ASSESSMENT OF HUMAN EXPOSURE TO FIPRONIL

By

Weiying Jiang, Ph.D., Staff Toxicologist

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California Environmental Protection Agency

Department of Pesticide Regulation

Human Health Assessment Branch

1001 I Street

P.O. Box 4015

Sacramento, California 95812-4015

www.cdpr.ca.gov

Contributors

Drinking Water Concentration Assessment:	Christopher DeMars Senior Environmental Scientist Human Health Assessment Branch Department of Pesticide Regulation
Reported Illnesses Analysis:	Michael Zeiss, Ph.D. (Retired) Senior Environmental Scientist Worker Health and Safety Branch Department of Pesticide Regulation

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ACRONYMS

AADD	annual average daily dose
AVMA	American Veterinary Medical Association
DAF	dermal absorption factor
DPR	Department of Pesticide Regulation
FAC	Food and Agricultural Code
HHA	Human Health Assessment Branch
HPLC	high-performance liquid chromatography
HUD	US Department of Housing and Urban Development
LADD	lifetime average daily dose
LC	liquid concentrate
LPM	liter per minute
LSC	liquid scintillation counter
M/L/A	mixer/loader/applicator
MOE	margin of exposure
MQL	minimum quantifiable level
NAS	National Academy of Sciences
NIOSH	National Institute for Occupational Safety and Health
NOEL	no-observed effect level
NRC	National Research Council
PCOC	Pest Control Operators of California
PHED	Pesticide Handlers Exposure Database
PISP	Pesticide Illness Surveillance Program
PPE	personal protective equipment
REI	restricted entry interval
PUR	Pesticide Use Reporting
RCD	risk characterization document
RTU	Ready-to-use
SENSOR	Sentinel Event Notification System for Occupational Risks
SOP	standard operating procedure
SADD	seasonal average daily dose
STADD	short-term absorbed daily dose
SURF	Surface Water Database
SWIMODEL	Swimmer Exposure Assessment Model
SWP	Surface Water Program
TTR	transferable turf residue
TWA	time-weighted average
US EPA	US Environmental Protection Agency
USGS	US Geological Survey

EXECUTIVE SUMMARY

Fipronil is a phenylpyrazole insecticide discovered by Rhône-Poulenc in 1987 and first registered in California in 1997. Fipronil is the active ingredient of many products used for structural pest control, pet flea/tick control, and lawn maintenance. Currently, no fipronil product is registered for agricultural produce use in California.

The Human Health Assessment (HHA) Branch of the California Department of Pesticide Regulation (DPR) initiated the comprehensive human health risk assessment for fipronil due to potential mammalian toxicity from both acute and chronic exposure. Surveillance networks in California and nationwide have reported human illness incidents associated with fipronil uses.

In 2013, the National Academy of Sciences (NAS) reviewed the risk assessment practices of DPR. Following the recommendations from NAS, DPR risk assessment process was improved with increased transparency and involvement of all stakeholders. Fipronil was selected as the first active ingredient to follow the revised process.

This assessment identified 25 exposure scenarios during the problem formulation phase. One additional scenario was suggested by the Pest Control Operators of California (PCOC). Of these 26 scenarios, low human exposure is expected for eight scenarios. Fipronil exposure was estimated for the remaining 18 scenarios. For these 18 scenarios, short-term absorbed daily dose (STADD) via individual exposure pathway, which represents short-term fipronil exposure, is summarized in Table E1. Seasonal, annual and life-time average daily doses (SADD, AADD and LADD), which represent intermediate and long-term exposures, are less than the STADDs and are listed under individual exposure sections. Anticipated fipronil concentrations in the surface water for use in dietary exposure assessment were also developed: 0.275 ppb for the acute and 0.033 ppb for the chronic dietary risk assessments.

Table E1. Fipronil exposure summary for evaluated use scenarios

Product	Handler/ Post-application	Human receptor	Exposure pathway	STADD[a] (µg/kg/d)
Turf granule	Handler	Adult	Dermal	0.66
			Inhalation	0.048
	Post-application, resident	Adult	Dermal	0.0069
		Child	Dermal	0.0099
			Incidental Oral	23
Pet spray	Applicator, groomer	Adult	Dermal	52
			Inhalation	1.3
	Applicator, home user	Adult	Dermal	19
			Inhalation	0.47
	Post-application, resident	Adult	Dermal	2.4
		Child	Dermal	4.6
			Incidental Oral	1.1
Pet spot-on	Applicator, groomer	Adult	Dermal	4.2
	Applicator, home user	Adult	Dermal	1.5
	Post-application, resident	Adult	Dermal	1.4
		Child	Dermal	2.6
			Incidental Oral	0.60
Structural dust	Applicator	Adult	Dermal	0.085
			Inhalation	0.022
Structural LC[b]	Handler, no overhead	Adult	Dermal	1.4
			Inhalation	0.53
	Handler, with overhead	Adult	Dermal	6.3
			Inhalation	0.17
	Post-application, resident	Adult	Dermal	0.026
			Inhalation	0.023
		Child	Dermal	0.018
			Inhalation	0.048
			Incidental Oral	0.073
Structural bait gel	Post-application, resident	Adult	Dermal	0.00043
		Child	Dermal	0.00031
			Incidental Oral	0.0012

a: short-term absorbed daily dose; b: liquid concentrate.

I. INTRODUCTION

Fipronil, 5-amino-1-[2,6-dichloro-4-(trifluoromethyl)phenyl]-4-[(trifluoromethyl)sulfinyl]-1H-pyrazole-3-carbonitrile, is a phenylpyrazole insecticide discovered by Rhône-Poulenc in 1987 and first registered in California in 1997. Fipronil is the active ingredient in many home-use and commercial pesticide products. In California, these products are used for various purposes including controlling structural pests, treating parasites on dogs/cats, and performing landscape maintenance. Although fipronil products are registered to control agricultural crop pests in some US states, no fipronil product is registered for use on agricultural produce in California (US EPA, 1998).

In 2013, the California Department of Pesticide Regulation (DPR) requested the National Academy of Sciences (NAS) independently peer review DPR risk assessment practices. In April 2015, the National Research Council (NRC), an external committee of NAS, completed its review and issued recommendations to improve DPR risk assessment process and risk characterization documents (RCDs, NRC, 2015). NRC recommended that for each specific pesticide, DPR conducts a problem formulation/scoping phase prior to drafting the RCD, during which DPR risk managers and risk assessors discuss the scope of the risk assessment. Information and data relevant to each pesticide are evaluated to determine the scope of the risk assessment. These data may include toxicology, pesticide use reports, pesticide sales, illness reports including adverse effects reports, primary uses of the pesticide, exposure scenarios identified on product labels, relevant US Environmental Protection Agency (US EPA) risk assessments, important sources of uncertainty and variability in the data, potential exposure pathways, and mitigation options that could address these potential exposure pathways. NRC also emphasized the importance of incorporating California-specific information into the risk assessment process when available and encouraged DPR to use more of such data, including the DPR Pesticide Use Reporting (PUR) database and reports from the Pesticide Illness Surveillance Program (PISP, NRC, 2015).

In response to NRC recommendations, the Human Health Assessment Branch (HHA) of DPR revised its human health risk assessment process and selected fipronil as the first pesticide to enter the new process. DPR initiated a comprehensive human health risk assessment for fipronil due to potential adverse human health effects associated with registered fipronil uses. This human exposure assessment document was prepared as part of the risk assessment. All fipronil products registered in California were considered and all label-described uses of these products were assessed for fipronil exposure, including occupational and non-occupational scenarios.

II. FACTORS CONSIDERED TO DEVELOP EXPOSURE SCENARIOS

Based on the NRC recommendations, this assessment includes a problem formulation/scoping step in the risk assessment process. NRC envisions the problem formulation as a phase when risk managers, risk assessors, and stakeholders are brought together to determine "the major factors to be considered, the decision-making context, and the timeline and depth needed to ensure that the right questions are being asked in the context of the assessment" (NRC, 2009).

HHA incorporated this recommendation into the risk assessment process. During the problem formulation stage, HHA reviewed information and data relevant to fipronil, especially the California-specific data. This section describes factors considered in developing the exposure scenarios. HHA focused on exposure to products with significant use in California and the scenarios with greatest exposure potential.

A. Physiochemical properties

The two-dimensional chemical structure of fipronil is shown in Figure 1. Some key physiochemical properties that affect fipronil environmental fate and human exposure potential are summarized below (Tomlin, 1996). Fipronil is considered a non-ionic hydrophobic compound based on its low water solubility and high octanol/water partition coefficient (K_{ow}). Fipronil also has very low vapor pressure (2.8 x 10^{-9} mmHg at 25 °C), indicating the inhalation exposure from gas phase fipronil is expected to be low (Teerlink, 2017). However, fipronil inhalation is still possible if humans are exposed to air containing fipronil aerosols.

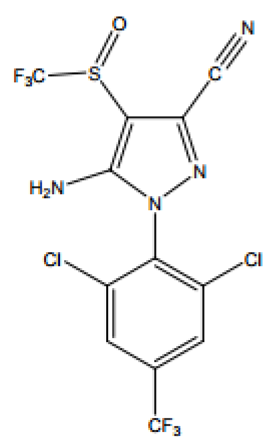

Figure 1. Chemical structure of fipronil

- Molecular formula: $C_{12}H_4Cl_2F_6N_4OS$
- Molecular weight: 437.2 g·mol^{-1}
- Octanol-water partition coefficient (Log K_{ow}): 4.0
- Henry's law constant: 3.7x10^{-5} Pa·m^3·mol^{-1}
- Solubility (g·L^{-1}, 20ºC): 0.002 in distilled water, 545.9 in acetone, 3.0 in toluene

B. Fipronil use and sales in California

Fipronil is used for structural, lawn, and pet treatments. There are no fipronil products registered for agricultural produce use in California. Some fipronil products have use restricted to licensed applicators, while many products can be used by both licensed applicators and the general public.

The DPR PUR database records fipronil use by licensed applicators. Title 3 of the California Code of Regulation (CCR) requires licensed applicators, either individuals, companies, or agencies in the business of pest control, to report their pesticide use to the agricultural commissioner of the county in which the application was made (3 CCR § 6627(a)). Fipronil use by licensed applicators in 2011-2015 is summarized in Table 1. Structural pest control accounted for almost all (>99%) fipronil use by licensed applicators.

Table 1. Fipronil use (lbs) by licensed applicators in 2011-2015

Commodity	2011	2012	2013	2014	2015
Structural Pest Control	63,345	53,156	70,928	79,245	91,339
Landscape Maintenance	113	109	57	68	136
Other	2	13	479	337	954
Total Use	63,460	53,278	71,464	79,650	71,464

The top five counties for fipronil use in 2015 are Orange, Los Angeles, Santa Clara, Sacramento and Riverside, which together accounted for 63% of total fipronil used by licensed applicators (Figure 2). Orange County alone had around 20,000 lbs of fipronil applied by licensed applicators in 2015, accounting for over 20% of total use by licensed applicators in California. In 2012-2015, the counties of Los Angeles, Orange, San Diego, Riverside and San Bernardino accounted for over 50% of annual fipronil use in California, indicating significant fipronil use by licensed applicators in Southern California.

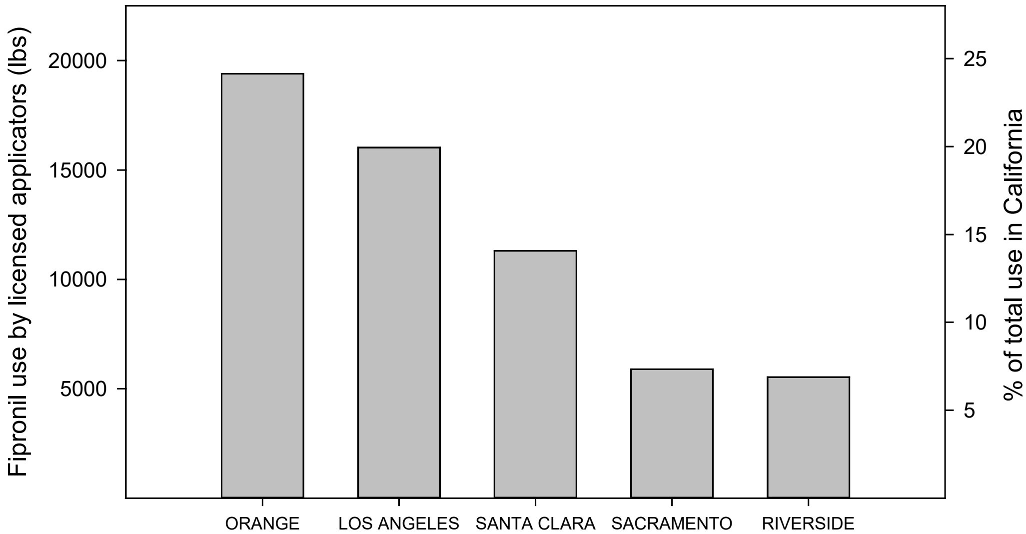

Figure 2. Fipronil use by licensed applicators in 2015: top five Counties

PUR data also showed licensed applicators used more fipronil during the warm, dry months (e.g., April to October, Figure 3). As shown in Figure 4, more fipronil was used during April-October than in other time of a year in both Southern and Northern California. For instance, in Orange County in 2015, months with >5% of annual fipronil use are all in the dry season.

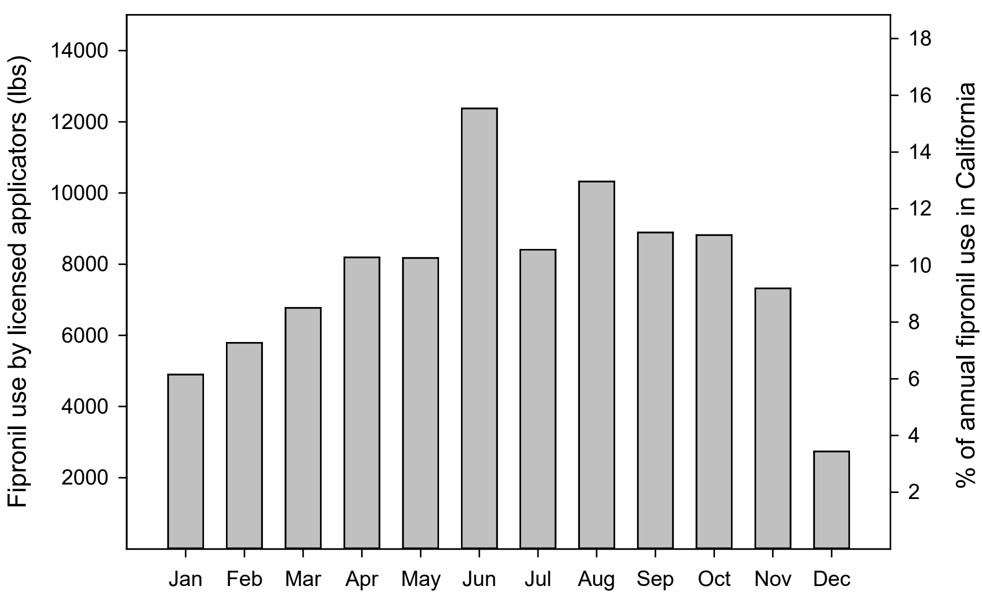

Figure 3. Monthly fipronil use by licensed applicators in California in 2015

Fipronil products are also sold at retail stores and can be used by home users, such as spot-on and spray products used by pet owners on their dogs/cats and bait gel and station products used by homeowners to control ants and roaches. Fipronil pet spot-on products that are commonly used to treat ectoparastic pests represent the largest number of fipronil products registered in California (DPR, 2020). However, their use by the general public is not recorded in the PUR database.

