ADD) was calculated as shown in the equation below (Zweig *et al.*, 1984; Zweig *et al.*, 1985), using the dermal absorption rate (DA) of 11.3% (Ampofo, 1995); default dislodgeable foliar residue calculated from 20% of the application rate; a default transfer coefficient (TC) based on exposure monitoring data for the activity; default

exposure duration (ED) of 8 hours; and default body weight (BW) of 70 kg (Thongsinthusak *et al*., 1993).

$$ADD\ (\mu g/kg/day) = \frac{DA \times DFR\ (\mu g/cm^2) \times TC\ (cm^2/hour) \times ED\ (hours/day)}{BW(kg)}$$

Table 13. Deltamethrin Exposure and Risk Estimates for High-Priority Agricultural Reentry Exposure Scenario

Exposure Scenario	DFR (µg/cm²) [a]	TC (cm²/hour) [b]	STADD (mg/kg/day) [c]	MOE [d]
Sweet corn hand harvesting	0.063	17,000	0.0138	7

[a] Dislodgeable foliar residue (DFR) estimated as 20% of the application rate.
[b] Transfer coefficient (TC) is rate of skin contact with treated surfaces. TC value from Frank (2009b).
[c] Short-term Absorbed Daily Dosage (STADD) calculated as described in text. Exposure estimates are for dermal route, as inhalation route assumed to be insignificant. Calculation assumptions include: dermal absorption = 11.3% (Ampofo, 1995); body weight = 70 kg (Thongsinthusak *et al*., 1993); and exposure duration of 8 hours.
[d] Margin of Exposure (MOE) calculated by dividing no observed effect level of 0.1 mg/kg/day by STADD.

Residential Handler Exposure and Risk

Exposure and risk estimates for high-priority residential handler scenarios are summarized in Table 14. Exposure estimates were based on data from a chemical-specific exposure monitoring study (Merricks, 1997); a surrogate exposure monitoring study (Klonne and Honeycutt, 1999); or on data from PHED (Appendix 3). Residential handlers applying flea collars on dogs were assumed to apply a collar to one pet in a day, according to U.S. EPA guidance (U.S. EPA, 1997b). There is a single flea collar product registered in California that contains deltamethrin; the collar weighs 0.9 ounces (25,500 mg) and contains 4% AI (1,020 mg AI). A person applying a pet collar was assumed to be exposed by the dermal route to 1% of the AI in the collar (U.S. EPA, 1997b).

Table 14. Deltamethrin Exposure and Risk Estimates for High-Priority Residential Handler Exposure Scenarios

Scenario [a]	# [b]	Short-Term Exposure Rate (µg/lb AI handled)		STADD [c] (mg/kg/day)			MOE [d]
		Dermal	Inhalation	Dermal	Inhalation	Total	
Hand Spread Granular [e]							
Applicator	15	505,000	1,270	0.245	0.00544	0.250	< 1
Hand-Held Duster [f]							
Applicator	- -	1,390,000	8,100	0.112	0.00579	0.118	< 1
Paintbrush [g]							
Applicator	28	820,300	729	0.0166	0.000130	0.0167	6
Flea Collar [h]							
Applicator	- -	- -	- -	0.0165	- -	0.0165	6

[a] All scenarios except dust and flea collar applicators were based on data from the Pesticide Handlers Exposure Database (PHED, 1995). Exposure rates and exposure estimates were rounded to three significant figures; dermal exposure rates may have four significant figures as a result of adding together hand and non-hand dermal exposures (see Appendix 3 for details).

[b] Scenario numbers from Beauvais *et al.* (2007). See Appendix 3 for summaries of scenarios and exposure rates. Handlers were assumed not to wear gloves, and may wear short-sleeved shirt, shorts, as no protective clothing or equipment is specified on product labels. However, PHED scenarios have limited data for handlers wearing shorts and t-shirt, and estimates are based on handlers wearing long-sleeved shirt and long pants. Only the hand-held duster applicator exposure estimate is based on handlers wearing shorts and t-shirt.

[c] Short-Term Absorbed Daily Dosage (STADD) is an upper-bound estimate. Calculation (except flea collar): STADD = [(short-term exposure) x (absorption) x (acres treated/day) x (application rate)]/(70 kg body weight). Calculation assumptions include: dermal absorption = 11.3% (Ampofo, 1995); body weight = 70 kg (Thongsinthusak *et al*., 1993); inhalation rate 16.7 liters/min (Andrews and Patterson, 2000); and inhalation absorption = 100% (Frank, 2008).

[d] Margin of Exposure (MOE) calculated by dividing no observed effect level of 0.1 mg/kg/day by total STADD.

[e] STADD estimates assume handling of 0.3 lb deltamethrin/day, for a handler treating 1,000 ft^2 of lawn at the maximum application rate (0.3 lb/1,000 ft^2).

[f] Estimates were based on data from Merricks (1997), as summarized by Beauvais (2011a). STADD estimates assumed handling of 0.05 lb deltamethrin/day, the amount in a 1-lb package (dusts contain 0.05% deltamethrin).

[g] STADD estimates assumed handling of 2 gallons paint/day (Smegal *et al.*, 2001).

[h] STADD estimates assumed application of 1 flea collar in a day, with handler being exposed to 1% of AI in collar (U.S. EPA, 1997b); exposure is assumed to be substantially through dermal route. Deltamethrin in flea collar = 4% of 0.9 ounce (25,500 mg) = 1,020 mg. Calculation includes dermal absorption of 11.3% (Ampofo, 1995) and body weight of 70 kg (Thongsinthusak *et al*., 1993).

Residential Post-Application Exposure and Risk

Reentry onto Treated Turf

Table 15 summarizes the high-priority residential reentry scenario, which is toddlers playing on deltamethrin-treated turf. Dermal exposures are estimated using data from a surrogate study in which exposure was monitored during choreographed activities on turf following an application of oxadiazon (Rosenheck and Sanchez, 1995). This study was reviewed by Beauvais (2012).