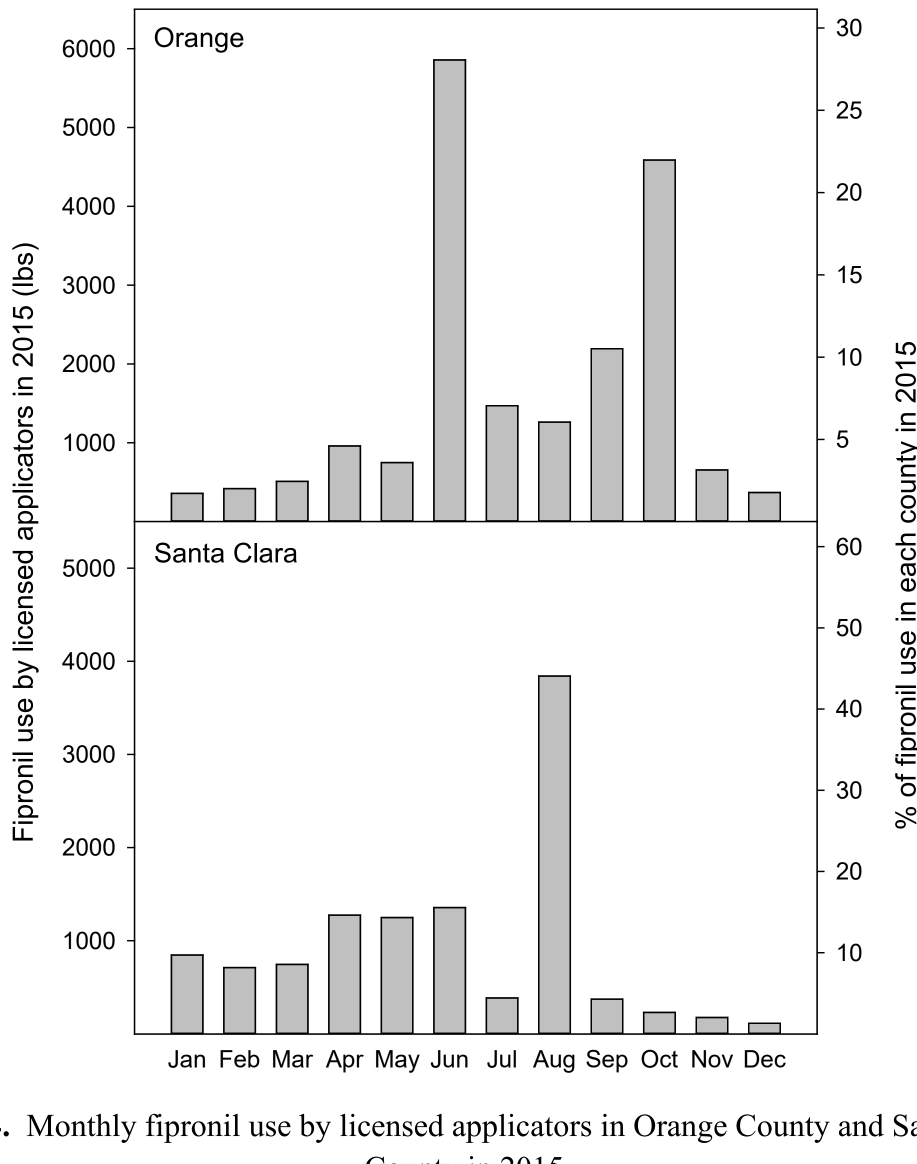

Figure 4. Monthly fipronil use by licensed applicators in Orange County and Santa Clara County in 2015

C. Registered products in California and labeled uses

As of January 2016, 124 products containing fipronil have active registrations in California (DPR, 2020). Registered products represent various formulation types, including dust, pressurized spray, liquid concentrate, ready-to-use (RTU) liquid, gel, baits, and granules and contain between 0.00045–9.8% fipronil. Based on the use purpose and formulation, these products were categorized into seven groups, as summarized in Table 2.

Table 2. Summary of fipronil products registered in California as of January 2016

Target site	Formulation	Application	Licensed user only	PPE[b] required	Use in indoor living space
Turf	RTU[c] granule	Broadcast	Yes	Yes	No
Dog/cat	RTU solution	Spot-on	No	No	N/A[a]
Dog/cat	RTU solution	Spray	No	Yes	N/A[a]
Structure	RTU dust/powder	Injection	Yes	No	No
Structure	LC[d]	Spray	Yes	Yes	No
Structure	RTU bait station	Placement	No	No	Yes
Structure	RTU gel/strip	Spots along cracks/crevices	No	No	Yes

a: not applicable as use locations was only included on the turf and structural product labels; b: personal protective equipment; c: ready-to-use; d: liquid concentrate.

<u>Turf products.</u> These include ready to use (RTU) granule products to control imported fire ants (*Solenopsis spp.*). In California, the use is limited to the Coachella Valley and the months of April to September.

<u>Dog/Cat spot-on products.</u> These products represent the largest number of fipronil products registered in California and can be used by both professional groomers and pet owners to treat ticks, fleas, and lice on cats and dogs. The product is applied by squeezing a full tube of liquid onto the skin between the shoulder blades of a dog or cat. There is one tube size for cats and four tubes sizes for dogs based on the body weight ranges (i.e., ≤ 22 lbs, 23-44 lbs, 45-88 lbs and 89-132 lbs). Gloves and other personal protective equipment (PPE) are not required when applying the spot-on products.

Dog/Cat spray products. This includes RTU liquid formulation products in pressurized or hand-trigger container. The person applying the spray is required to wear household latex or rubber gloves before application. To apply, ruffle the dog or cat hair with one gloved hand while holding and applying a spray product with the other gloved hand. For head and eye areas, spray the product on one gloved hand and then gently rub the product onto the treated area.

Structural LC products. These are LC formulations used to control structural pests such as termites. The products must be diluted with water prior to application. They can be applied for termite control during pre-construction (e.g., broadcast spray on surface to be covered beneath the concrete slab) and post-construction (e.g., trenching and rodding along exterior perimeter and in accessible crawl space) phases. They can also be applied along exterior foundation perimeters to control invasive insects such as ants and spiders. Broadcast application of these products to indoor living spaces is restricted.

Structural dust/powder products. This formulation is a RTU solid in a non-refillable package exclusively used with specially designed application equipment. The product label does not require PPE during application.

Structural bait station products. This formulation is a RTU in a secure reservoir. The products can be applied in both indoor and outdoor areas by placing these stations in spots with known or suspected pest activities. PPE is not required during application.

Structural bait gel/strip products. This formulation is RTU packed in syringes or strips and applied for spot treatments in both indoor and outdoor areas. PPE is not required during application.

D. Reported Illnesses

Pesticide illness data are evaluated to determine the exposure-specific data associated with the human illnesses, including the product type, formulation, and exposure routes. Descriptive data from the most recent five years of reports available at the time were used to develop relevant exposure scenarios used in this exposure assessment. Pesticide-related illness cases in California are recorded by DPR's Pesticide Illness Surveillance Program (PISP). Case reports are received throughout the state from poison control centers, the Department of Industrial Relations, local health officers, emergency departments, and medical doctors. The PISP scientists review the cases, and the information is logged into a database where it can be used for future assessments of worker protection standards and evaluation of illness trends. Analysis of the PISP data has been included in the problem formulation document (DPR, 2017) and also discussed below.

Between 2009 and 2013, PISP recorded 27 illness cases that are associated with the potential exposure to fipronil. Three of these cases occurred during structural and pet pest control applications and 20 cases occurred during post-application. Four cases resulted from product misuse or unidentified causes. Six cases were categorized as "Probable", indicating the illness was most likely caused by fipronil use, but the evidence was limited or circumstantial. One case was categorized as "Definite", meaning the exposure and consequent illness were supported by both physical and medical evidence. In this "Definite" case, a home user was exposed to fipronil while the pet spot-on product broke and a portion of the content splashed into the eye. Seven cases included exposure to other pesticides in addition to fipronil, so it is not possible to assign an illness to fipronil alone.

The National Institute of Occupational Safety and Health (NIOSH) maintains the SENSOR database and records pesticide illnesses in some US states. Acute illnesses related to fipronil exposure in 11 states from 2001-2007 were summarized by Lee et al. (Lee *et al.*, 2010). Most illness cases reported were associated with structural applications of LC product Termidor® suspended concentrate (SC), followed by the pet spot-on product Frontline® Plus. Pesticide handlers accounted for less than 40% of total illnesses. Pet care products, including both spray and spot-on formulations, were associated approximately 40% of total illnesses recorded by SENSOR. There have also been over 4000 adverse effects reports submitted to US EPA as required by Section 6(a)(2) of the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). More detail on these reports is found in the Risk Characterization Document.

E. Occurrence in Environmental Media with Human Exposure Potential

Air. The DPR Air Monitoring Network (AMN) measures airborne pesticides in agricultural communities (Vidrio *et al.*, 2017). Fipronil is not monitored as part of the AMN and air concentration data are scarce. Given its low volatility and no agricultural produce use in California, non-occupational human exposure to fipronil from outdoor air is expected to be low.

Residential areas. Fipronil is used in residential areas by both licensed applicators and home users for controlling home-invading pests and treating dogs/cats. Residues of fipronil and fipronil degradates have been detected in both residential indoor and outdoor areas. In 2009, US EPA and the US Department of Housing and Urban Development (HUD) published findings on pesticide occurrence inside residential homes (Stout *et al.*, 2009). This study sampled 500 public and private housing units across the US between June 2005 and March 2006. Indoor hard surfaces were sampled by isopropanol wipes. Fipronil was one of the most detected pesticides, with a detection frequency of 40% and an arithmetic mean concentration of 0.16 ng/cm^2. In another study, Mahler et al. (2009) collected indoor and outdoor floor dust from 24 apartments in Austin, TX from April–July, 2008 (Mahler *et al.*, 2009). Fipronil was measured by collecting floor dust using a high-volume surface sampler. The median and maximum concentration in the indoor dust was 89 and 9800 ng/g, and the median and maximum concentration in the outdoor dust was 4.81 and 300 ng/g, respectively. The authors found that the indoor and outdoor concentrations were not correlated, suggesting that the fipronil residues found in these two areas originated from different applications.

Fipronil residues in residential indoor areas in California have not been well quantified. However, Jiang et al. recently published data on fipronil occurrence in residential outdoor areas in California (Jiang *et al.*, 2016a). In this study, Jiang et al. used a commercial vacuum cleaner to sample three outdoor surfaces adjacent to residential homes. The houses were located in two neighborhoods in Riverside, CA and were sampled three times from May to September 2011. Dust samples (*N*=360) were analyzed for fipronil and three fipronil degradates (i.e., desulfinyl, sulfide and sulfone). The detection frequency and concentrations of fipronil and degradates are summarized in Table 3. Outdoor concentrations of fipronil and degradates in this study were similar to those found in Mahler et al. (2009). Fipronil concentrations increased from May to September, suggesting that fipronil and its degradates accumulate on residential outdoor surfaces during the dry summer months (Jiang *et al.*, 2016a).

Table 3. Detection frequency and concentration (ng/g) of fipronil and degradates on residential outdoor surfaces

Pesticide[a]	May		July		September	
	D%[b]	*C*[c]	D%	*C*	D%	*C*
Neighborhood 1						
fipronil	15.0	<RL[d] (3.1)	51.7	1.0 (100.3)	71.7	2.5 (59.2)
desulfinyl fipronil	20.0	<RL (14.2)	75.0	2.3 (90.1)	78.3	1.8 (18.6)
fipronil sulfide	0.0	<RL	13.3	<RL (21.3)	11.6	<RL (3.0)
fipronil sulfone	36.7	<RL (15.2)	91.7	4.6 (184.1)	90.0	4.9 (105.1)
Neighborhood 2						
fipronil	10.0	<RL (29.1)	25.0	<RL (58.4)	55.0	1.2 (858.9)
desulfinyl fipronil	18.3	<RL (14.2)	58.3	2.0 (128.9)	68.3	3.0 (34.6)
fipronil sulfide	1.7	<RL (2.5)	10.0	<RL (12.8)	8.3	<RL (16.8)
fipronil sulfone	28.3	<RL (23.0)	71.7	4.5 (380.7)	95.0	6.9 (85.7)

a: Data is obtained from Jiang et al., 2016; b: percent of detection, N=60; c: the median concentration value (ng fipronil/g total sample) in all the samples analyzed (N=60). Values in brackets are the maximum concentration value; d: less than reporting limit (RL), which equals to 1 ng/g.

A similar study was conducted in Orange County, CA in which gutters, driveways, and street surfaces were sampled around twenty homes (Richard, 2013). The same homes were sampled three times, in August and October 2013 and in February 2014. Fipronil detection frequency was 36.3% and the median and maximum concentrations were <1.0 and 3663.9 ng/g, respectively. Dust on driveways contained higher fipronil concentrations than either the gutter or the street, which the authors attributed to the closer proximity of driveway to the perimeter of houses where fipronil was usually applied.

Urban surface water. The product labels prohibit fipronil applications directly to surface water. However, outdoor surface runoff and indoor drainage transfer of fipronil from urban and residential areas into receiving water bodies contribute to fipronil contamination in urban surface waters in California. Fipronil occurrence in California surface water has been measured in several studies. A summary of these studies is found in Jiang et al. (2016b).

DPR's Surface Water Protection Program (SWPP) maintains the Surface Water Database (SURF) that catalogues pesticide occurrence data from California surface waters. Table 4 summarizes data on fipronil and fipronil degradates as of June 2015. Fipronil and its degradates are among the most frequently detected insecticides in urban surface water in both Southern and Northern California (Ensminger, 2015; Budd, 2016).

Table 4. Occurrence of fipronil and degradates in California surface water

Pesticide	*N*[a]	Mean[b]	Max
Surface water (µg/L)			
fipronil	1075	0.031	2.11
desulfinyl	981	0.012	0.305
sulfide	1011	0.001	0.102
sulfone	1011	0.02	0.546
amide	552	0.007	0.246
Sediment (µg/kg)			
fipronil	217	0.002	0.046
sulfide	164	0.011	0.091
sulfone	123	0.038	0.189

a: number of samples; b: The quantification levels varied among different sampling sites. To calculate the mean, for all the samples, non-quantifiable values were treated as zero.

An analysis of the impact of surface water contamination on drinking water residues is found later in this document.

F. Label precautions and regulations

Pesticide labels use three signal words, i.e., Danger, Warning, or Caution, to categorize how dangerous a product can be to humans. All fipronil product labels carry the signal word "Caution", meaning the products are generally less dangerous than products with "Danger" or "Warning" signs if handled following label instructions. Fipronil product labels also state "harmful if swallowed, absorbed through skin or inhaled", "keep out of reach of children", and "wash thoroughly with soap and water after handling and before eating and drinking".

Only licensed applicators can use turf, structural LC, and structural dust/powder products. Different groups of fipronil products also have different PPE requirements. Applicators are required to wear long sleeved shirt, long pants, waterproof gloves, shoes and socks when applying turf and structural LC products. The labels of structural LC products also require applicators to wear respirator when working in a non-ventilated area. Dog/cat spray products require any applicators, including pet owners, to wear gloves.

III. EXPOSURE SCENARIOS AND CONCEPTUAL MODELS

Based on the information discussed above, nine handler and sixteen post-application exposure scenarios were selected during the problem formulation phase to enter into exposure assessment. These scenarios are summarized in Table 5 and 6 and were prioritized as “High”, “Medium” or “Low” based on criteria detailed in the table footnotes. Briefly, this assessment first ranked individual scenarios based on the fipronil exposure potential and then increased the priority of scenarios with significant use/sales in California or with recorded illnesses. This assessment evaluated all the identified scenarios but prioritized assessment of exposures with a “High” priority assigned.

Conceptual models illustrate sources, exposure pathways and human receptors for the exposure scenarios, and are recommended by NRC as they “*serve as a guide for determining what types, amount, and quality of data are needed for the assessment to address the issues and concerns of interest to decision-makers*” (NRC, 2009). The conceptual model for fipronil was initially developed during the problem formulation phase of exposure assessment (Figure 5). The exposure assessment document followed each of the scenarios identified in the conceptual model to assess human exposures via different exposure routes. Dermal contact and inhalation are the primary routes of fipronil exposure during application. Exposure may occur during mixing and loading of LC and granular products as well as application of all products (all formulations). Because fipronil has a low vapor pressure, inhalation exposure from gas phase fipronil is anticipated to be low. However, inhalation of aerosols during loading of granular products and during mixing and application of liquid formulation products may constitute a non-negligible fipronil exposure route.