Table 15. Exposure and Risk Estimates for the High-Priority Residential Reentry Scenario on Deltamethrin-Treated Turf

	Body Weight (kg) [a]	Body Surface Area (cm^2) [b]	Exposure Rate (µg/kg/hour) [c]	Dermal Exposure (mg/kg/day) [d]	STADD (mg/kg/day) [e]	MOE [f]
Toddler	15.0	6,565	48.41	0.0109	0.0130	8

[a] Default toddler body weight, which is the mean of the median values for male and female 3 year-old children (U.S. EPA, 1997a). The mean body weight of adults in the exposure monitoring study of Rosenheck and Sanchez (1995) was 69.4 kg; the ratio of assumed adult/toddler body weights = 69.4/15 = 4.63.
[b] Default toddler body surface area assumed for toddlers, which is the mean of the male and female median values for 3 year-old children (U.S. EPA, 1997a). The default body surface area of 18,150 cm^2 assumed for adults is the mean of the male and female median values for adults aged 18 and above; the ratio of assumed body surface areas = 18,150/6,565 = 2.76.
[c] Rosenheck and Sanchez (1995) monitored exposure of adults performing a Jazzercise® routine on treated turf. Beauvais (2012) reviewed this study and calculated the exposure rate for adults. An estimated toddler exposure rate was calculated by multiplying the adult exposure rate of 28.86 µg/kg/hour by the adult/toddler ratio of body weights and dividing by the adult/toddler body surface area ratio: (28.86 µg/kg/hour) x 4.63/2.76 = 48.41 µg/kg/hour.
[d] Dermal exposure calculated as described in text. Calculation assumptions include a dermal absorption of 11.3%, and that toddlers spend 2 hours/day on treated turf (U.S. EPA, 1997b).
[e] Short-term Absorbed Daily Dosage (STADD) includes non-dietary ingestion exposure of 1.9 µg/kg/day, calculated as described in Appendix 4.
[f] Margin of Exposure (MOE) calculated by dividing no-observed-effects-level of 0.1 mg/kg/day by STADD.

Briefly, Rosenheck and Sanchez (1995) monitored exposure of 10 adult volunteers performing a 16-minute Jazzercise® routine on turf treated with a liquid oxadiazon product at a rate of 3.0 lbs AI/acre. Dermal exposure was monitored with outer whole-body dosimeters, cotton gloves, hand washes, and face/neck wipes. The 95th percentile exposure rate, adjusted to the maximum application rate of 0.13 lbs AI/acre for deltamethrin (i.e., after multiplying by 0.13/3.0), is 28.86 µg/kg/hour (Beauvais, 2012). Toddlers are assumed to weigh 15 kg, which is the mean of the median values for male and female 3 year-old children (U.S. EPA, 1997a). Dermal exposure of toddlers playing on deltamethrin-treated lawns is estimated by multiplying estimated adult exposure rate from Rosenheck and Sanchez (1995) by the ratio of the mean body weight of 69.4 kg of adults in the exposure monitoring study of Rosenheck and Sanchez (1995) to the default toddler body weight, and dividing by the adult/toddler ratio of assumed body surface areas as summarized in Table 15. The resulting exposure rate is 48.41 µg/kg/hour. The short-term dermal exposure for toddlers was calculated from the 95th percentile exposure rate as follows, assuming 11.3% dermal absorption and that toddlers are on treated turf for up to 2 hours/day (U.S. EPA, 1997b):

(48.41 µg/kg/hour) x (2 hours/day) x 0.113 = 10.9 µg/kg/day = **0.0109 mg/kg/day**.

Potential inhalation exposure was monitored with stationary air samplers; residues recovered from the samplers were more than 4 orders of magnitude below dermal residues and did not contribute significantly to estimated exposure.

In addition to dermal exposure, toddlers potentially absorb turf-applied pesticides through non-dietary ingestion of residues transferred when hands contact turf then are placed in the

mouth (hand-to-mouth transfer), ingestion of residues transferred when objects (e.g., toys or grass itself) contact turf then are placed in the mouth (object-to-mouth transfer), and soil ingestion (U.S. EPA, 1997b). Non-dietary exposures were estimated from application rates, using assumptions from U.S. EPA (U.S. EPA, 1997b; Smegal *et al*., 2001). Assumptions and calculation details are given in Appendix 4. Total exposure, reported as STADD and including dermal, hand-to-mouth, and object-to-mouth exposure routes (inhalation and soil ingestion resulted in small amounts that did not alter total exposure), was calculated as follows: STADD = 0.0109 + 0.0019 + 0.00012 = **0.0130 mg/kg/day**.

Post-Application Flea Collar

Table 16 summarizes exposure and risk for adults and children interacting with a dog wearing a Scalibor Flea Collar, which contains 4% deltamethrin impregnated in a collar weighing 0.9 ounces (25,500 mg). Exposures were estimated using default assumptions from U.S. EPA (1997b). Twenty percent of the AI applied to the pet is assumed to be retained on the pet's fur as dislodgeable residue, and 10% of that is considered to be transferred to the skin of a person touching (petting, hugging, etc.) the pet. The amount of "dislodged residue," or deltamethrin transferred to the skin, is 2% of 1,020 mg, which is 20.4 mg. Dermal exposure was calculated by multiplying the dislodged residue by 11.3% dermal absorption, and then dividing by body weight.

Table 16. Post-Application Exposure and Risk Estimates for Deltamethrin Flea Collar

	Body Weight (kg) [a]	Dislodged Residue (mg) [b]	Dermal Exposure (mg/kg/day) [c]	STADD (mg/kg/day) [d]	MOE [e]
Adult	70	20.4	0.0329	0.0329	3
Toddler	15	20.4	0.154	0.402	< 1

[a] Body weight is mean the mean of the median values for male and female adults and 3 year-old children, respectively (U.S. EPA, 1997a).
[b] Scalibor Flea Collar contains 4% deltamethrin, and weighs 0.9 ounces (25,500 mg); 4% of 25,500 mg = 1,020 mg. Dislodged residue calculated according to U.S. EPA (1997b), with 20% of AI applied to pet assumed to be retained on pet's fur and 10% of that assumed transferred to skin of person touching pet: 0.2 x 0.1 x 1,020 mg = 20.4 mg.
[c] Dermal exposure calculated as described in text. Calculation assumptions include a dermal absorption of 11.3% (Ampofo, 1995).
[d] Short-term Absorbed Daily Dosage (STADD) includes non-dietary ingestion exposure for toddlers, from estimated hand-to-mouth exposure of 0.248 mg/kg/day (see Appendix 4).
[e] Margin of Exposure (MOE) calculated by dividing no-observed-effects-level of 0.1 mg/kg/day by STADD.

For adults, STADD consists of dermal exposure. For toddlers, non-dietary exposure was estimated according to guidance in U.S. EPA (1997b), as shown in Appendix 4. Total exposure, including dermal and hand-to-mouth exposure routes, was calculated as follows: STADD = 0.154 + 0.248 = **0.402 mg/kg/day**.

EXPOSURE AND RISK APPRAISAL

Uncertainties are associated with all estimates of exposure and risk. Frank and Kellner (2000) appraised uncertainties affecting the hazard identification and calculations of risk estimates. Uncertainties affecting exposure estimates are described in this section.

With the default exposure interval for occupational scenarios (8 hours/day without time for breaks and driving from job to job), daily exposure estimates may overestimate actual exposures. Conversely, during a growing season some periods can have intensive activity that results in work days exceeding 8 hours, in which case exposures may be underestimated to some extent. In the absence of scenario-specific data, exposure estimates incorporate defaults; relationships between defaults and actual values are often unknown.

Pharmacokinetics and Toxicity

The dermal absorption was estimated at 11.3%, based on a study using rats (Ampofo, 1995). DPR welcomes additional data, from a well-conducted study with appropriate dose levels, to refine the estimated dermal absorption. As explained by Frank (2009c) in discussing DPR's approach to dermal absorption studies, "*in vitro* animal and/or human data alone were insufficient for determining the dermal absorption pattern of a given pesticide. This position was based primarily on the lack of a detailed, standardized methodology for *in vitro* dermal absorption studies." However, "*in vitro* data may prove to be useful if combined with other information, in a weight-of-evidence approach, for predicting a Dermal Absorption Factor (DAF)…when laboratory studies demonstrate that the ratio of the animal *in vitro* to *in vivo* DAF is close to 1, a human in vitro study conducted under the same laboratory conditions as the animal test is potentially a good predictor of human dermal absorption."

DPR's approach to *in vitro* dermal absorption data for deltamethrin differs from that used by U.S. EPA (Dotson *et al*, 2010). DPR estimates 11.3% dermal absorption for deltamethrin, based on studies in rats following 10 hours exposure (Ampofo, 1995). U.S. EPA assumed a dermal absorption of 1% for pyrethroids, including deltamethrin (Dotson *et al*., 2010). This estimate was based on an *in vivo* study in rats with bifenthrin and a published *in vitro* study with deltamethrin, bifenthrin, and cis-permethrin (Hughes and Edwards, 2010). The chemical-specific study conducted by Ampofo (1995) was not discussed in U.S. EPA's risk assessment for deltamethrin. The difference in dermal absorption estimates results in an order of magnitude difference in MOEs.

In DPR's RCD, Frank and Kellner (2000) used both a NOEL of 0.1 mg/kg/day and an ENOEL of 0.01 mg/kg/day to estimate risk associated with deltamethrin exposure; both values were based on autonomic nervous system dysfunction in dogs. In this RCD Addendum, only the consensus NOEL of 0.1 mg/kg/day is used. DPR believes this NOEL is appropriate, rather than the NOEL of 1 mg/kg/day used by U.S. EPA, which is based on decreased activity in rats, as "[t]he dog appeared to be more sensitive than the rat to deltamethrin toxicity" (Frank and Kellner, 2000). However, use of the NOEL of 0.1 mg/kg/day rather than the ENOEL of 0.01 mg/kg/day might result in an underestimate of risk, if dogs better predict human response to deltamethrin than rats.

Handler Exposure Estimates

In the absence of chemical-specific or suitable exposure monitoring studies, most handler exposures were based on PHED. In order to account for some of the uncertainty inherent in using PHED and to increase our confidence that exposures are not underestimated, DPR uses the 90% upper confidence limit (UCL) on an exposure statistic, instead of the statistic itself, when using PHED. UCLs are used not because DPR believes that exposures are consistently

greater than the population mean, but because available data are so sparse that it is likely that the sample mean is not close to the true population mean. In exposure monitoring, ranges of sample results can be quite broad, and can include values that are substantially higher than sample means (Grover *et al.*, 1986; Vercruysse *et al*., 1999). Some exposure monitoring studies have reported sample ranges that span as much as three orders of magnitude (e.g., Hines *et al.*, 2001). Thus, it is apparent that handlers could have exposures well above sample means. The approximation used to estimate the UCL results in a several-fold increase in estimated exposure, as demonstrated for DPR's endosulfan exposure assessment (Beauvais *et al.*, 2010). Table 5 in Powell (2007) summarizes multipliers used to achieve the UCL on the 95th percentile and the mean; multipliers range from 3 to 5 for the 95th percentile and 1.1 to 1.9 for the mean.

Like DPR, U.S. EPA also used PHED to estimate some occupational handler exposures. However, U.S. EPA approaches PHED data differently than DPR. First, as explained in U.S. EPA's policy for use of PHED data (U.S. EPA, 1999): "Once the data for a given exposure scenario have been selected, the data are normalized (i.e., divided by) by the amount of pesticide handled resulting in standard unit exposures (milligrams of exposure per pound of active ingredient handled). Following normalization, the data are statistically summarized. The distribution of exposure values for each body part (i.e., chest upper arm) is categorized as normal, lognormal, or "other" (i.e., neither normal nor lognormal). A central tendency value is then selected from the distribution of the exposure values for each body part. These values are the arithmetic mean for normal distributions, the geometric mean for lognormal distributions, and the median for all "other" distributions. Once selected, the central tendency values for each body part are composited into a "best fit" exposure value representing the entire body." In other words, U.S. EPA uses various central tendency estimates (often the geometric mean or median, as PHED data rarely follow a normal distribution), while DPR believes the arithmetic mean is the appropriate statistic regardless of the sample distribution (Powell, 2003). Second, for acute exposure estimates DPR uses a 95th percentile upper bound estimate (Frank, 2009a), while U.S. EPA uses a central tendency estimate for all exposure durations (USEPA, 1998). Third, DPR calculates upper 90% confidence limits for both upper bound and mean exposures based on PHED (Frank, 2007), while U.S. EPA does not. The impact of the different approaches by the two agencies on handler exposure estimates was examined by Beauvais *et al.* (2010), using endosulfan as a model compound.