Two handler and four post-application exposure scenarios were categorized as “Low” priority. These scenarios were not assessed in this document with the reasons summarized below.

Structural bait station products. These are a group of RTU products contained in a secure reservoir/child-resistant packaging. The fipronil content in these products ranges from 0.01% to 0.03%. The product is applied by placing the stations near ant trails or where ant activities are frequently seen. No replacement stations are needed for at least three months. The primary exposure route for the handler is dermal contact. As the applicator does not directly contact the fipronil formulation, HHA determined the exposure was negligible; this determination is consistent with the US EPA assessment (US EPA, 2012; US EPA, 2020a). Post-application exposure is also negligible because the fipronil formulation is securely contained. Therefore, both applicator and post-application exposures were not assessed for bait station products.

Structural bait gel/strip products. This contains a group of RTU products with fipronil formulation packed as syringe tubes or strips. Fipronil content of these products ranges from 0.001% to 0.05%. The bait gel product is applied by touching the tip of the syringe to the target surface and depressing the syringe plunger. The strip product is applied by peeling off the cover film and placing the strip to the target surface. Both types of products are applied to areas with suspect pest activities, such as cracks and crevices, and are effective up to one month. The primary exposure route for applicator is dermal contact. As the handler does not directly contact the formulation, handler exposure is minimal, which is consistent with the US EPA assessment (US EPA, 2012; US EPA, 2020a). Therefore, applicator exposure was not assessed for the bait gel/strip products.

Swimmer. Direct application of fipronil into surface water is prohibited. However, fipronil is detected in California surface water samples (DPR, 2016). Thus, human (adult and child) exposure from swimming in contaminated water may be a potential exposure pathway. Primary exposure routes are dermal contact, inhalation, and incidental oral ingestion. A screening assessment of swimmer exposures using US EPA guidelines and fipronil water concentration at 0.275 µg/L indicates that fipronil exposure was low for both adult and child swimmers (Table 7, US EPA, 2003). Therefore, a higher-tier assessment of swimmer exposures, other than values present in Table 7, was not included in this document.

Table 5. Fipronil handler exposure scenarios

Exposure Scenario	Human receptor	Exposure based evidence					Use and illness based adjustment								Final priority decision
		Exposure estimate			Amount handled[d]	Preliminary priority decision[e]	Use restricted to licensed applicator[f]?	PUR data (Licensed use)		Sales data (if exempt from PUR)		Illnesses within CA (CalPISP)		Increase from preliminary priority decision?	
		Source of exposure estimate[a]	Label-required PPE deviated from default PPE[b]?	Exposure estimate[c]				Priority[g]	Source	Priority[h]	Source	% of Cases in 5 yrs[i]	Highest association[j]		
Turf, Granule	Handler	DPR Scenario 27	No	High	Low	Medium	Yes	Low (< 10% of use)	2010-2014 PUR					No	Medium
Pet, Spray	Applicator, home user	EPA C-113	Yes (gloves)	High	Low	Medium	No			Low	Internal database, 2015	7% (1 / 15)	Probable	Yes	High
	Applicator, groomer	EPA C-113	Yes (gloves)	High	Low	Medium								Yes[l]	High
Pet, Spot-on	Applicator, home user	EPA C-130	No	High	Low	Medium	No			Low[k]	Internal database, 2015	27% (4 / 15)	Definite	Yes	High
	Applicator, groomer	EPA C-130	No	High	Low	Medium								Yes	High
Structural, Dust	Applicator	EPA C-32	No	High	Low	Medium	Yes	Low (< 10% of use)	2010-2014 PUR			7% (1 / 15)	Possible	No	Medium
Structural, Liquid concentrate	Handler	DPR Scenario 23	No	High	Medium	High	Yes	High (> 90% of use)	2010-2014 PUR			7% (1 / 15)	Possible	No	High
Structural, Bait gel	Applicator	EPA 7-4	No	Low	Low	Low	No			Low	Internal database, 2015			No	Low
Structural, Bait station	Applicator	EPA 7-4	No	Low	Low	Low	No			Low	Internal database, 2015			No	Low

a: Two reference was used to determine exposure estimate: DPR, which represents DPR Memo HS-1826 (http://www.cdpr.ca.gov/docs/whs/pdf/hs1826.pdf), and EPA, which represents US EPA Standard Operation Procedure (SOP) for Residential Pesticide Exposure Assessment (https://www.epa.gov/sites/production/files/2015-08/documents/usepa-opp-hed_residential_sops_oct2012.pdf).

b: Exposure estimates provided in DPR and US EPA SOPs include description of PPE used (i.e., default PPE) when the exposure estimates were obtained. If the actual PPE of this specific scenario and specific pesticide is different from the default PPE, the exposure estimate will be lower (for actual PPE is more protective than default PPE) or higher (for actual PPE is less protective than default PPE) than default that with default PPE.

c: Exposure estimate of >5000, 500-5000 and <500 µg/lb active ingredient was categorized as "High", "Medium" or "Low" respectively.

d: "High" represents handling of >100 ac area or >100 gallons of finished solution; "Medium" represents handling of 1-100 ac area or 1-100 gallons of finished solution; "Low" represents handling of <1 ac area or <1 gallon of finished solution.

e: Preliminary decision was made based on "Exposure estimate" and "Amount handled" (DPR, 2017).

f: If yes (i.e., products with use restricted to licensed applicators), use “PUR data"; If no (i.e., use of products not restricted to licensed applicators), use “Sales data”.

g: High, Medium or Low is assigned to a category that account for >50%, 10-50% or <10% use of the active ingredient. A "High" in "PUR data" will increase "Final priority decision" from "Preliminary priority decision” by one level.

h: High, Medium or Low was assigned to a category that account for >50%, 10-50%, or <10% sale of the active ingredient. A "High" in "Sales data" will increase "Final priority decision" from "Preliminary decision on exposure priority" by one level.

i: Intentional pesticide ingestion (e.g., suicide commitment) and any other illegal exposure are suggested to be removed. The percentage sum of “% of cases” may not equal to 100% because some illness cases were not possible to determine the exposure scenario.

j: Observation of California PISP case(s) with "Definite" or "Probable" association will increase "Final decision on exposure priority" by one level.

k: Pet groomer handlers more pets per day than pet owner. Therefore, even though use and illness evidence did not suggest adjustments, the groomer exposure scenario was given the same priority decision as the pet owner scenario.

Table 6. Fipronil post-application exposure scenarios

Category	Human receptor	Exposure based evidence					Use and illness based adjustment								Final priority decision
		Transfer coefficient			Child involved?[d]	Preliminary priority decision[e]	Use restricted to licensed applicator?[f]	PUR data (Licensed Use)		Sales data (if exempt from PUR)		Illnesses within CA (CalPISP)[i]		Increase from preliminary decision?	
		Source of transfer coefficient[a]	Transfer coefficient[b]	Exposure duration[c]				Priority[g]	Source	Priority[h]	Source	% of Cases in 5 yrs[i]	Highest Association[j]		
Turf, Granule	Reentry, Adult	EPA 3-9	High	Medium	No	High	Yes	Low (< 10% of use)	2010-2014 PUR					No	High
	Reentry, Child	EPA 3-9	High	Medium	Yes	High								No	High
Pet, Spray	Reentry, Adult	EPA 8-7	High	Low	No	Medium	No			Low	Internal database, 2015			No	Medium
	Reentry, Child	EPA 8-7	Medium	Medium	Yes	High						13% (2 / 15)	Probable	Yes	High
Pet, Spot-on	Reentry, Adult	EPA 8-7	High	Low	No	Medium	No			Low	Internal database, 2015			No	Medium
	Reentry, Child	EPA 8-7	Medium	Medium	Yes	High						20% (3 / 15)	Probable	Yes	High
Structural, Dust	Reentry, Adult	Professional judgement	Low	Low	No	Low	Yes	Low (< 10% of use)	2010-2014 PUR			13% (2 / 15)	Probable	Yes	Medium
	Reentry, Child	Professional judgement	Low	Low	Yes	Medium								No	Medium
Structural, Liquid concentrate	Reentry, Adult	EPA 7-24[k]	High	Low	No	Medium	Yes	High (> 90% of use)	2010-2014 PUR			40% (6 / 15)	Probable	Yes	High
	Reentry, Child	EPA 7-24	Medium	Low	Yes	High								No	High
Structural, Bait gel	Reentry, Adult	EPA 7-24	High	Medium	No	High	No			Low	Internal database, 2015			No	High
	Reentry, Child	EPA 7-24	Medium	Medium	Yes	High								No	High
Structural, Bait station	Reentry, Adult	Professional judgement	Low	Low	No	Low	No			Low	Internal database, 2015	7% (1 / 15)	Possible	No	Low
	Reentry, Child	Professional judgement	Low	Low	Yes	Low								No	Low
Public	Swimmer, Adult	N/A	N/A	N/A	No	Low[l]								No	Low
	Swimmer, Child	N/A	N/A	N/A	Yes	Low								No	Low

a: Transfer coefficient was obtained primarily from US EPA Standard Operation Procedure for Residential Pesticide Exposure Assessment (https://www.epa.gov/sites/production/files/2015-08/documents/usepa-opp-hed_residential_sops_oct2012.pdf).

b: Transfer coefficient of >5000, 1000-5000, and <1000 cm^2/hr was respectively categorized as "High", "Medium" and "Low".

c: Exposure time of >4, 1-4 and <1 h was respectively categorized as "High", "Medium" and "Low".

d: If the human receptor is a child/toddler, the preliminary priority decision will be increased by one level from the decision based on transfer coefficient and exposure duration (e.g., increase from "Medium" to "High"). The only exception is when the pesticide is in a closed container, such as bait station.

e: Preliminary decision was made based on both "Transfer coefficient" and "Amount handled" (DPR, 2017).

f: If yes (i.e., products with use restricted to licensed applicators), use “PUR data"; If no (i.e., use of products not restricted to licensed applicators), use “Sales data”.

g: High, Medium or Low is assigned to a category that account for >50%, 10-50% or <10% use of the active ingredient. A "High" in "PUR data" will increase "Final priority decision" from "Preliminary priority decision" by one level.

h: High, Medium or Low was assigned to a category that account for >50%, 10-50%, or <10% sale of the active ingredient. A "High" in "Sales data" will increase "Final priority decision" from "Preliminary priority decision" by one level.

i: Intentional pesticide ingestion (e.g., intentional harm or suicide) and any other illegal exposure are suggested to be removed. The percentage sum of “% of cases” may not equal to 100% because some illness cases were not possible to determine the exposure scenario.

j: Observation of California PISP case(s) with "Definite" or "Probable" association will increase "Final priority decision" from "Preliminary priority decision" by one level.

k: No reference is available. Indoor hard surface was used as surrogate. The exposure duration was determined as low because of less time spent in outdoor areas than indoor areas.

l: Swimmer exposure will be categorized as "High" or "Low" based on whether this pesticide is allowed to be applied directly to natural water bodies. Also the child swimmer scenario shares the same exposure routes (dermal and oral) as the adult swimmer, so the child exposure scenario will not be designated as a higher priority.

Table 7. Preliminary assessment of short-term swimmer exposures to fipronil

Human receptor	Oral (µg/kg/d)	Inhalation (µg/kg/d)	Dermal (µg/kg/d)
Child, 7-10 yrs old	2.28	0.015	0.47
Child, 11-14 yrs old	0.86	0.0056	0.25
Adult	0.48	0.0013	0.35

All the exposures were assessed using default values and equations provided in the SWIMODEL (US EPA, 2003). The fipronil concentration was assumed to be 0.275 ppb, which is the same as used in the short-term drinking water assessment.

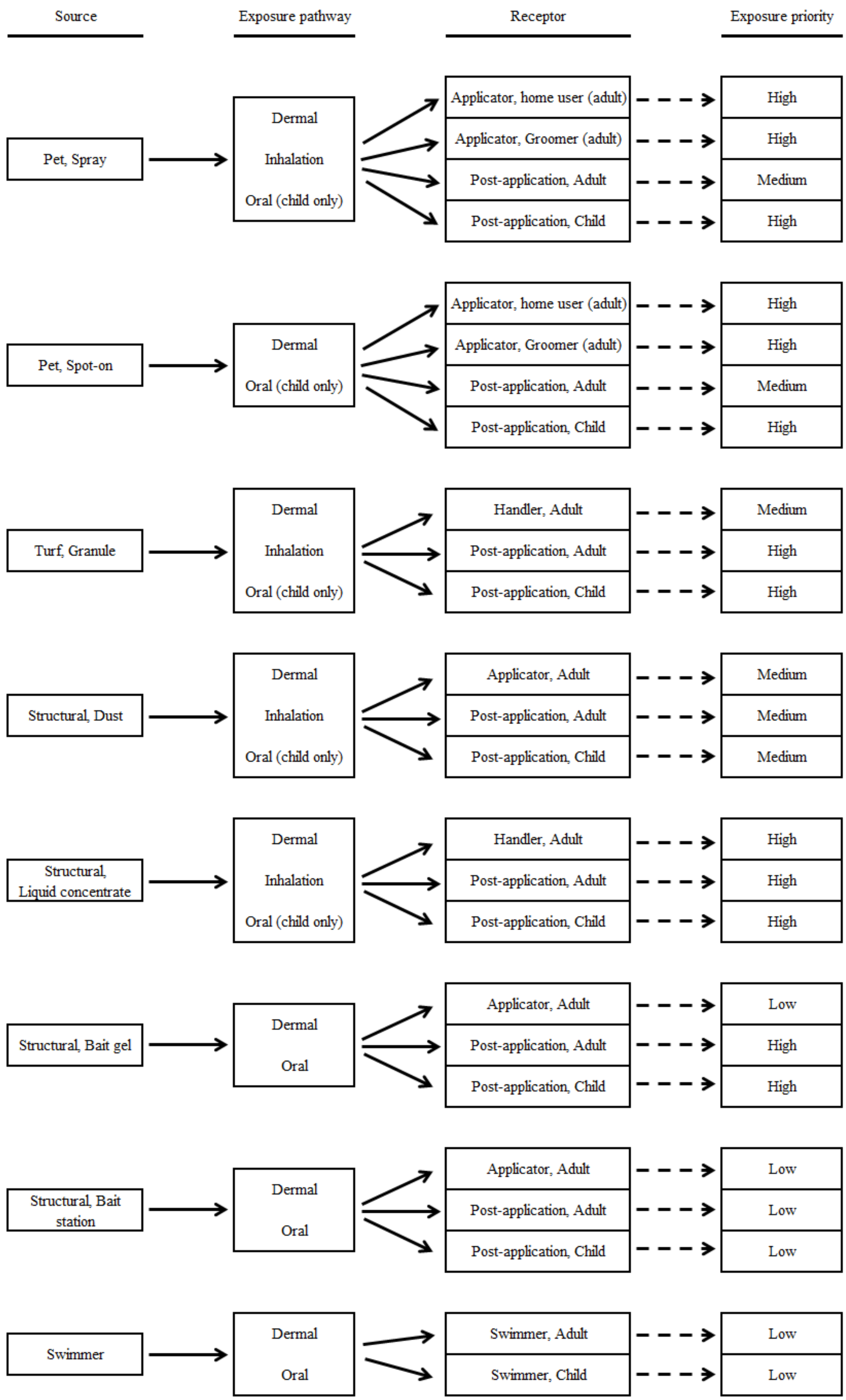

Figure 5. Conceptual models for fipronil exposure scenarios

IV. EXPOSURE ASSESSMENT

A. Exposure duration

Handler and post-application scenarios are assessed for short-, intermediate- and long-term exposures. Short-term exposure, expressed as short-term absorbed daily dose (STADD), represents the highest exposure an individual may realistically experience while performing a label-permitted activity. An upper-bound estimate (e.g., the estimated 95th percentile of exposure) is used to calculate the daily exposure (Powell, 2002; Beauvais *et al.*, 2007; Kwok, 2017). In addition, for post-application STADD, this assessment assumes a human subject (adult or child) enters the treated areas or contacts the treated objects immediately after the expiration of the "no-contact" post-application interval as specified on the product label. Intermediate-term exposure is assessed using seasonal average daily dose (SADD), and long-term exposure is assessed using annual average daily dose (AADD) and lifetime average daily dose (LADD). For SADD, AADD and LADD, the average daily exposure instead of the upper-bound estimate is used, assuming for an extended period, continuous daily exposure at the "upper-bound" level is unlikely and average daily exposure is received (Kwok, 2017).

B. Absorption rate

Dermal. Dermal absorption factor (DAF) of fipronil (i.e., 4.3%) was derived by Thongsinthusak (1999) based on a registrant submitted study (Cheng, 1995; Thongsinthusak, 1999). This DAF of 4.3% is used in this document.

Inhalation. Absorption rate of fipronil through inhalation is not available. When no inhalation absorption rate estimate is available, this assessment uses a default rate of 100% (Frank, 2008).

Oral. This document uses 100% as the fipronil oral absorption rate, which is the same as determined in the RCD.

C. Structural LC products

These are concentrated formulations used by licensed applicators for both pre- and post-construction pest controls. Fipronil content in these products is 9.1%. Unlike other fipronil products, structural LC products need to be diluted to the desired concentration (e.g., 0.06%, 0.09% or 0.125%) before application. The product labels do not specify the application frequency, but the Pest Control Operators of California (PCOC) indicates the typical above-ground perimeter application is twice per year per product, but more than two applications per year are possible if multiple products are used (Van Steenwyk, 2016).

Handler. Handlers apply structural LC products in both pre- and post-construction stages to control termites. During pre-construction treatments (i.e., construction phases prior to the final grade installation), diluted LC products may be applied beneath concrete slabs, in trenches along foundation walls, or to achieve a thorough horizontal and vertical barrier around the structural site. Structural LC products are also applied during the post-construction phase to protect the structure from termite infestation or to control existing termite populations through trenching around the foundation or drilling and injecting at areas where trenching is not permissible (e.g., surface with concrete pavement). In California, LC products are also used on outdoor surfaces and along structural foundation perimeters to control other home invasive pests, especially ants. PPE required on the product labels include long-sleeve shirt, long pants, socks, shoes, and chemical-resistant gloves. A respirator is also required if the handler works in a non-ventilated space such as crawl space and basement. The handler exposure for a licensed applicator was categorized as High priority in the Problem Formulation Document, and this assessment evaluated exposures from both dermal contact and inhalation (DPR, 2017).

A registrant submitted study monitored fipronil handler inhalation exposure during the application of the structural LC product Termidor® 80 WG (Honeycutt and Kennedy, 2001). However, the submitted study lacked critical information for use in handler exposure calculations including information on the amount of fipronil applied by each handler. This study specified the application rates at 4 gallons finished solution per 10 linear feet on outer and interior walls and 2 gallons finished solution per 10 linear feet injected into foundation walls. However, the treated lengths of outer, interior, and foundation walls were not reported. Therefore, it was difficult to calculate the normalized exposure rate based on the amount of fipronil handled. In addition, this study used a product called Termidor® 80 WG, a dry powder formulation sealed in a water soluble package which is not registered in California. Termidor® 80 WG is expected to have lower handler exposure than a fipronil LC product, as the formulation is securely sealed in a water-soluble bag and less likely to contact with a handler. Lastly, this study did not monitor handler dermal exposure.

Accordingly, the handler exposure was assessed using Pesticide Handlers Exposure Database (PHED) Scenario 22: Low pressure handwand mixer/loader/applicator (M/L/A) using liquid formulation (open pour) (Beauvais *et al.*, 2007). PPE of pesticide handlers in this scenario include long pants, long-sleeve shirt, and gloves, which are the same as the PPE requirements on fipronil structural LC product labels.

This assessment assumed each handler prepares and applies 40 gallons of the finished solution, which is the default pesticide volume that a low-pressure handwand M/L/A handles during a work day (US EPA, 2001). Fipronil concentration in the finished solution was assumed at 0.125%, which was the highest rate instructed on product labels. With the information above, the calculated dermal and inhalation STADDs are summarized in Table 8.

Table 8. Inhalation and dermal fipronil exposure for handlers applying structural LC products

Exposure pathway	STADD[a] (μg/kg/d)	SADD[b] (μg/kg/d)	AADD[c] (μg/kg/d)	LADD[d] (μg/kg/d)
Dermal contact	1.4	0.49	0.28	0.15
Inhalation	0.53	0.19	0.11	0.059

a: short-term absorbed daily dose (STADD) = exposure (88.9 and 5271 μg/lb for inhalation and dermal respectively) × fipronil handled (0.42 lb/d) × absorption rate (0.043 for dermal and 1 for inhalation) ÷ body weight (70kg)
b: seasonal average daily dose (SADD) = exposure (31.9 and 1895 μg/lb for inhalation and dermal respectively) × fipronil handled (0.42 lb/d) × absorption rate (0.043 for dermal and 1 for inhalation) ÷ body weight (70kg)
c: annual average daily dose (AADD) = SADD × annual use months (7, April-October) ÷ 12
d: lifetime average daily dose (LADD) = AADD × 40 years of work in a lifetime ÷ 75

During the problem formulation phase, DPR invited all stakeholders to provide input relevant to fipronil risk assessment, including why and how fipronil is used in California and potential exposure scenarios. PCOC responded to the DPR request by describing an application of fipronil SC products to overhead spaces, such as under the eaves, that may result in high fipronil exposure (Van Steenwyk, 2016).

Handler fipronil exposure from overhead application may be higher due to aerosols generated from the spray. After reviewing relevant studies, no appropriate data was found to establish the assumptions for a structural overhead scenario. Therefore, the handler scenario for tree application was used as a surrogate. Fipronil is not registered for tree applications, so this assessment used a study that measured handler exposure during application of carbaryl to trees using hand-held pump (Merricks, 1998). The US EPA SOP for tree handler exposure assessment uses the same data set, and this assessment also considered this study as the best information available for this scenario (US EPA, 2012).

In Merricks (1998), 20 non-professional volunteers were recruited and asked to mix, load, and apply a carbaryl liquid concentrate product to citrus (around 8 ft tall) and ornamental (around 4 ft tall) trees. The volunteers were suited in long-sleeve shirts and long pants as working apparel. They also wore another set of long-sleeve shirts and long pants beneath the working apparel as dermal dosimeters to monitor carbaryl exposure on the body, legs and arms. Face/neck wipe and handwash samples were taken as well to monitor the exposure on face/neck and hands. This study also monitored inhalation exposure by attaching a personal air sampling pump set to 2 liters per minute (LPM) to each volunteer. The sampled air from the breathing zone was pumped through XAD-2 sorbent tubes and analyzed for fipronil.

This assessment used the raw data available in the data volume rather than the results summarized and reported by the investigator. First, handlers in this study did not wear gloves, while the fipronil LC product label requires gloves for handlers. Therefore, the monitored hand exposure was adjusted assuming gloves provided 90% exposure reduction. Second, the calculated 95th percentile exposure rates were smaller than the highest monitored values, thus the latter was used for STADD calculations (Table 9) (Frank, 2009). As above, it was assumed that each handler applied 40 gallons of a 0.125% solution per day. A statistical summary of dermal and inhalation exposure rates is shown in Table 9 and the calculated exposure is provided in Table 10.

Table 9. Dermal and inhalation exposure rates (µg/g) for handlers who mix, load, and apply carbaryl pesticides to trees using hand-held pump[a]

	Dermal									Inhalation[b]
	Forearm	Upper arm	Front torso	Back torso	Lower leg	Upper leg	Hand	Face/Neck	Total	
Mean	0.57	0.064	0.23	0.075	0.096	0.15	9.9	0.19	11	0.024
STD[c]	0.51	0.0086	0.43	0.032	0.092	0.13	12	0.46	12	0.014
Max.[d]	2.0	0.087	2.1	0.17	0.46	0.58	53	2.2	54	0.063
95th percentile[e]	2.1	0.078	0.53	0.12	0.19	0.36	25	0.38	28	0.045

a: The raw data is from Merricks (1998);

b: breathing rate at 1.6 m^3/h;

c: standard deviation;

d: 95th percentile value was calculated based on the method described elsewhere (Frank, 2009). Shapiro-Wilk test was performed to confirm the log-normal distribution of measured dermal exposure data. This test was not performed for the inhalation data as most of the data (13 out of 20) were below the detection limit. Inhalation exposures were much lower than dermal exposures.

Table 10. Inhalation and dermal fipronil exposure for handlers applying structural LC products to overhead areas

Exposure pathway	STADD[a] (µg/kg/d)	SADD[b] (µg/kg/d)	AADD[c] (µg/kg/d)	LADD[d] (µg/kg/d)
Dermal contact	6.3	1.3	0.74	0.40
Inhalation	0.17	0.064	0.037	0.020

a: short-term absorbed daily dose (STADD) = exposure (28 and 24642 µg/lb for inhalation and dermal respectively) × fipronil handled (0.42 lb/d) × absorption rate (0.043 for dermal and 1 for inhalation) ÷ body weight (70kg);

b: seasonal absorbed SADD = exposure (11 and 5092 µg/lb for inhalation and dermal respectively) × fipronil handled (0.42 lb/d) × absorption rate (0.043 for dermal and 1 for inhalation) ÷ body weight (70kg);

c: annual average daily dose (AADD) = SADD × annual use months (7, April-October) ÷ 12;

d: lifetime average daily dose (LADD) = AADD × 40 years of work in a lifetime ÷ 75.

Post-application, resident. This scenario estimates exposure of either an adult or child resident entering a treated structure. Product labels state that contact with contaminated areas is prohibited. The labels also state that residents should not enter a treated structure before cleanup is completed and the spray is dried. However, there is no clear "restricted entry interval (REI)-equivalent" language on product labels. This assessment assumes a resident enters the treated structure immediately after the application is complete. For adults, this assessment evaluated exposure from dermal contact and inhalation, and for children, exposures from dermal contact, inhalation, and incidental oral ingestion were assessed. In the Problem Formulation document, the post-application exposure was categorized as High priority for both adults and children.

Post-application inhalation exposure occurs while aerosols from spraying remain in the air after application. Therefore, the highest air concentration is expected shortly after the application. Only one registrant submitted study measured post-application fipronil air concentrations (Honeycutt and Kennedy, 2001). This study treated 16 houses in nine US states for termites. These houses have a range of characteristics, including size, floor number, foundation type, and were treated with solutions containing varying percentages of fipronil (Table 11). The applied product was Termidor® 80 WG, which is a dry powder formulation sealed in a water soluble package. The product is applied by diluting into water. The application rate of the spraying solution was 4 gallons finished solution per 10 linear feet on outer and interior walls and 2 gallons finished solution per 10 linear feet injected into foundation walls.

Fipronil indoor air concentrations were monitored by placing sampling equipment in the kitchen, den, and bedroom. The sampling equipment consisted of an air pump run at 2.0 LPM and an attached XAD air sorbent tube positioned approximately 2 ft above the floor. Air sampling started immediately after fipronil application started and continued for 24 hours. Duplicate samples were collected in each room. A statistical summary of the highest concentration found in each house is provided in Table 12. For post-application exposure, this document used the highest measured 24-h time weighted average (TWA) concentration and assumed a breathing rate of 0.59 and 0.28 m3/kg/d for child and adult respectively (Andrews, 2000). Calculated inhalation STADD and SADD values for adult and child are summarized in Table 13.

Table 11. Characteristics of houses treated with Termidor® 80 WG

House No.	App. month[a]	Base. type[b]	State located	Story[c]	Size (sq. ft.)	Linear ft. treated[d]	% Fipronil[e]	App. psi[f]
1	May	BA	KY	2	3193	363	0.08	25
2	June	CS	NC	2	2402	498	0.08	10-15
3	Jun.	CS	NC	2	2637	460	0.07	10-15
4	Jun.	CS	NC	N/A[g]	N/A	344	0.07-0.08	~25
5	Jun.	CS	NC	1	2048	360	0.07-0.08	15
6	Jun.	BA	MO	1	2280	443	0.08	50
7	Jul.	BA	NY	2	1586	420	0.05	25
8	Jul.	CS	SC	1	1164[h]	142	0.08	30-40
13	Aug.	SL	FL	N/A[i]	N/A	440[j]	0.08	40
14	Aug.	SL	FL	N/A	N/A	440	0.08	40
15	Aug.	SL	FL	N/A	N/A	440	0.08	40
16	Aug.	SL	FL	N/A	N/A	440	0.08	40
17	Aug.	SL	LA	N/A[g]	N/A	142	0.125	50-70
25	Nov.	BA	KY	1	4114	312	0.08	60
26	Nov.	BA	KY	1	1320[d]	NR[j]	0.08	100
27	Dec.	BA	VA	N/A[g]	N/A	300	0.08	60

Data was summarized from Honeycutt and Kennedy (2001); a: application month; b: basement type, including full basement (BA), crawl space (CS) and slab (SL); c: information on house story number and size was obtained from public realtor website and may not be accurate; d: fipronil percent in the finished solution; e: application pressure (psi); f: Not available, this location could not be found; g: The information on story and size may not be accurate, as the zip code does not match; h: Houses 13-16 are apartments in the same community and the house information is unknown; i: This includes entire building treatment and House 13-16 are individual units within this building; j: not recorded.

Table 12. Statistical summary of indoor air fipronil concentrations

	24-h TWA concentration (ng/L)
Mean	0.021
Standard Deviation	0.020
Minimum	< 25 ng per sample[a]
Maximum	0.081
95th percentile[b]	0.049

Data was summarized from Honeycutt and Kennedy (2001).
a: The volume of air pumped varied among samples. This is approximately 0.0087 ng/L;
b: 95th percentile value was calculated based on the method described elsewhere (Frank, 2009). Shapiro-Wilk test was performed to confirm the data followed log-normal distribution.

Table 13. Fipronil inhalation exposure in a post-application indoor environment

Human receptor	Exposure pathway	STADD[a] (µg/kg/d)	SADD[b] (µg/kg/d)
Adult	Inhalation	0.023	0.0056
Child	Inhalation	0.048	0.012

a: short-term absorbed daily dose (STADD) = maximum 24-h TWA concentration (0.081 ng/L) × inhalation rate (0.59 and 0.28 m^3/kg/d for child and adult respectively);
b: seasonal average daily dose (SADD) = average 24-h TWA concentration (0.020 ng/L) × inhalation rate (0.59 and 0.28 m^3/kg/d for child and adult respectively).

This assessment assumes that fipronil from treated outdoor areas may be transferred onto indoor surfaces through spray drift and deposition, by wind, by tracking indoors. Post-application dermal and oral exposure occurs when a resident is in contact with fipronil contaminated indoor surfaces. No data on indoor deposition of fipronil following outdoor treatments with structural LC product was found in either registrant submitted studies or in open literature. In addition, no study has measured fipronil occurrence in indoor areas in California. Instead, this assessment used a study conducted by US Geological Survey (USGS) in Austin, TX as it is considered as the best information available (Mahler *et al.*, 2009).

The USGS study collected dust samples from 24 apartments using a high-volume surface sampler. Eighteen of the 24 sampled surfaces were carpeted and 16 surfaces were hard floor (concrete, wood, linoleum or tile). The collected dust was analyzed for fipronil and two degradates, i.e., fipronil desulfinyl and fipronil sulfone.

The raw data was obtained from the author by permission and further analyzed. The USGS study did not collect information on the number of days that elapsed between fipronil treatments and the sampling. Therefore, for purposes of this assessment, HHA assumed all fipronil degradates were formed from the same application event and the total concentration of all three fipronil compounds (parent fipronil and two measured degradates) was used to represent the maximum amount of fipronil deposited on indoor surfaces. Second, the USGS study fractionated the collected dust and analyzed the <0.05 mm fraction. To extrapolate the total surface concentration, it was assumed all particles had the same fipronil concentration. Third, the measured fipronil amount was divided by the surface area sampled to calculate the surface area-normalized concentration. A statistical summary of the recalculated data is provided in Table 14.