Handlers of the agricultural-use products Battalion™ 0.2 EC and Decis® 0.2 EC are required by product labels to wear coveralls over long-sleeved shirt and long pants (when handling the concentrate) or over short-sleeved shirt and shorts (when handling dilute mixtures). Mixer-loaders and M/L/As were assumed to handle the concentrate, and exposures were calculated using a 90% protection factor applied to parts of body covered by coveralls (Thongsinthusak *et al*., 1993). Their exposures could be underestimated if the actual protection of coveralls is less than 90%. Applicators were assumed to handle the dilute formulation; flaggers were also assumed to be exposed to the dilute formulation. Little exposure monitoring data are available for handlers wearing short-sleeved shirts and shorts, and exposure estimates for applicators and flaggers were based on data for handlers wearing long-sleeved shirt and long pants. Those exposures may be overestimated if the extra layer of protective clothing over the torso, upper arms and upper legs affords substantial protection.

Residential Post-Application Exposure

Residential reentry exposures on deltamethrin-treated turf were estimated from a study using a choreographed Jazzercise® routine (Rosenheck and Sanchez, 1995). Exposure estimates for residential turf reentry cover a range of activities, such as lawn mowing, crawling and playing, and golfing on treated turf. As the Jazzercise® routine involves lying on the ground and moving around, the exposure estimates based on data from Rosenheck and Sanchez (1995) are anticipated to be health protective, and could overestimate exposures for reentry activities like golfing that involve less contact with treated turf.

New U.S. EPA Exposure Assessment Guidance

U.S. EPA has recently updated exposure guidance for occupational and residential handler and reentry scenarios. DPR is in the process of reviewing data and assumptions used by U.S. EPA. Some scenarios would have very different exposure estimates under the new guidance (e.g., residential handlers of flea collars); other scenarios do not change substantially.

CONCLUSIONS

This RCD Addendum contains high-priority exposure and risk estimates associated with legal uses of deltamethrin in California. When the NOEL for an adverse effect is derived from a laboratory animal study, a calculated MOE of 100 is generally considered adequate for protection against potential toxicity of a chemical. This benchmark of 100 includes an uncertainty factor of 10 for intraspecies variability, as well as an uncertainty factor of 10 for inter-species variability. For deltamethrin, several MOEs are below the benchmark of 100. Exposure and risk estimates are given for the eighteen high-priority scenarios having MOEs less than 15. Three of the four highest priority scenarios, with MOE < 1, involve residential uses and dust applications, as indicated in the Risk Management Directive (Gosselin, 2004); they include non-agricultural occupational applicators using a duster and residential handlers applying dusts and hand-spreading granules. One additional scenario with MOE < 1, toddlers interacting with treated pets, relates to a use that was not registered when the Risk Management Directive was issued.

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APPENDIX 1: OCCUPATIONAL REENTRY SCENARIOS FOR DELTAMETHRIN IN CALIFORNIA

This table was prepared by reviewing deltamethrin product labels. Maximum application rates and the preharvest intervals (PHI) were the same on the agricultural use product labels. Rows are sorted by site category (FC = Field Crops; FN = Fruits and Nuts; V = Vegetables; M = Miscellaneous; OT = Ornamentals, Herbs, Trees, Nursery/Greenhouse), then by use sites.

In preparing the table, reentry activities were listed for each site, then assigned to tiers based on anticipated exposure. Tier I: Most of the body (approximately > 50 % of the body surface) is in contact with residues. Tier II: Some of the body (approximately 25 - 50 % of the body surface) is in contact with residues (e.g., hands, arms and face; or hands, forearms, feet, and lower legs). Tier III: Very little of the body (approximately < 25 % of the body surface) is in contact with residues (e.g., hands only; or hands and feet only). Within Tier I and Tier II, suggested representative activities are shown in bold. Tier III activities are considered to be covered by Tier I and Tier II activities.

Site Cat [a]	**Use Site**	**Rate** [b] **(lb AI/A)**	**PHI** [c] **(days)**	**Tier I Activities**	**Tier II Activities**	**Tier III Activities**
FC	Canola, Crambe, and Rapeseed	0.009	7	None	None	Irrigating, Scouting, Swathing, Mech. Harvesting
FC	Corn, Field and Pop	0.022	21	**Scouting**	None	Irrigating, Mech. Harvesting, Weeding
FC	Corn, Sweet	0.028	1	**Scouting, Hand Harvesting**	None	Irrigating, Weeding, Mech. Harvesting
FC	Cotton	0.030	21	**Scouting**	Irrigating, Hand Weeding/Roguing, Mechanical Harvesting	None
FC	Sorghum	0.022	14	None	Irrigating, **Scouting**	Weeding/Roguing, Mechanical Harvesting
FC	Soybean	0.022	21	None	Irrigating, **Scouting**	Weeding, Mechanical Harvesting
FN	Pome Fruits (Apples, Pears)	0.022	21	Harvest (Hand), **Thinning**	**Pruning** (Nondormant)	Scouting, Irrigating, Weeding, Propping, Pruning And Tying (Dormant), Transplant/Propagate
FN	Tree Nuts (Almond, Chestnut, Filbert, Pecan, Pistachio, Walnut)	0.033	21	None	**Harvesting** (Mech Shake And Sweep [d])	Weeding (Mechanical), Irrigating, Scouting, Transplant/Propagate, Pruning (Dormant)
M	Turfgrass, Sod	0.13	0	None	**Landscape Maintenance, Mechanical Harvesting, Laying Sod**	Irrigation, Weeding, Scouting