Table 14. Statistical summary of total fipronil compound concentrations on indoor surfaces[a]

	Concentration of total fipronil[b] (µg/cm^2)
Mean	0.0011
Maximum	0.013
95th percentile[c]	0.020

a: Raw data is cited from Mahler et al. (2009);
b: Total concentration of fipronil and 2 measured degradates;
c: 95th percentile value was calculated based on the method described elsewhere (Frank, 2009). Shapiro-Wilk test was performed to confirm the data followed log-normal distribution.

Dermal and oral exposure was assessed following the US EPA SOP (US EPA, 2012) and the maximum concentration in Table 14 was used for the calculations (Frank, 2009). Calculated STADDs and SADDs are summarized in Table 15.

Table 15. Post-application dermal and oral exposure from fipronil in indoor space

Human receptor	Exposure pathway	STADD[a] (µg/kg/d)	SADD[b] (µg/kg/d)
Adult	Dermal contact[c]	0.026	0.0022
Child	Dermal contact	0.018	0.0016
	Oral, hand-to-mouth[d]	0.064	0.0055
	Oral, object-to-mouth	0.0086	0.00073
	Incidental Oral, total	0.073	0.0062

a: short-term absorbed daily dose (STADD) was calculated using the maximum value of fipronil on indoor space in Table 14;
b: seasonal average daily dose (SADD) was calculated using the mean value of fipronil on indoor space in Table 14;
c: STADD and SADD (dermal) = fipronil concentration (0.013 and 0.0011 µg/cm^2 for STADD and SADD respectively) × transferable fraction (0.06) × transfer coefficient (6800 and 1800 cm^2/hr for adult and child respectively) × exposure time (8 and 4 hr for adult and child respectively) × dermal absorption rate (0.043) ÷ body weight (70 and 13 kg for adult and child respectively);
d: STADD and SADD (oral, hand-to-mouth and object-to-mouth) calculation equations can be found on US EPA SOP page 7-39 and 7-44 (US EPA, 2012).

D. Pet spray products

Fipronil spray products are used by both professional groomers and home users to treat ticks and fleas on dogs and cats. The products are packaged in aerosol or triggered spray cans. The fipronil concentration is 0.29%. For products in trigger spray cans, labels suggest one to two pumps per pound of dog and/or cat body weight. For products in aerosol cans, labels suggest spraying one to two seconds per pound of dog and/or cat body weight (pets with long or dense coats may need a higher application rate). The label language directs that dog or cat head and eye areas should be treated by spraying the product onto a gloved hand and then rubbing the product into the hair. The spray product labels suggest monthly application for effective tick/flea controls. The only PPE required on the product labels is gloves (e.g., latex or rubber gloves).

Applicator, pet groomer. Professional groomers, including commercial and veterinary groomers, were selected as the representative of frequent fipronil handlers. Professional groomers treat dogs and/or cats on a daily basis and handle more pets than pet owners. Their fipronil exposure was categorized as High priority in the Problem Formulation document. This assessment evaluated exposures from both inhalation and dermal contact (US EPA, 2012).

Only one registrant submitted study measured dermal and inhalation exposure of professional groomers from using fipronil spray products (Meo *et al.*, 1997b). This study recruited sixteen groomers and each groomer treated eight dogs (except one groomer that treated nine dogs) using Frontline® spray. The groomers followed the label instructions by applying two pumps (~3 mL) of the product per pound of the dogs. The amount of fipronil used by each groomer was estimated by counting the number of pumps of the product applied (Table 16). All the groomers in this study wore latex gloves, short-sleeved cotton shirt, long-cotton pants, long-sleeved ribbed cuff smock, socks and shoes.

Each groomer was asked to wear a long whole-body suit as the dosimeter to monitor body dermal exposure. The suit was worn underneath the work clothing and PPE, but over the undergarments. Hand exposure was measured by asking each groomer to wear a pair of cotton gloves underneath the latex gloves when treating dogs. Face and neck exposure was measured by wiping the groomer's face and neck with ethanol cloth patches after the dog treatment.

Inhalation exposure was monitored by attaching an air-sampling pump to each groomer and the pump ran at 1.5 LPM during the entire dog treatment period. The pump was attached to a cassette that contained a glass fiber filter (1 μm pore size) and a cellulose support pad to retain fipronil in aerosol phase, and a Chromosorb 102 tube to retain fipronil in vapor phase.

This assessment used raw data provided in the report appendix, and made numerical adjustments to account for work apparel differences between this study and requirements on fipronil product labels. This study used a whole-body suit as the dermal dosimeter and each groomer also wore a long-sleeved smock, a short-sleeved shirt and long pants over the suit. The groomers also wore latex gloves over the cotton gloves that were used to monitor hand exposure. These PPE and apparel are not required by the label and, so, are not required to be used by the groomers in California. A registrant submitted survey showed professional groomers often do not wear a uniform or PPE (other than gloves) while treating dogs and/or cats (Irwin, 1997). This assessment assumes the working apparel for groomers includes short-sleeved shirts and long pants. Calculated dermal exposure on different body parts assumes that one layer of clothes provides a 90% exposure reduction. A statistical summary of the re-calculated dermal and inhalation exposure measures is provided in Table 17.

Table 16. Time and total amount of fipronil used by individual professional groomers when treating dogs using Frontline® spray[a]

Groomer No.	Length of treatment (min)	Dog weight[b] (lbs)	Fipronil applied (mg)
1	52	39 (7-70)	1505
2	55	23 (6-67)	1077
3	48	29 (12-70)	1483
4	49	28 (8-72)	1581
5	70	31 (11-75)	2118
6[c]	68	57 (13-122)	2907
7	59	28 (5-86)	1657
8	48	18 (11-33)	1147
9	60	25 (7-48)	1643
10	48	45 (12-78)	2959
11	63	25 (7-37)	1717
12	49	21 (12-45)	1115
13	49	28 (8-46)	1484
14	61	36 (13-75)	2389
15	38	21 (7-45)	859
16	72	58 (13-89)	2733

a: The raw data is cited from Meo et al. (1997b);
b: mean (minimum-maximum);
c: this groomer treated nine dogs.

Table 17. Dermal and inhalation exposure (μg/g) of professional groomers who used a pet spray product to treat dogs[a]

	Dermal[b]								Inhalation[c]		
	Forearm	Upper arm	Chest	Back	Lower body	Face/Neck	Hand	Total	Aerosol	Vapor	Total
Mean	6740	902	259	7.0	105	4.1	8.3	8024	9.5	0.84	10
STD[d]	6350	1331	430	4.2	367	3.1	10	6611	7.6	0.49	7.6
Max.[e]	25840	4457	1735	15	1527	10	34	26347	29	2.3	30
95th percentile[f]	27629	5555	1305	16	158	13	31	31788	32	1.7	33

a: The raw data is obtained from Meo et al. (1997b);
b: Exposure on forearm, upper arm, chest, back and lower body was multiplied by 10 as one extra layer of work apparel was used in the study and the protection factor was assumed at 90%;
c: breathing rate at 1.6 m^3/h;
d: standard deviation;
e: maximum;
f: 95^{th} percentile value was calculated based on the method described elsewhere (Frank, 2009). Shapiro-Wilk test was performed to confirm both dermal and inhalation data followed log-normal distribution.

The amount of fipronil applied daily depends on the number of dogs and/or cats treated by a groomer and the size of treated dogs and/or cats. A registrant submitted survey indicates that a commercial groomer treats an average of 9.62 dogs and/or cats per day, and a veterinary groomer treats an average of 4.1 dogs and/or cats per day (Irwin, 1997). This assessment assumed a pet groomer treats 10 dogs per day. This assessment also assumed the number of small (14 lbs), medium (33 lbs) and large (66 lbs) dogs treated is four, three, and three respectively, which is based on a national survey conducted by American Veterinary Medical Association (AVMA) in 2012. Results from that survey showed that 39.2%, 33.4 % and 27.3 % of US dogs are in small, medium and large size, respectively (AVMA, 2012). The calculated dermal and inhalation exposure are summarized in Table 18.

Table 18. Dermal and inhalation exposure for pet groomers using a spray product

Exposure pathway	STADD[a] (µg/kg/d)	SADD[b] (µg/kg/d)	AADD[c] (µg/kg/d)	LADD[d] (µg/kg/d)
Dermal contact	52	13	13	6.9
Inhalation	1.3	0.39	0.39	0.21

a: short-term absorbed daily dose (STADD) = exposure (33 and 31788 µg/g for inhalation and dermal respectively) × fipronil handled (2.6 g/d) × absorption rate (0.043 for dermal and 1 for inhalation) ÷ body weight (70kg);
b: seasonal average daily dose (SADD) = exposure (10 and 8024 µg/g for inhalation and dermal respectively) × fipronil handled (2.6 g/d) × absorption rate (0.043 for dermal and 1 for inhalation) ÷ body weight (70kg);
c: annual average daily dose (AADD) is the same as SADD. There is no data to analyze use pattern of pet spray products over a year, so this assessment assumes year round use;
d: lifetime average daily dose (LADD) = AADD × 40 years of work in a lifetime ÷ 75.

Applicator, home user. Spray products can also be used by pet owners to treat their own dogs and/or cats. The exposure estimates, i.e., dermal and inhalation exposure per gram of fipronil handled, are expected similar to pet groomers, but the pet owner is assumed to treated fewer dogs and/or cats per day. In the Problem Formulation document, pet owner exposure as spray product handler is categorized as High priority (DPR, 2017).

This assessment used the same registrant study above to assess pet owner exposure (Meo et al., 1997b). This assessment assumes a pet owner has two dogs. This is based on the AVMA surveys which showed around 90% of pet-owning households only have one or two dogs/cats. (AVMA, 2012). The same surveys also showed the average number of dogs in dog-owning households in California is 1.6. This assessment assumes a pet owner treats two large size (66 lbs) dogs per month, and the calculated dermal and inhalation STADDs are summarized in Table 19. Only STADDs are calculated, as the pet owners are expected to use these products once per month as suggested on the labels.

Table 19. Dermal and inhalation exposure for a home user using a spray product

Exposure pathway	STADD (µg/kg/d)
Dermal contact	19
Inhalation	0.47

95th percentile values in Table 17 are used to calculate STADDs (Frank, 2009);
Short-term absorbed daily dose (STADD) = exposure (33 and 31788 µg/g for inhalation and dermal respectively) × fipronil handled (0.99 g/d) × absorption rate (0.043 for dermal and 1 for inhalation) ÷ body weight (70kg).

Post-application, resident. This is the exposure scenario for a pet owner, either an adult or a child, contacting dogs and/or cats treated with spray products. In the Problem Formulation document, the post-application exposure was categorized as Medium and High priority for adult and child, respectively, for this exposure scenario (DPR, 2017). For adults, this assessment evaluated post-application exposures from dermal contact, and for children, the assessed exposure pathways were dermal contact and incidental oral ingestion. Considering the low volatility of fipronil and the small amount applied for pet products, this assessment determined the post-application inhalation exposures were negligible. This agrees with US EPA guidelines. In addition, the latest US EPA fipronil risk assessment did not include post-application inhalation exposures from pet product use (US EPA, 2012; US EPA, 2020a).

Post-application exposure is determined by dislodgeable fipronil residue on treated dogs and/or cats that is readily transferable to humans. This assessment reviewed all four registrant submitted studies and used them to determine the dislodgeable fipronil residue (de Fontenay *et al.*, 1997a; de Fontenay *et al.*, 1997b; Hughes, 1997a; Hughes, 1997b). These four studies have similar study design and sampling strategies. In one study, six Beagle dogs were weighed and treated with Frontline® spray (fipronil content: 0.29%, w/w) at the label rate (i.e., 6 ml/kg dog weight) (de Fontenay *et al.*, 1997a). After treatment, the study investigator wore a cotton glove and petted the whole-body surface of the dog with the glove-wearing hand by stroking five times from the head to the tail, i.e., one stroke each on the back, right and left flank, and right and left side of the ventral zone. Total mass of fipronil collected on the glove was measured as the dislodgeable fipronil residue on the dog. The same dogs were petted in the same way at different post-treatment intervals, i.e., 0 d (before treatment), 1 hour, 4 hours, 8 hours, and post-application days 1, 2, 4, 7, 14, 21, and 28 to determine the dissipation of dislodgeable fipronil residue.

A summary of findings from these four studies is provided in Table 20. In de Fontenay et al. (1997a), each dog was treated with 125,671 to 148,491 µg fipronil. At 1 h (the sampling interval closest to the treatment), the measured dislodgeable fipronil residue was 653–2674 µg, which is equivalent to 0.52–1.06 % of the application rate. The highest dislodgeable residue (1053–2674 µg or 0.83–2.06 % of application rate) was seen at 4 h following application of fipronil. Two fipronil degradates, i.e., fipronil sulfide and sulfone, were also detected on the gloves, but their total concentrations were <5% of fipronil at both 1 and 4 h post treatment.

The 95th percentile dislodgeable fipronil residue was calculated from these studies (Frank, 2009). The highest value was equivalent to 2.2% of the application rate (Table 20). This value is slightly higher than the default dislodgeable fraction of 2% application rate based on the US EPA SOP (US EPA, 2012). To estimate short-term exposures (STADDs), this assessment assumes 2.2% of the applied fipronil is available to transfer. It also assumes that the treated dog is large in size (66 lbs) and has the body surface area of 11000 cm^2. According to the US EPA SOP, a large-size dog has the largest body weight-surface area ratio and hence the highest transferable residue per dog surface area. For intermediate-term exposures (SADDs), this assessment used the same study from de Fontenay et al. (1997a) to calculate 7-day average fipronil residues (0.46 % of the applied fipronil) for the first week after the application. This 7-day average was calculated using the highest measured dislodgeable residue within the first day after application (Day 0) and the estimated daily residues for the following 6 days from fitting the measured values (i.e., measurements at 8 hr, and Day 1, 2, 4 and 7) into a first-order decay model. The rationale of adopting this computational approach is due to the biphasic decrease of dislodgeable fipronil residue observed within the first seven days, with a much faster decrease in Day 0 than in subsequent days. The calculated dermal and oral STADDs and SADDs are summarized in Table 21.

Table 20. Summary of fipronil dislodgeable residues on pets treated with pet spray products

Source	Dislodgeable fipronil residue[a]			Comment
	Range	Mean ± STD.[b]	95th percentile[c]	
de Fontenay et al., 1997a	0.83-2.06%	1.37±0.44 %	2.20%	Six Beagle dogs. Highest dislodgeable residues were seen at 4 h.
Hughes, 1997a	Short-haired: 0.44-1.37%	Short-haired: 0.84±0.36 %	Short-haired: 1.58 %	Five short-haired dogs. Highest dislodgeable residues were seen mostly at 12 h.
	Long-haired: 0.43-0.84%	Long-haired: 0.67±0.13 %	Long-haired: 0.95 %	Five long-haired dogs. Highest dislodgeable residues were seen mostly at 4 h.
de Fontenay et al., 1997b	0.49-0.91 %	0.68±0.15 %	0.95 %	Six cats. Highest dislodgeable residues were seen mostly at 4 h.
Hughes, 1997b	0.20-0.54 %	0.43±0.12 %	0.73 %	Five cats. Highest dislodgeable residues were seen mostly at 4 h.

a: expressed as % of the application rate;
b: mean ± standard deviation; c: 95th percentile value was calculated based on measured concentrations (Frank, 2009).

Table 21. Post-application dermal and oral exposure for pet spray products

Human receptor	Exposure pathway	STADD[a] (µg/kg/d)	SADD[b] (µg/kg/d)
Adult	Dermal contact[c]	2.4	0.51
Child	Dermal contact	4.6	0.96
	Oral, hand-to-mouth	1.1	0.22

a: short-term absorbed daily dose (STADD) was calculated using the maximum dislodgeable fipronil percentile (2.2%) in Table 20;
b: seasonal average daily dose (SADD)s were calculated using 7-day average dislodgeable fipronil percentile (0.46%) from de Fontenay et al., 1997a;
c: short-term absorbed daily dose (STADD) and SADD (dermal) = applied fipronil amount (495 mg) × dislodgeable fraction (0.022 and 0.0046 for STADD and SADD respectively) ÷ pet surface area (11000 cm^2) × transfer coefficient (5200 and 1400 cm^2/h for adult and child respectively) × exposure time (0.77 and 1 h for adult and child respectively) ÷ body weight (70 and 13 kg for adult and child respectively) × dermal absorption rate (0.043);
b: short-term absorbed daily dose (STADD) and SADD (oral, hand-to-mouth) calculation equations can be found on US EPA SOP page 8-12 (US EPA, 2012).

E. Pet spot-on products

Fipronil is also formulated as spot-on products and used by professional groomers and pet owners to treat dogs and/or cats. The products are contained in small pre-measured tubes and contain fipronil up to 9.8%. During each application, the applicator selects a tube volume appropriate to the pet weight and applies the entire tube contents onto the skin between the shoulder blades of the dog or cat (Table 22). The treated area should not be contacted until dry, and a dog or cat should not be treated more than once per month.

Table 22. Selection of tube size according to the treated pet size

Weight range	Tube size (mL)	Application rate (mg)
Cat	0.50	5.0
Dog, 5-22 lbs	0.67	6.7
Dog, 23-44 lbs	1.34	13.4
Dog, 45-88 lbs	2.68	26.8
Dog, 89-132 lbs	4.02	40.2

This chart is based on Frontline® Top Spot® for dogs and cats. The weight range, tube size, and application rates may be slightly different for other spot-on products.

Applicator, pet groomer. Professional groomers were selected as representative of frequent handlers of fipronil spot-on products. Their fipronil exposure was categorized as High priority in the Problem Formulation document. As the products are in liquid formulation and applied by squeezing a tube of contents onto a pet, the inhalation exposure is considered negligible (US EPA, 2012). This assessment only evaluated applicator exposure from dermal contact.

This assessment reviewed available data, including registrant submitted studies and open literature, and selected a registrant submitted study based on the data quality and completeness (Meo *et al.*, 1997a). This study measured dermal exposure of professional groomers during the application of fipronil spot-on product. Sixteen commercial pet groomers were recruited, and each groomer was asked to treat eight dogs using Frontline® Top Spot™. The working apparel and PPE of these groomers include long-cotton pants, long-sleeved smock, short-sleeved shirt, latex gloves, socks and shoes. The average amount of fipronil applied by each groomer during the day was 1047 mg fipronil, with a range of 670–1809 mg (Table 23).

Table 23. Time and total amount of fipronil used by individual professional groomer when treating dogs using Frontline® Top Spot™

Groomer	Length of treatment (min)	Fipronil applied (mg)	Weight range of treated dogs (lbs)
1	26	1072	7-79
2	25	938	8-83
3	32	1139	11-72
4	14	737	7-30
5	26	1474	13-96
6	21	737	9-50
7	21	1809	12-170
8	17	804	3-55
9	17	1139	12-115
10	17	670	8-37
11	22	938	11-75
12	19	871	8-62
13	17	871	6-71
14	17	1206	4-80
15	18	1139	13-75
16	15	1206	9-68

The raw data is cited from Meo et al., 1997a.

Dermal exposure was monitored using the same method described above for groomers using the spray product. Briefly, each groomer wore a long whole-body suit to monitor body exposure except for the face, neck and hands. The suit was worn underneath the work apparel, but over the undergarments. Hand exposure was measured by asking each groomer to wear a pair of cotton gloves underneath the latex gloves when treating dogs. Face and neck exposure was measured by wiping the groomer's face and neck with ethanol-wetted cotton patches after the dog treatment.

This assessment used the raw data provided in the appendix instead of the summary of results presented directly in the report. In this study, a whole-body suit was used as the dermal dosimeter and each groomer wore a long-sleeved smock, a short-sleeved shirt, and long pants over the suit. The cotton gloves were worn underneath latex gloves. However, long-sleeved smock and gloves are not required by the label and so, are not required to be used by the groomers in California. This assessment assumes the working apparel for groomers include short-sleeved shirt, long pants, socks and shoes, and recalculated the dermal exposure by assuming one layer of clothes provides 90% exposure reduction. A statistical summary of the re-calculated dermal exposure on different body parts are provided in Table 24.

As the maximum observed exposure value is greater than the estimated 95th percentile value, the maximum value in Table 24 was used to calculate the dermal exposure (Powell, 2002). Similar to the spray product, this assessment assumes a pet groomer treats 10 dogs per day, including four small-size (14 lbs) dogs, three medium-size (33 lbs) dogs and three large-size (66 lbs) dogs. Accordingly, the pet groomer uses four 0.67 mL tubes, three 1.34 mL tubes and three 2.68 mL tubes, and total applied fipronil is 1474 mg. The calculated dermal exposure is shown in Table 25.

Table 24. Dermal exposure of professional groomers who used a pet spot-on product to treat dogs

	Dermal[a] (µg/g)							
	Forearm	Upper arm	Chest	Back	Lower body	Face/ Neck	Hand	Total
Mean	130	157	383	14	8.1	14	80	787
STD[b]	251	430	1107	33	22	42	153	1270
Max.[c]	781	1693	4533	142	94	175	528	4591
95th %ile[d]	407	272	660	31	17.5	33.8	349.1	3379

The raw data is cited from Meo et al. (1997a);
a: exposure on forearm, upper arm, chest, back and lower body was multiplied by 10 as one extra layer of work apparel was used in the study and the protection factor was assumed at 90%;
b: standard deviation;
c: maximum;
d: estimated 95th percentile of the distribution of concentrations based upon measured concentrations (Frank, 2009). Shapiro-Wilk test was performed to confirm the dermal data followed log-normal distribution.

Table 25. Dermal exposure for groomers using pet spot-on products

Human receptor	Exposure pathway	STADD[a] (µg/kg/d)	SADD[b] (µg/kg/d)	AADD[c] (µg/kg/d)	LADD[d] (µg/kg/d)
Adult	Dermal contact	4.2	0.71	0.71	0.38

a: short-term absorbed daily dose (STADD) = exposure (4591 µg/g) × fipronil handled (1.5 g/d) × absorption rate (0.043) ÷ body weight (70kg);
b: seasonal average daily dose (SADD) = exposure (787 µg/g) × fipronil handled (1.5 g/d) × absorption rate (0.043) ÷ body weight (70kg);
c: annual average daily dose (AADD) is the same as SADD. There is no data to analyze use pattern of pet spot-on products over a year;
d: lifetime average daily dose (LADD) = AADD × 40 years of work in a lifetime ÷ 75.

Applicator, home user. Pet owners may use spot-on products to treat their own dogs and/or cats. Dermal exposure per gram of fipronil handled is expected to be the same as for pet groomers, but the pet owner is assumed to only treat their dogs/cats once per month. Product labels do not require pet owners to use gloves or wash hands after application. In the Problem Formulation, pet owner exposure as spot-on product handler is categorized as High priority.

This assessment assumed dermal exposure estimate for pet owner is the same as professional groomer and the same registrant study was used for assessment (Meo et al., 1997a). This assessment also assumes a pet owner has two large size (66 lbs) dogs. Accordingly, the pet groomer uses two 2.68 mL tubes, and the total applied fipronil is 536 mg. The calculated dermal exposure is shown in Table 26. Only STADDs are calculated, as the pet owners are expected to use these products once per month as recommended on the labels.

Table 26. Dermal exposure for a home user using pet spot-on products

Human receptor	Exposure pathway	STADD[a] (µg/kg/d)
Adult	Dermal contact	1.5

a: short-term absorbed daily dose (STADD) = exposure (4591 µg/g) × fipronil handled (0.54 g/d) × absorption rate (0.043) ÷ body weight (70kg).

Post-application, resident. This is the exposure scenario for a pet owner, either an adult or a child, contacting dogs/cats treated with spot-on products. In the Problem Formulation, the post-application exposure was categorized as Medium and High priority for adult and child, respectively. As stated earlier for pet spray products, the post-application inhalation exposures are negligible (US EPA, 2012; US EPA, 2020a). For adults, this assessment evaluated exposures from dermal contact. For children, the assessed exposure pathways were dermal contact and incidental oral ingestion.

This assessment reviewed all five studies submitted by registrants that measured dislodgeable fipronil residues on spot-on treated dogs and/or cats (de Fontenay *et al.*, 1997c; de Fontenay *et al.*, 1997d; Hughes, 1997c; Hughes, 1997d;). These studies had similar design and sampling strategies as the pet spray products. In one study from de Fontenay et al., six Beagle dogs, weighing approximately 10 kg each, were treated with Frontline (fipronil content: 9.83%) (de Fontenay *et al.*, 1997d). The applied fipronil amount for each dog was 172 mg. The study investigator measured dislodgeable fipronil residues on each treated dog by wearing a cotton glove and stroking the whole body surface of the dog. The amount of fipronil transferred onto the glove represented the dislodgeable residue.

A summary of findings from these four studies is provided in Table 27. The highest fipronil dislodgeable residue was seen on fipronil-treated cats in de Fontenay et al. (1997c). The 95th percentile value was 16.77% of the application rate.

Table 27. Summary of the highest dislodgeable fipronil residue on dogs or cats after treatments with Frontline® spot-on

Source	Dislodgeable fipronil residue[a]			Comment
	Range (percentage)	Ave. ± Stdev.[b]	95th percentile[c]	
de Fontenay et al., 1997c	2.13-13.63%	6.46±4.91%	16.77%[d]	Six cats. Highest dislodgeable residues were seen at 1 h.
de Fontenay et al., 1997d	0.38-3.12%	1.21±0.91%	2.84%	Six Beagle dogs. Highest dislodgeable residues were mostly seen at 4 h.
Hughes, 1997c	0.40-1.65%	1.02±0.51%	2.20%	Five cats. Highest dislodgeable residues were seen mostly at 4 h.
Hughes, 1997d	Short-haired: 0.36-1.16%	Short-haired: 0.80±0.28 %	Short-haired: 1.47 %	Five short-haired dogs. Highest dislodgeable residues were seen mostly within 2 d after treatment.
	Long-haired: 0.45-1.29%	Long-haired: 0.67±0.31	Long-haired: 1.16%	Five long-haired dogs. Highest dislodgeable residues were seen mostly at 4 h.
Mallipudi, 2012	2.14-3.29%	2.72±0.48%	3.61%	Five beagle dogs. Highest dislodgeable residues were seen at 4 hr.
	1.37-2.47%	2.10±0.38%	2.91%	Five beagle dogs. Highest dislodgeable residues were seen at 4 hr.
	2.38-3.50%	2.73±0.41%	3.40%	Five beagle dogs. Highest dislodgeable residues were seen at 4 hr.

a: expressed as % of the application rate;
b: mean ± standard deviation;
c: 95th percentile value was calculated based on measured concentrations (Frank, 2009);
d: Shapiro-Wilk test was performed to confirm the data followed log-normal distribution.

For short-term exposures (STADDs), the calculated 95th percentile value (16.8%) was selected as the fraction of application rate that is readily transferable to humans (Powell, 2002). The pet selected was a small-size cat with 1500 cm^2 body surface area. According to the US EPA SOP, a small size cat has the largest body weight-surface area ratio for spot-on products and hence the highest transferable residue per pet surface area (US EPA, 2012). For intermediate-term exposures (SADDs), this assessment used the same study from de Fontenay et al. (1997c) to calculate 7-day average fipronil residues (1.1% of the applied fipronil) for the first week after the application. This 7-day average was calculated using the highest measured dislodgeable residue within the first day after application (Day 0) and the estimated daily residues for the following 6 days from fitting the measured values (i.e., post-application measurements at 8 hr, and Day 1, 2, 4 and 7) into a first-order decay model. The rationale of adopting this computational approach is due to the biphasic decrease of dislodgeable fipronil residue observed within the first seven days, with a much faster decrease in Day 0 than the following days. The post-application exposure was calculated in the same way as described above for spray product, and the calculated short- (STADD) and intermediate-term (SADD) dermal and oral exposures were summarized in Table 28.

Table 28. Post-application dermal and oral exposure for pet spot-on products

Human receptor	Exposure pathway	STADD[a] (µg/kg/d)	SADD (µg/kg/d)
Adult	Dermal contact[c]	1.4	0.090
Child	Dermal contact	2.6	0.17
	Oral, hand-to-mouth[d]	0.60	0.040

a: short-term absorbed daily dose (STADD) was calculated using the maximum dislodgeable fipronil percentile (16.77%) in Table 27;
b: seasonal average daily dose (SADD) was calculated using the 7-day average dislodgeable fipronil percentile (1.1%) from de Fontenay et al., 1997c;
c: STADD and SADD (dermal) = Applied fipronil amount (5 mg) × Dislodgeable fraction (16.77% and 1.1% for STADD and SADD respectively) ÷ Pet surface area (1500 cm^2) × Transfer coefficient (5200 and 1400 cm^2/h for adult and child respectively) × Exposure time (0.77 and 1 h for adult and child respectively) ÷ Body weight (70 and 13 kg for adult and child respectively) × Dermal absorption rate (0.043);
d: STADD (oral, hand-to-mouth) calculation equation can be found on US EPA SOP page 8-12 (US EPA, 2012).

F. Turf granule products

These products are formulated as granules and used to treat fire ants on turf. Turf product use is restricted to licensed applicators and applications can only be made in Coachella Valley from April through September. The highest fipronil content in this group of products is 0.1%. The maximum application rate is 0.0125 lbs fipronil per acre, and the product may not be applied more than once per year. The label also suggests irrigating the treated turf after application for best fire ant control.

Handler. This exposure scenario is for licensed applicators using broadcast equipment to apply fipronil turf granule products Applicators are required to wear long sleeved shirt, long pants, waterproof gloves, socks, and shoes while handling the product. In the Problem Formulation Document (DPR, 2017), handler exposure was categorized as Medium priority. This assessment evaluated exposures from dermal contact and inhalation.

As there is no fipronil-specific data on turf granule products handler exposure. Therefore, the PHED database was used as a surrogate to calculate handler exposure. The calculation is based on HS-1826 Scenario 27, i.e., a mixer/loader/applicator (M/L/A) applying granular formulation with a belly grinder (Beauvais *et al.*, 2007). This scenario includes data for an M/L/A wearing long pants, long-sleeve shirt and gloves, which is consistent with the requirements on the fipronil turf granule product labels. This assessment also assumed each applicator can treat one acre per day using belly grinder, and the application rate is 0.0125 lbs fipronil per acre (US EPA, 2001). The calculated dermal and inhalation exposure are summarized in Table 29.

Table 29. Handler dermal and inhalation exposure for turf granule products

Human receptor	Exposure pathway	STADD[a] (µg/kg/d)	SADD[b] (µg/kg/d)	AADD[c] (µg/kg/d)	LADD[d] (µg/kg/d)
Adult	Dermal contact	0.66	0.24	0.12	0.063
	Inhalation	0.048	0.017	0.0085	0.0045

a: short-term absorbed daily dose (STADD) = Exposure (86100 and 266 µg/lb for dermal and inhalation respectively) × fipronil handled (0.0125 lb/d) × absorption rate (0.043 for dermal and 1 for inhalation) ÷ body weight (70kg);
b: seasonal average daily dose (SADD) = Exposure (30992 and 95.5 µg/lb for dermal and inhalation respectively) × fipronil handled (0.0125 lb/d) × absorption rate (0.043 for dermal and 1 for inhalation) ÷ body weight (70kg);
c: annual average daily dose (AADD) = SADD × annual use months (6, April-September) ÷ 12
d: lifetime average daily dose (LADD) = AADD × 40 years of work in a lifetime ÷ 75

Post-Application, resident. This exposure scenario is for an adult or a child entering a treated turf area. In the Problem Formulation, the post-application exposure was categorized as High priority for both adult and child. For adults, this assessment evaluated post-application exposures from dermal contact, and for children, the assessed exposure pathways were dermal contact and incidental oral ingestion. The post-application inhalation exposures from turf products were considered minimal due to the low vapor pressure of fipronil and dilution in outdoor air (US EPA, 2012; US EPA, 2020a).