Site Cat [a]	Use Site	Rate [b] (lb AI/A)	PHI [c] (days)	Tier I Activities	Tier II Activities	Tier III Activities
OT	Ornamental Plants	1	0	None	None	Irrigating, Scouting, Thinning, Turning, Tying, Weeding, Transplanting
V	Artichoke	0.028	3	**Harvesting (Hand)**	Irrigating, **Scouting**	Weeding, Transplanting, Mechanical Harvesting
V	Root Vegetables Except Sugar Beets (Horseradish, Radish, Turnip)	0.028	3	None	Harvesting (Hand)	Irrigating, Scouting, Thinning, Weeding, Transplanting, Harvesting (Mech)
V	Cucurbits (Cucumber, Melons, Pumpkin, Squash)	0.028	3	Tying, Staking, **Harvesting (Hand)**	Irrigating, **Scouting**	Weeding, Thinning, Transplanting, Harvesting (Mech)
V	Eggplant	0.028	1	Staking, Tying, Pruning (Hand) [g] **Harvesting (Hand)**	Irrigating, **Scouting**	Weeding, Transplanting
V	Bulb Vegetables (Garlic, Leeks, Onions, Shallots)	0.028	1	None	**Harvesting (Hand)**	Irrigating, Scouting, Thinning, Weeding, Transplanting, Harvesting (Mech)
V	Peppers	0.028	1	Staking, Tying, Thinning, **Harvesting (Hand)**	Irrigating, **Scouting**	Weeding, Transplanting
V	Tuberous and Corm Vegetables (Potato, Yam)	0.028	3	None	Irrigating, **Scouting,** Harvesting (Hand) [e]	Weeding, Transplanting, Harvesting (Mech)
V	Tomato (Fresh Market)	0.028	1	Tying/Training, Staking, Pruning (Hand), **Harvesting (Hand)**	Irrigating, **Scouting**	Weeding, Thinning, Transplanting
V	Tomato (Processing/ Canning)	0.028	1	Tying, Training, Staking	Irrigating, **Scouting,** Pruning (Hand)	Weeding, Transplanting, Harvesting (Mech)

[a] Site categories: FC = Field Crops; FN = Fruits and Nuts; M = Miscellaneous; OT = Ornamentals, Herbs, Trees, Nursery/Greenhouse; V = Vegetables.
[b] Rate = Maximum application rate listed for crop in California on any product label.
[c] PHI = Preharvest interval listed for crop on any product labels.
[d] Mechanical harvesting by shaking and sweeping to drop and collect fruits/nuts, respectively, may generate dust and debris (falling leaves, branches, produce) sufficient to expose harvester to pesticide residues by dermal contact with or inhalation of debris/dust.
[e] This activity isn't practiced commercially in California at present.

APPENDIX 2: SELECTION OF REPRESENTATIVE AGRICULTURAL REENTRY SCENARIOS

Crops were grouped by growth form (e.g., tree) and by similar cultural practices. These crop groups are summarized in Table A2-1.

Table A2-1. Crop Groups for Selecting Representative Scenarios

Category [a]	Representative Crop	Crops Included [b]
FC	Sweet Corn	Tall field crops (e.g., field corn, popcorn, sorghum)
FC	Cotton	Low and medium-height field crops (e.g., soybeans)
FN	Apple	Pome fruit (e.g., pear) and tree nuts (e.g., almond, pistachio, walnut)
OT	Turf	Sod, lawns (e.g., residential, parks, golf courses), and ornamentals
V	Cucumber	Cucurbits (e.g., melons, pumpkin, squash)
V	Potato	Root vegetables (e.g., carrots, garden beets, radish, sweet potato, turnip)
V	Tomato	Fruiting vegetables (e.g., eggplant, peppers)

[a] FC = Field Crops; FN = Fruits and Nuts; OT = Ornamentals, Nursery/Greenhouse; V = Vegetables.
[b] Crop addressed separately (i.e., no other crops in group): artichoke.

Once crops were grouped, representative activities were selected for each group. In Appendix 1, reentry activities listed for each site were assigned to tiers, using the following definitions, based on anticipated exposure:

- Tier I: Most of the body (approximately > 50 % of the body surface) is in contact with residues.
- Tier II: Some of the body (approximately 25 - 50 % of the body surface) is in contact with residues (e.g., hands, arms and face; or hands, forearms, feet, and lower legs).
- Tier III: Very little of the body (approximately < 25 % of the body surface) is in contact with residues (e.g., hands only; or hands and feet only).

Available information about crops or groups of crops was used to determine the representative activities in Tier I and Tier II. Within each use site, suggested representative reentry scenarios are indicated in bold the "Tier I Activities" and "Tier II Activities" columns in Appendix 1.

Table A2-2 summarizes representative agricultural reentry scenarios for deltamethrin. Exposure estimates generated for representative scenarios are anticipated to be the best available for other scenarios as indicated. The last column in Table A2-2 lists activities and crops covered by the representative scenario. Scenarios grouped under a representative scenario are not all expected to have identical exposures; however, the representative scenario is anticipated to involve exposures similar to or greater than all scenarios covered by it. In other words, representative scenarios might overestimate exposure for other scenarios, but should not underestimate exposure.

For most crops, hand harvesting is the activity having the greatest contact with treated foliage, which can result in the highest exposure potential. Some exceptions are fruit tree thinning and grape leaf pulling, which have higher potential contact than hand harvesting. Furthermore, if harvesting occurs several days after treatment (as required by longer PHI), then less foliar residue is available for transfer, which results in a lower actual exposure.