The post-application exposure is determined by transferable turf residue (TTR), which is the portion of applied pesticide readily transferable to humans. There was a registrant submitted study that measured fipronil TTR after granular formulation treatment and is used in this assessment to determine TTR (Macy, 1998).

This study was conducted in California and North Carolina. Turf plots at each location were treated with a 0.1% fipronil granular formulation at 0.025 lbs A.I. per acre (140.1 ng/cm^2). The treated plots were then irrigated with approximately 0.25 in water, either within four hours or 48 hours after the application at different post-application intervals, fipronil TTR was measured using the "California Roller" method. Fipronil TTRs were below the 0.0736 ng/cm^2 at all post-application intervals at the California site.

As the fipronil application rate in this study is twice of the maximum rate allowed in California (0.0125 lbs A.I. per acre.), this assessment expected the TTR at the California maximum application rate to be <0.0736 ng/cm^2. This assessment used 1/2 of the value, i.e., 0.0368 ng/cm^2, as the TTR value to calculate adult and child post-application exposure. Following the US EPA SOP, this assessment also assumes an adult receives dermal exposure through normal physical activities and when mowing the treated turf. This assessment assumes a child will be exposed through incidental oral exposure (e.g., hand-to-mouth, object-to-mouth, incidental soil ingestion and episodic granular ingestion). The calculated dermal and oral STADDs for adult and child are summarized in Table 30.

Table 30. Post-application dermal and oral exposure for turf granule product

Human receptor	Exposure pathway	STADD[a] (µg/kg/d)
Adult	Dermal, normal physical activity[b]	0.0068
	Dermal, Mowing[c]	0.00012
	Total dermal	0.0069
Child	Dermal, normal physical activity	0.0099
	Oral, hand-to-mouth	0.0021
	Oral, object-to-mouth	0.00013
	Oral, incidental soil ingestion	0.00036
	Oral, episodic granular ingestion	23
	Total oral	23

a: short-term absorbed daily dose (STADD) (dermal, normal physical activity) = TTR (0.0368 ng/cm^2) × transfer coefficient (200000 and 54000 cm^2/h for adult and child respectively) × exposure time (1.5 h) ÷ body weight (70 and 13 kg for adult and child respectively) × dermal absorption rate (0.043);
b: short-term absorbed daily dose (STADD) (dermal, mowing) = TTR (0.0368 ng/cm^2) × transfer coefficient (5500 cm^2/h) × exposure time (1 h) ÷ body weight (70 kg) × dermal absorption rate (0.043);
c: short-term absorbed daily dose (STADD) (oral, hand-to-mouth, object-to-mouth and incidental soil ingestion and episodic granular ingestion) calculation equations can be found on US EPA SOP page 3-14, 3-18, 3-22 and 3-24 (US EPA, 2012).

G. Structural bait gel/strip products

This contains a group of RTU products with fipronil formulation packed as syringe tubes or strips. Fipronil content ranges from 0.001% to 0.05% (w/w). The bait gel product is applied by depressing the syringe plunger and applying appropriate amount (e.g., dime-size) to the target surface. The strip product is applied by peeling off the cover film and placing the strip on the target surface. The products can be applied to both indoor and outdoor areas with suspected pest activities, such as cracks and crevices. Each application is effective for up to a month.

Post-application, resident. This exposure scenario is for an adult or a child in contact with indoor surfaces of a treated structure. These products do not have a REI-equivalent statement, therefore a resident may enter the treated indoor area immediately after fipronil application. For adults, this assessment evaluated post-application exposures from dermal contact; for children, the assessed exposure pathways were dermal contact and incidental oral ingestion. The post-application inhalation exposures were determined to be minimal considering the low vapor pressure of fipronil and small amounts applied.

There is no fipronil-specific study measuring post-application exposure for the bait gel/strip products. Exposure information on structural bait gel/strip products is also scarce. There is no exposure scenario directly corresponding to bait gel/strip products in the US EPA SOP. This assessment followed the US EPA guidelines for indoor crack and crevice post-application and used monitoring data from a surrogate pesticide with application methods similar to fipronil bait gel/strip products (US EPA, 2012). Details of the assessment method are provided below.

This assessment did not use the default 0.3 µg/cm as surface deposited residue in the US EPA SOP because this value is too high for fipronil bait products and might significantly overestimate the exposure (US EPA, 2012). In the US EPA SOP, crack and crevice application is defined as "an application of pesticides with the use of a pin stream nozzle, into cracks and crevices in which pests hide or through which they may enter a building" (US EPA, 2012). Crack and crevice application was considered to be similar to perimeter pin stream application, but with a smaller treatment area. For crack and crevice application, the US EPA SOP assumes the default deposition rate for untreated area is 10 % of the application rate, which is expected to be higher than bait products.

Structural bait gel/strip products are applied to similar areas as crack and crevice applications. However, these products are applied in a non-continuous fashion. The application rates for structural bait gel/strip products are also lower. Using the default 0.3 $\mu g/cm^2$ surface deposition rate and the product with the highest fipronil content (i.e., 30 g with 0.01% fipronil), it was determined that a 10 m^2 area will need 10 gel/strip products to be sufficient. Therefore, this assessment only followed the US EPA's method for crack and crevice application for post-application exposure assessment, but determined the surface deposition residue using a separate registrant submitted study (Rosenheck and Schuster, 1995). The surrogate pesticide used in this study is abamectin, which is also a non-volatile, hydrophobic compound with use similar as fipronil.

This study used two abamectin products: 1) a flowable dust formulation (abamectin content: 0.05%; density: 0.67 g/cm^3) packed in a squeeze tube with a long, narrow spout; and, 2) a pressurized gel formulation (abamectin content: 0.05%, density: 1.05 g/cm^3) in a non-aerosol spray pump bottle fitted with a plastic extension tube. These products were applied in hotel rooms behind tile, behind bed headboards, into wall voids, into heaters, into cracks next to cabinets, and spaces behind baseboards. Approximately 0.15 g of the product was dispensed at each testing location and approximately 24 baits were placed per 100 square feet. The applied abamectin amount in each room is summarized in Table 31.

Abamectin surface depositions were measured by placing two pieces of 100% cotton cloth (29×59 cm) in the treated room. One piece of cloth was placed on the floor and the other was placed on the bed. Each set of cloths was at placed and retrieved at different times to monitor abamectin deposition during different post-application intervals, i.e., -2–0 h (pre-treatment), 0–0.5 h, 0.5–2 h, 2–12 h, 12–24 h and 24–48 h. The abamectin levels were below the minimum quantifiable level (MQL) (102 ng, or 0.06 ng/cm^2) for all cloth samples.

Avert® Prescription Treatment® contains abamectin in flowable dust formulation, which is different from fipronil in bait strip/gel products. A flowable dust formulation is expected to be more easily transferable to untreated surfaces, resulting in higher deposition residues. Monitoring results for this product were also included for exposure assessment, as there were only two gel formulation applications. This assessment used ½ MQL, i.e., 0.03 ng/cm^2, as the abamectin surface deposition residue and normalized this value to the application rate in each room (Table 31). The 95th percentile application rate-normalized surface deposition residue was calculated at 13 ng/g/cm^2 and was used to assess post-application exposure (Frank, 2009).

This assessment also assumed that the entire content of a product package was applied during each application. The largest size of bait gel products in California is 33 g and the highest fipronil concentration is 0.05%. The calculated dermal and oral are summarized in Table 32.

Table 31. Summary of abamectin surface deposition after crack and crevice treatments

Formulation	Abamectin applied (mg)	Abamectin deposition (ng/cm^2)	Normalized deposition[b] (ng/g/cm^2)
Flowable dust	5.3	<MQL	5.6
Flowable dust	8.2	<MQL	3.6
Flowable dust	4.8	<MQL	6.2
Flowable dust	5.6	<MQL	5.3
Pressured gel	28	<MQL	1.1
Pressured gel	59	<MQL	0.51
Mean:			3.7
95th percentile[c]:			13

a: The raw data is cited from Rosenheck and Schuster (1995); b: Assuming the surface deposition residue at ½ minimum quantifiable level (MQL), i.e., 0.03 ng/cm^2, and divided this value by the abamectin application rate in each room; c: Estimated 95th percentile of the distribution of concentrations based upon measured concentrations (Frank, 2009). Shapiro-Wilk test was not performed as all the measurements were below MQL.

Table 32. Post-application dermal and oral exposure for structural bait gel product

Human receptor	Exposure pathway	STADD (µg/kg/d)	SADD (µg/kg/d)
Adult	Dermal	0.00043	0.00012
Child	Dermal	0.00031	0.000088
	Oral, hand-to-mouth	0.0011	0.00031
	Oral, object-to-mouth	0.00014	0.000041
	Oral, Total	0.0012	0.00035

a: short-term absorbed daily dose (STADD) and seasonal average daily dose (SADD) of dermal exposure = deposition residue (2145 and 619 ng/m^2 for STADD and SADD respectively) × dislodgeable fraction (0.06) × transfer coefficient (6800 and 1800 cm^2/h for adult and child respectively) × exposure time (8 and 4 h for adult and child respectively) ÷ body weight (70 and 13 kg for adult and child respectively) × dermal absorption rate (0.043);
b: STADD and SADD (oral, hand-to-mouth) calculation equations can be found on US EPA SOP page 7-39 and 7-44 (US EPA, 2012).

H. Structural dust products

This group contains only one active registered product, Termidor® Dry California. This product contains 0.5% fipronil and is used only by licensed applicators to control subterranean and drywood termites. The product is packed as a RTU formulation, and is applied by a specially designed bulb duster to areas such as structural voids, galleries, utility poles, etc. There is no PPE requirement while handling this product. Re-application to the same areas is allowed after 30 days.

Applicator. This represents exposure scenario of a licensed applicator during the application of the dust product. The exposure was categorized as Medium Priority in the Problem Formulation Document (DPR, 2017). This assessment evaluated applicator exposures from dermal contact and inhalation.

There is no fipronil-specific study quantifying handler exposure for the structural dust product, and exposure monitoring data for handlers that inject dust/powder formulations into structural voids is also not available. This assessment used the US EPA SOP plunger duster handler scenario as a surrogate. However, instead of using the default exposure values directly provided by the US EPA SOP, this assessment instead used the raw data from the study specifically supporting the plunger duster handler scenario (Merricks, 1997).

Apparel adjustment was made to the raw data before use in the exposure calculations. In this study, each handler wore a long-sleeve shirt and long pants to monitor dermal exposure, and a second layer of long-sleeve shirt and long pants over the inner set. However, the fipronil dust product label does not require PPE. This assessment assumed a handler wears a short-sleeve shirt and long pants. Correspondingly, this assessment used pesticide on the forearm outer layer plus on upper arm, front and back torso, and upper and lower leg parts of the inner layer to calculate total body exposure. A statistical summary of the recalculated dermal and inhalation exposure on different body parts is provided in Table 33.

This assessment also assumed each handler applied 2 cans of the product. This is the default value in US EPA SOP (US EPA, 2012) and agrees with DPR PUR data. In 2012–2014 in California, the median amount of dust-formulated fipronil used in one application was 0.04 g, which is equivalent to 1.6 cans of the product. The calculated dermal and inhalation exposures are summarized in Table 34.

Table 33. Statistical summary of applicator dermal and inhalation exposure for structural dust product

	Dermal[e] (µg/g)									Inhalation[f] (µg/g)
	Forearm	Upper arm	Front torso	Back torso	Lower leg	Upper leg	Hand	Face/ Neck	Total	
Mean	84	1.0	2.1	1.4	1.8	2.6	348	1.8	443	4.4
STD[b]	101	0.90	1.8	1.4	2.4	3.6	571	1.6	604	6.6
Max.[c]	428	3.9	7.8	6.2	10	15	2546	6.5	2765	31.2
95th percentile[d]	250	2.8	5.9	4.5	5.1	8.3	1211	6.1	1447	20

a: the raw data is cited from Merricks (1997);
b: standard deviation;
c: maximum;
d: 95th percentile value was calculated based on the method described elsewhere (Frank, 2009). Shapiro-Wilk test was performed to confirm the exposure data followed log-normal distribution;
e: forearm data is from the outer layer dosimeter, and other body part data is from the inner layer dosimeter;
f: breathing rate at 1.6 m^3/h.

Table 34. Applicator dermal and inhalation exposure for structural dust product

Human receptor	Exposure pathway	STADD[b] (µg/kg/d)	SADD[b] (µg/kg/d)	AADD (µg/kg/d)	LADD (µg/kg/d)
Adult	Dermal	0.085	0.014	0.0091	0.0048
	Inhalation	0.022	0.0031	0.0021	0.0011

a: short-term absorbed daily dose (STADD) = exposure (2765 and 31.2 µg/g for dermal and inhalation respectively) × fipronil handled (0.00011 lb/d) × absorption rate (0.043 for dermal and 1 for inhalation) ÷ body weight (70kg);
b: seasonal average daily dose (SADD) = exposure (443 and 4.4 µg/g for dermal and inhalation respectively) × fipronil handled (0.00011 lb/d) × absorption rate (0.043 for dermal and 1 for inhalation) ÷ body weight (70kg);
c: annual average daily dose (AADD) = SADD × annual use months (8) ÷ 12. The number of annual use months is based on 2012-2014 PUR;
d: lifetime average daily dose (LADD) = AADD × 40 years of work in a lifetime ÷ 75

Post-application, resident. These are exposure scenarios for residents, either an adult or a child, entering a treated structure. The exposure was categorized as Medium priority in the Problem Formulation Document for both adults and children (DPR, 2017). The primary exposure routes are dermal contact and inhalation for adults, and dermal contact, inhalation, and incidental oral ingestion for a child.

There were no fipronil-specific studies quantifying post-application exposure following structural dust product treatment. Information on similar exposure scenarios for other pesticides is also lacking. In the Problem Formulation Document (DPR, 2017), the priority was first determined as Low because the product is applied to areas that are inaccessible to residents during normal activities. One illness case was identified (Table 6) that upon review appeared to be caused by other fipronil products. Therefore, HHA maintains that post-application exposure for structural dust products is low and do not warrant inclusion in this assessment.

I. Anticipated residue in drinking water

Fipronil is not used in California on agricultural crops, however it is the active ingredient in many home and commercial products used for controlling structural pests, for landscape maintenance, and for flea and tick treatments. Even without agricultural crop use, fipronil has been detected in surface water, likely due to run off from structural and landscape use in urban areas (Budd 2016; Jiang et al., 2016b). Fipronil and its degradates have also been detected in treated wastewater, where removal during treatment is minimal, resulting in constant discharge of fipronil and degradates to receiving waters (Teerlink 2017; Teerlink et al., 2017).

DPR's Pesticide Use Reporting (PUR) database contains records for pesticide use by professional applicators. The majority of fipronil applications by professionals (> 99%) are structural (DPR, 2022). Products purchased directly by consumers (i.e., pet products, gels, and baits) are not reported in the PUR. However, by evaluating internal data on pesticide sales, the mass of fipronil introduced from structural applications to the environment was estimated to be approximately 1.5 – 5.6 times higher than for pet products (Teerlink 2017). Fipronil is used widely across the state, although the data are spatial and temporally limited to county and month (Figure 6).

DPR's Environmental Monitoring Branch (EM) curates a database containing the results of surface water testing conducted in California by DPR, USGS, and other state, local, and federal agencies (SURF). DPR has conducted monitoring for fipronil and its degradates across the state since 2002, and in urban environments since 2008. There are 404 SURF surface water sampling sites where fipronil was tested for at least once, with 103 of those having at least one positive detection above the limit of quantitation (mean LOQ of 0.021 ppb, standard deviation 0.017 ppb), for a total of 576 positive detections. Samples were collected from 11/15/2002 to 4/18/2017. The location of SURF sites covers high use counties and thus is representative of the range of concentrations that could be found in surface water (Figure 6). Degradates were not included in the potable surface water analysis because all degradate data came from a subset of the same samples that were analyzed for fipronil (approximately two-thirds of total fipronil detections were also tested for degradates). The results indicated concentrations of degradates low enough to have no impact on the acute exposure estimate based on the highest detected value) and would only reduce the chronic exposure estimate by 0.003 ppb.