Table A2-2. Representative Agricultural Reentry Scenarios for Deltamethrin

Crop [a]	Rate [b]	Activity [c]	Represents [d]
Apple	0.022	Thinning (REI)	All activities in tree crops
Artichoke	0.022	Hand Harvest (PHI: 1)	All activities in artichokes
Corn	0.028	Hand Harvest (PHI: 1)	All activities tall field crops
Cotton	0.030	Scouting (REI)	All activities in low and medium height field crops
Cucumber	0.028	Scouting (REI)	Activities in all cucurbits
Potato	0.028	Scouting (REI)	All activities in root vegetables
Turf	0.13	Maintenance (PHI: 0)	All activities in turf and sod
Tomato	0.028	Staking/Tying (REI)	All activities in fruiting vegetables

[a] Representative crops from Table A2-1.
[b] Maximum application rate allowed on crop in pounds of active ingredient per acre, in pounds active ingredient per acre (lbs AI/acre).
[c] PHI: preharvest interval; number of days. REI: restricted entry interval; REI is 12 hours (i.e., on Day 0) unless otherwise stated as number of days. Exposures in crops with PHI = 0 are assessed at the day the REI expires.
[d] All scenarios covered by the representative crop and activity are anticipated to have exposure equivalent or less than that of the representative scenario. See Table A2-1 for specific crops covered by each scenario.

APPENDIX 3: UNIT EXPOSURE ESTIMATES FROM PHED

This appendix summarizes information on values used in handler exposure estimates based on the Pesticide Handlers Exposure Database (PHED, 1995). The California Department of Pesticide Regulation (DPR) uses PHED to estimate handler exposure for scenarios that do not have adequate chemical-specific exposure data. DPR's approach to PHED was summarized in two memos (Frank, 2007; Powell, 2007) and detailed in a report by Beauvais *et al*. (2007). Appendix I in Beauvais et al. (2007) specifies how subsets were generated for each scenario. For each scenario, two tables and a figure are provided.

- Table 1 gives parameters (specifications) used to generate the subsets.
- Figure 1 is a copy of the PHED "Summary Statistics" output for the dermal subset. (Appendix III explains the elements of the PHED output.)
- Table 2 summarizes calculations and presents estimates to be used in exposure assessments.

As an example, subset information is given below for Scenario 1, "Mixer/Loader, Open Pour, Wettable Powder (With Gloves)." Table A3-1 records both the selections made to generate the dermal, hand, and inhalation ("airborne") subsets and the resulting characteristics for each parameter. Data quality grades reported in PHED are based on Quality Assurance (QA) data provided in exposure study reports. Grades A and B are high-quality grades, with lab recoveries of 90-110% and 80-110%, respectively (field recoveries range 70-120% and 50-120%); grade C represents moderate quality, with lab and field recoveries of 70-120% and 30-120%, respectively; grade D represents poor quality, with lab recovery of 60-120% and field recovery that is either in the range of 30-120% or missing; E is the lowest quality grade, and is assigned to PHED data that do not meet basic quality assurance (U.S. EPA, 1998).

Table A3-1. Description of Pesticide Handlers Exposure Database (PHED) Subsets [a]

Parameter	Specifications used to generate subsets [a]	Actual characteristics of resulting subsets
Data Quality Grades [b]	A,B	A,B
Solid Type	Wettable powder	Wettable powder
Mixing Procedure	Open	Open

[a] Subsets of Mixer/Loader data in the Pesticide Handlers Exposure Database (PHED). Parameter descriptions are from screens displayed in the PHED program.
[b] Data quality for Dermal Uncovered, Dermal Covered and Hand are all Grade A or B; Airborne data are all Grade A. Data quality grades are defined in the text and in Versar (1992).

Figure A3-1 summarizes results from the non-hand dermal subset. All fields contributing to the arithmetic and geometric mean exposure estimates are shown, along with the number of observations for each field.

Figure A3-1. Summary of Results from the PHED Dermal Subset for Scenario 1 [a]

SCENARIO: Long pants, long sleeves

PATCH LOCATION	MICROGRAMS PER LB AI MIXED Mean	Coef of Var	Geo. Mean	Obs.
HEAD (ALL)	12.1008	159.063	3.243	24
NECK.FRONT	49.7781	241.7376	1.6288	24
NECK.BACK	35.299	250.8502	.9205	24
UPPER ARMS	181.099	412.7976	15.4083	30
CHEST	155.2533	458.3228	9.6478	36
BACK	165.361	437.2647	9.8479	36
FOREARMS	12.2599	180.986	4.6336	28
THIGHS	5.7027	140.9473	2.8042	28
LOWER LEGS	4.046	120.7341	1.9477	28

Table A3-2 summarizes exposure results for the dermal, hand, and inhalation subsets, and sums them for the total exposure. All exposure estimates reported by DPR for PHED were rounded to three significant figures. All estimates were rounded to the same extent because the resolution of measurements within each study could not be readily determined; PHED reports results to four decimal places regardless of the resolution in the original data. DPR considers three significant figures to be a reasonable default resolution (when hand exposure is added to non-hand dermal exposure to get the total dermal exposure rate, to avoid rounding differences a fourth significant figure is sometimes used).

Table A3-2. PHED Data from Dermal, Hand, and Inhalation Subsets and Calculated Exposure Rates for Scenario 1 [a]

Exposure Category	Mean Subset Exposure Rate (µg/lb AI handled)	Number of Observations in Subset	Short-Term Exposure Rate (µg/lb AI handled) [b]	Long-Term Exposure Rate (µg/lb AI handled) [c]
Dermal (non-hand) [d]	623	33 [e]	2,090	750
Hand (with gloves)	23.7	20	83.7	30.1
Inhalation	49.4	17	178	64.0
Total exposure	696	--	2,350	844

[a] Results from subsets of Mixer/Loader data in the Pesticide Handlers Exposure Database (PHED), and upper confidence limits (UCL) for mean and 95th percentile (%ile) calculated from these results. All values rounded to three significant figures.
[b] UCL for 95th %ile exposure = 1/SQRT(2)*MEAN*EXP[Z(0.95)*0.8326 + Z(0.90)*0.8326/SQRT(n)]; Equation 5 in Powell (2007).
[c] UCL for arithmetic mean exposure = MEAN*EXP[Z(0.90)*0.8326/SQRT(n)]; Eq. 6 in Powell (2007).
[d] Dermal total includes addition of default feet value of 0.52 x (value for lower legs); ratio of feet/lower leg surface area (U.S. EPA, 1997a).
[e] Effective sample size for number of dermal observations was estimated as the harmonic mean, weighted by the squared mean dermal exposure.

Table A3-2 shows an example calculation of total exposure for both short-term (upper-bound estimate) and long-term (based on arithmetic mean of PHED results) durations for Scenario 1. Arithmetic mean hand and inhalation exposures each involve a single parameter, with mean values and associated number of observations reported directly from PHED outputs. The arithmetic mean dermal exposure is calculated from values shown in Figure A3-1, with the addition of an estimated value for foot exposure. Foot exposure assumed to be equal to lower leg exposure, adjusted for the difference in median surface area: foot surface area is 1,225 cm^2

and lower leg surface area is 2,370 cm^2 (median values combined from data sets for men and women; U.S. EPA, 1997a). Calculations for foot exposure and total dermal exposure for Scenario 1 are shown below:

Foot Exposure: a) 1,225/2,370 = 0.52. b) 0.52 x 4.046 = 2.104 µg/lb AI handled

Total Average Dermal Exposure (mean values from Figure A3-1): 12.101 + 49.778 + 35.299 + 181.099 + 155.253 + 165.361 + 12.260 + 5.703 + 4.046 + 2.104 = 623.004 µg/lb AI handled

The number of observations in the dermal subset is the effective sample size, which is estimated as a weighted harmonic mean (Powell, 2007). The weighted harmonic mean is calculated by dividing the sum of the squared means by the sum of squared means divided by the number of observations. The calculation for Scenario 1 is shown in Table A3-3; both the numbers of observations (N) and means for this scenario are taken from Figure A3-1. The estimated effective sample size, 32.822, rounds to 33, the value reported in Table A3-2.

Table A3-3. Effective Sample Size Calculation for Scenario 1 [a]

Body Part	N [b]	Mean [c]	$(Mean)^2$	$(Mean)^2/N$
Head	24	12.101	146.4342	6.101425
Neck front	24	49.778	2477.849	103.24372
Neck back	24	35.299	1246.019	51.917475
Upper arms	30	181.099	32796.85	1093.2283
Chest	36	155.253	24103.49	669.5415
Back	36	165.361	27344.26	759.56279
Forearms	28	12.26	150.3076	5.3681286
Thighs	28	5.703	32.52421	1.1615789
Lower Legs	28	4.046	16.37012	0.584647
Feet	28	2.104	4.426816	0.1581006
Total (Σ, i.e., summed values)		623.004	88318.53	2690.8676
Effective sample size [d]				32.822

[a] Calculated according to method described in Powell (2007).
[b] Number of observations.
[c] Arithmetic mean exposure for body part.
[d] Effective sample size calculated as [total $(Mean)^2$]/[total $(Mean)^2/N$]

As explained by Powell (2007), PHED does not allow estimation of the standard deviation on the dermal mean. However, the standard deviation is needed to calculate the 90% upper confidence limit (UCL) on both the mean and the 95th percentile. As the standard deviation is unknown, the UCL values are estimated by multiplying the mean by a multiplier related to the number of observations; multipliers are in Table 5 of Powell (2007). As shown above, the effective sample size for dermal exposures for Scenario 1 is 33; the multipliers are 1.204 and 3.349 for the 90% UCL on the mean and 95th percentile, respectively. The mean dermal exposure of 623 is multiplied by these values to get 750.092 and 2,086.427, which round to 750 and 2,090 µg/lb AI handled.

Inhalation exposure rates were calculated using a default inhalation rate of 16.7 liters/min (1.0 m^3/hour), assuming that the typical handler work-hour consists primarily of light activity. Default inhalation rates used by DPR for various activity levels are documented in Andrews and Patterson (2000).

The total exposure calculations are shown below:

Short-Term: 2,090 + 83.7 + 178 = 2,351.7, which rounds to 2,350 µg/lb AI handled.

Long-Term: 750 + 30.1 + 64.0 = 844.1, which rounds to 844 µg/lb AI handled.

Detailed information on set-up and results from the other scenarios included in this exposure assessment is given in Beauvais *et al.* (2007). The following tables contain brief summaries of the subsets and results used to estimate handler exposures in this exposure assessment.

Table A3-4 summarizes characteristics of PHED data sets used to estimate high-priority handler scenarios. Data in Table A3-4 can be found in Beauvais *et al.* (2007), and reflect handlers wearing long-sleeved shirts, long pants, shoes and socks.

Table A3-4. Summary of PHED Data Sets for Handler Scenarios [a]

Scenario No.	Scenario [b]	Data Quality [c]			Numbers of Observations [d]		
		Dermal	Hand	Inhalation	Dermal	Hand	Inhalation
5	Open Pour M/L, L, gl	A,B	A	A,B	99	59	85
7	Flagger, L, gl	A	A,B	A,B	21	30	28
15	Hand Spread Bait, gl	A,C	C	A,C	16	15	16
16	ROW Sprayer, L, gl	A,C	A, B	A	5	16	16
17	Aerial Applicator, L, OC, gl	A,C	A,C	B,C	12	9	14
21	HPHW Open Pour, L, gl	A	C	A	11	13	13
28	Paintbrush, gl	C	B	C	15	15	15

[a] Scenario numbers and details summarized from Appendix I in Beauvais *et al.* (2007). PHED: Pesticide Handlers Exposure Database.
[b] Abbreviations: gl = wearing chemical-resistant gloves; HPHW = high-pressure handwand; L = liquid; M/L = mixer/loader; OC = open cockpit.
[c] Data quality grades are defined in Beauvais *et al.* (2007) and in Versar (1992).
[d] Effective sample size for number of dermal observations was estimated as the harmonic mean, weighted by the squared mean dermal exposure (Powell, 2007).

Table A3-5 summarizes exposure results for subsets in each handler scenario.

Table A3-5. Summary of PHED Results for Handler Scenarios [a]

Scen. No.	Scenario [b]	Short Term Exposure Rate (µg/lb AI handled) [c]		
		Dermal	Hand	Inhalation
5	Open Pour M/L, Liquids, gl	1,340	186	7.34
7	Flagger, Liquids, gl	131	2.02	0.680
15	Hand Spread Bait, gl	334,000	17,100	1,270
16	ROW Sprayer, Liquids, gl	48,400	403	12.3
17	Aerial Applicator, Liquids, OC, gl	198	38.2	2.12
21	HPHW Open Pour, Liquids, gl	25,200	1,270	565
28	Paintbrush, gl	80,300	74,000	729

[a] Scenario numbers and exposure rates summarized from Appendix I in Beauvais *et al.* (2007). PHED: Pesticide Handlers Exposure Database.
[b] Abbreviations: gl = wearing chemical-resistant gloves; HPHW = high-pressure handwand; M/L = mixer/loader; OC = open cockpit.
[c] Upper confidence limit (UCL) for 95th %ile exposure = 1/SQRT(2)*MEAN*EXP[Z(0.95)*0.8326 + Z(0.90)*0.8326/SQRT(n)]; see Equation 5 in Powell (2007).

Product labels require engineering controls and personal protective equipment (PPE) for agricultural handlers, as summarized in the Label Requirements section. Table A3-6 summarizes exposure rates with PPE (chemical-resistant apron) required on agricultural-use product labels.

Table A3-6. Exposure Rates for Handlers Wearing PPE Required by Deltamethrin Product Labels [a]

Scenario No.	Scenario	Short Term Exposure Rate (µg/lb AI handled) [b]		
		Dermal	Hand	Inhalation
5	Open Pour Mixer/Loader, Liquids	1,260	186	7.34

[a] Scenario number and details summarized from Appendix I in Beauvais *et al.* (2007). Exposure rates assume protective clothing, personal protective equipment (PPE), and engineering controls required on product labels, and are calculated with the following protection factor: chemical-resistant apron, 90% on chest, stomach, and front half of thighs.
[b] Upper confidence limit (UCL) for 95th %ile exposure = 1/SQRT(2)*MEAN*EXP[Z(0.95)*0.8326 + Z(0.90)*0.8326/SQRT(n)]; see Equation 5 in Powell (2007).

APPENDIX 4: NON-DIETARY INGESTION FOR RESIDENTIAL POST-APPLICATION SCENARIOS

Treated Turf

Hand-to-mouth (HTM) transfer is estimated based on transferable residues on turf (TTR). No TTR data are available for deltamethrin, and a default value assuming 5% of the application rate was used instead (Smegal *et al*., 2001). Following application of deltamethrin at the rate of 0.13 lb AI/acre, the default Day 0 TTR was 0.0728 µg/cm². Other factors used in estimating HTM transfer include the surface area of a toddler's hands expected to contact the mouth, the number of times the hands contact both turf and mouth in an hour, the percentage of residues transferred from the hands to the mouth with each contact, and the number of hours toddlers play on turf. The median surface area of both hands contacting the mouth was assumed to be 20 cm² (Smegal *et al*., 2001). The rate of HTM contact for estimating a short-term exposure was assumed to be 20 events/hour, based on the 90th percentile contact rate from a study reviewed by U.S. EPA (Smegal *et al*., 2001). With each HTM contact, 50% of residues were assumed to be transferred to the mouth; 100% transfer from turf to hands was assumed as well (Smegal *et al*., 2001). Finally, toddlers were assumed to spend 2 hours/day on turf (U.S. EPA, 1997b). The exposure calculation is shown below:

HTM = [(0.0728 µg/cm²) x (20 cm²) x (20 events/hour) x (0.5) x (2 hour/day)]/(15 kg)
= 1.9 µg/kg/day = **0.0019 mg/kg/day**.

Object-to-mouth (OTM) transfer was also estimated based on Day 0 TTR, which for deltamethrin was assumed to be 0.0728 µg/cm^2 (U.S. EPA, 1997b). Unlike HTM transfer, OTM transfer assumes that small objects (including grass) are swallowed, and that 100% of residues on the swallowed grass or similar objects are available for absorption. For this reason, the only other factor used in estimating OTM transfer is the surface area of the object (including grass) expected to be ingested during play. For this scenario U.S. EPA (1997b) assumes that children may ingest 25 cm^2/day (i.e., 2 x 2 inches or 4 in^2), based on "the approximate area from which a child may grasp a handful of grass." The exposure calculation is shown below:

OTM = [(0.0728 µg/cm²) x (25 cm²)]/(15 kg) = 0.12 µg/kg/day = **0.00012 mg/kg/day**.

Soil ingestion was estimated based on application rate and assumptions given in U.S. EPA (1997b). The resulting estimate did not contribute significantly to total exposure. For toddlers, total exposure, reported as STADD was calculated as follows:

STADD = 0.0109 + 0.0019 + 0.00012 = **0.013 mg/kg/day**.

Flea Collar

Scalibor Flea Collar, which contains 4% deltamethrin impregnated in a collar weighing 0.9 ounces (0.05625 lb; 25,500 mg). The amount of deltamethrin applied to a dog wearing the

flea collar is 4% of 25,500 mg, which is 1,020 mg. Exposures were estimated using default assumptions from U.S. EPA (1997b). Twenty percent of the AI applied to the pet is assumed to be retained on the pet's fur as dislodgeable residue, and 10% of that is considered to be transferred to the skin of a person touching (petting, hugging, etc.) the pet. The amount of "dislodged residue," or deltamethrin transferred to the skin, is 2% of 1,020 mg, which is 20.4 mg.

U.S. EPA (1997b) calculates HTM exposure using the dislodged residue as follows:

Default DR (mg/cm^2) = [Rate (mg) x [percent (2% assumed) of rate available as dislodgeable]/[surface area of pet (6000 cm^2 assumed)]

DR (mg/cm^2) = [(1020 mg) x (0.02)]/6000 cm^2 = 0.0034 mg/cm^2

[(0.0034 mg/cm^2) x (350 cm^2) x (1.56 events/hr) x (2 hours/day)]/(15 kg) = **0.248 mg/kg/day**

Total post-application exposure for toddlers interacting with a pet wearing a flea collar sums dermal and HTM exposure.