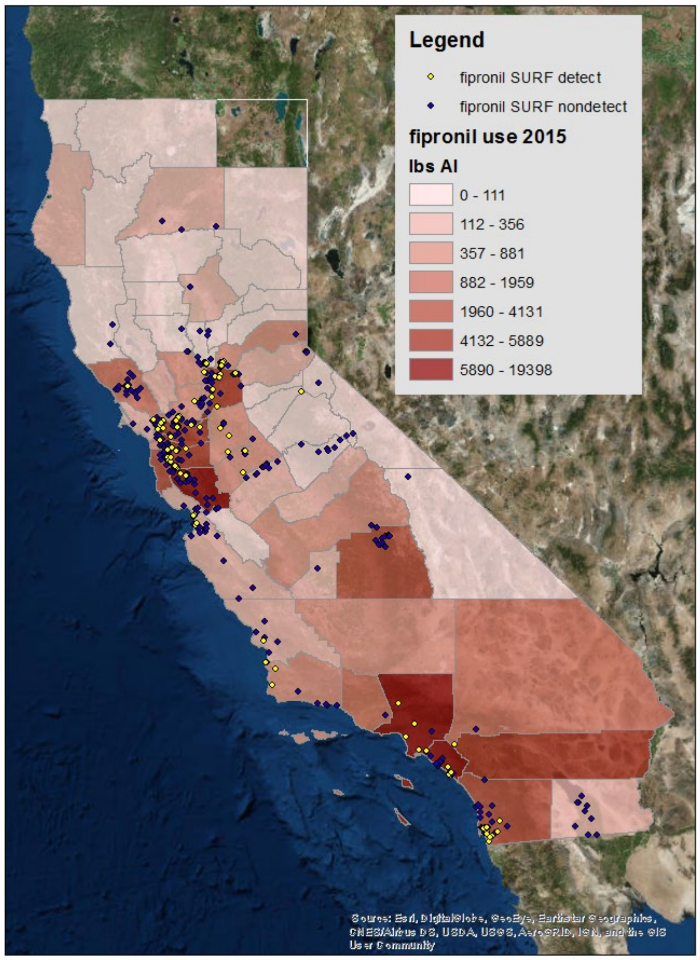

Figure 6. Statewide fipronil use for 2015 and all SURF sites that tested for fipronil at any time

Because the majority of fipronil use is for structural pest control or retail household use, DPR has located many SURF sampling sites at storm drains near residential housing complexes. These storm drain samples are expectedly of much higher concentrations than those from natural waterways (Figure 7).

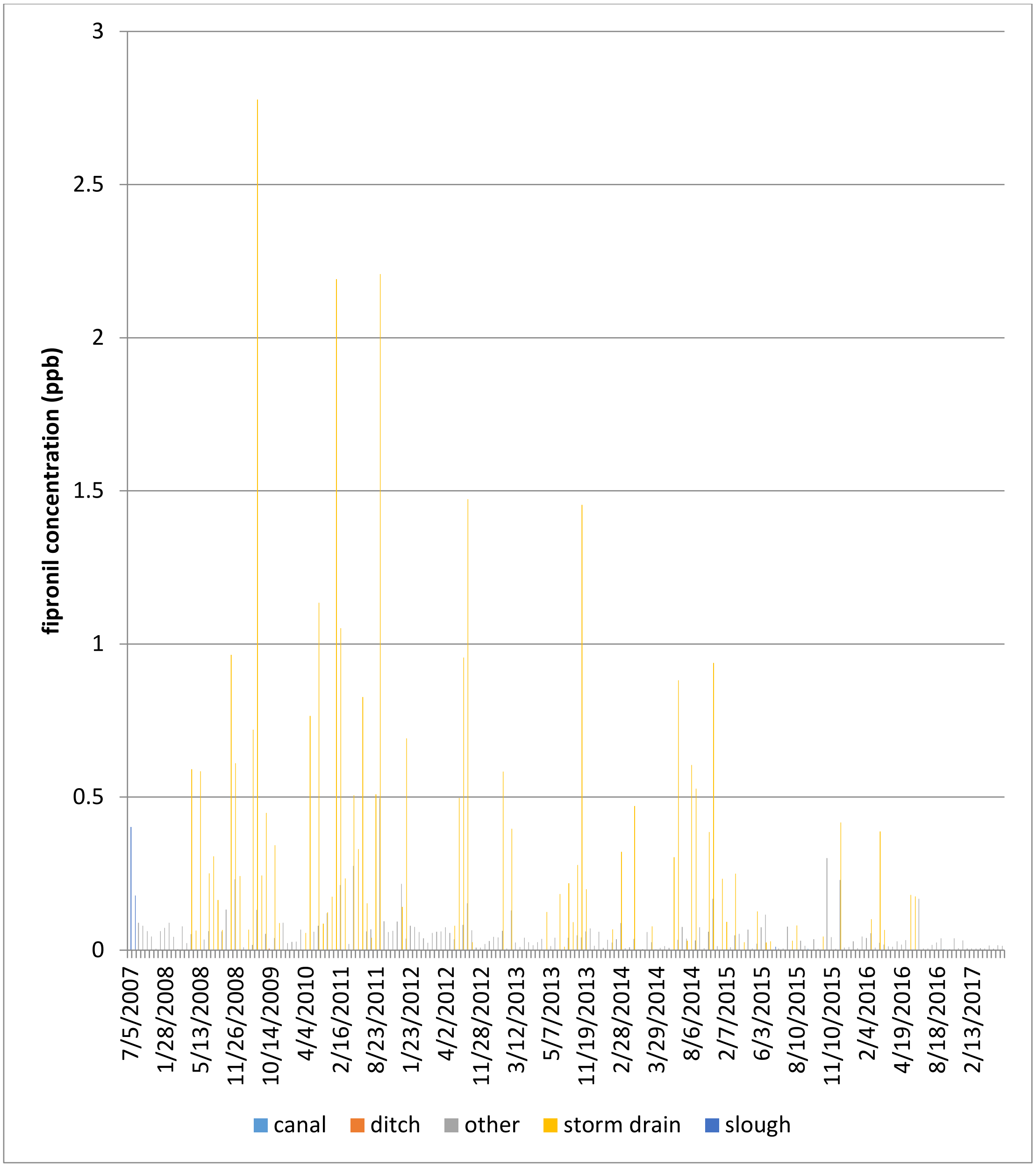

Figure 7. Fipronil SURF detections in surface water by waterway type

Since drinking water is not taken directly from neighborhood storm drains, these samples were excluded from further human risk assessment calculations. Similarly, it is unlikely that sloughs are used for drinking water. Therefore, these datasets, which accounted for the highest concentrations of fipronil and its degradates in the SURF database, were excluded from further analysis. To do so, SURF 'site' names containing 'storm drain' or 'slough' were excluded. Sampling results from other likely non-potable sources such as ditches did not change the chronic or acute exposure estimates when removed from the analysis and were therefore retained in the final dataset. Lacking accurate spatial location of pesticide application precludes the option of identifying specific drinking water extraction sites that are downstream of fipronil use. The remaining sites may or may not be co-located near a drinking water extraction site, and therefore may contribute to potable water. Once the storm drain and slough samples were removed from the analysis (Figure 8), the remaining fipronil detections (n = 303) ranged from 0.0017 ppb to 0.275 ppb (mean 0.033 ppb). Therefore, the recommended concentrations (point estimates) for use in drinking water exposure assessment are 0.275 ppb for the acute dietary and 0.033 ppb for the chronic dietary.

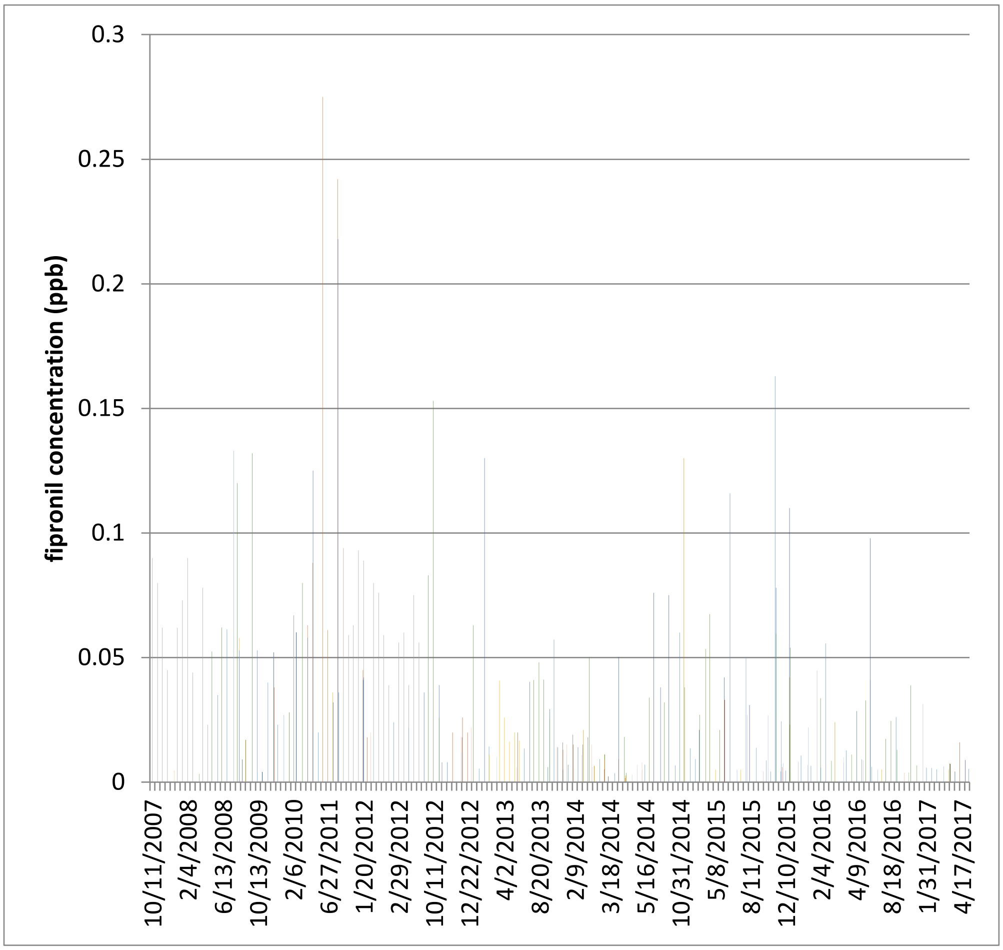

Figure 8. Fipronil SURF detections in surface water by waterway type, no storm drains (colored by site)

V. EXPOSURE APPRAISAL

This section evaluates the uncertainties that may occur in this assessment. This assessment used the best information available to evaluate fipronil exposure. However, defaults were used for some scenarios due to a lack of data. This appraisal section also discusses these data gaps identified during the exposure assessment and how they were addressed.

A. Exposure to fipronil degradates

For handler and post-application scenarios, this document only assessed human exposures to fipronil. For handlers, this assessment assessed exposures occurring at the time of application, so the primary human exposures are to the parent compound (fipronil). For post-application scenarios, this assessment estimated human exposures on the same day of the application. This is considered as the worst-case post-application scenarios and is based on the absence of restricted entry interval requirements for fipronil products. Considering the half-lives of fipronil, its degradation within one day is expected to be minimal, and therefore, the human exposures to fipronil degradates are expected to be much lower compared to fipronil (US EPA, 2020b).

B. Structural LC products

<u>Handler.</u> Handler exposure was assessed using PHED Scenario 22, which contains low pressure handwand M/L/A data for liquid formulations (open pour) (Beauvais *et al.*, 2007). Detailed discussions on the PHED data can be found elsewhere (Beauvais *et al.*, 2007). To assess fipronil handler exposure, this assessment also assumed each handler uses 40 gallons solution that contains 0.125% fipronil, which is the highest rate allowed per the product label. This rate is equivalent to 0.42 lb fipronil per application. This is in comparison to 2012-2014 PUR data showing the median amount of fipronil per application was 0.094 lb, and that 75.7% of the applications used <0.42 lb fipronil. Therefore, the application rate selected for this assessment is higher than that used for most application events, ensuring that the calculated STADD provides the maximum reasonable protections under scenarios permitted on the product labels.

Exposure of handlers applying LC products to overhead areas was based on a registrant submitted study that measured handler exposure during pesticide application to trees (8ft tall) using hand-held pumps (Merricks, 1998). This study was the only registrant submitted study that measured handler exposure using a hand-held pump to treat trees and no other handler data were available to assess exposure from structural overhead applications. Using these data likely overestimated the STADDs for several reasons. First, although Merricks (1998) did not state the amount of pesticide applied to trees, it is assumed greater than for structural overhead applications. Second, the active ingredient used in this study, i.e., carbaryl, is more volatile than fipronil, so the inhalation exposure may be overestimated (Gunasekara and Troung, 2007;

Teerlink, 2017). Third, this assessment is based on highest application rate permitted on fipronil labels.

<u>Post-application, resident.</u> Post-application inhalation exposure was assessed using a registrant submitted study (Honeycutt and Kennedy, 2001). As stated above, this study was not acceptable for use in handler exposure assessment because it did not provide information on the total amount of fipronil applied to each house. However, the application rate in this study was similar to rates used in California. Also, houses in this study had a wide range of characteristics, including size, foundation type and number of stories. Although the product used, Termidor® 80 WG, is not registered in California, it requires mixing with water before use, so the application method is similar to the LC products. This study represents typical fipronil applications in California and findings from this study could be used for post-application inhalation exposure assessment.

There were no available data to characterize indoor fipronil deposition after structural pest control. Instead, post-application dermal and oral exposures were based on a USGS study that monitored fipronil occurrence on residential indoor surfaces (Mahler *et al.*, 2009). This study did not specify the individual fipronil sources, so it is possible that indoor contamination resulted from multiple products (including both structural and pet products) applied at different times. Correspondingly, the calculated post-application exposure represents combined exposure from both structural and pet product use. For this reason, this assessment did not evaluate fipronil transfer from pet spray and spot-on products from treated animals to indoor surfaces.

This assessment used the total analyzed fipronil compounds (fipronil and two degradates) from Mahler et al. (2009) to represent the highest possible fipronil amount on indoor surface dust. However, it is unknown whether these two degradates were formed in indoor environment. If the degradates were formed elsewhere and transferred into indoor areas afterward, using the total combined concentrations will overestimate the actual fipronil exposure. Mahler et al. (2009) also did not analyze one common fipronil degradate, i.e., fipronil sulfone, which is formed through oxidation process (Gunasekara and Troung, 2007; Teerlink, 2017). Although there is no study analyzing its occurrence in residential indoor areas, evidence has shown its common detections on residential outdoor surfaces, at levels comparable or even higher than parent fipronil (Jiang *et al.*, 2016a; Jiang *et al.*, 2016b). Therefore, the calculated exposure did not account for the portion of fipronil transformed to fipronil sulfone and may underestimate indoor exposure.

There was no available data to characterize post-application outdoor air concentrations. To control termites, fipronil is injected into structural inaccessible areas through small holes. To control other pests such as ants, fipronil is applied onto exterior structural surfaces. US EPA considers the post-application inhalation exposure in similar settings, i.e., application on outdoor lawn/turf, to be minimal due to pesticide low vapor pressure and dilution effect in outdoor air (US EPA, 2012). As such, this assessment assumes that outdoor air concentration of fipronil from either termite or ant control to be minimal.

Exposure to fipronil from contaminated outdoor surfaces was also considered for this assessment, based on the studies from Mahler et al. (2009) and Jiang et al. (2016a). For exterior surface treatment, fipronil is applied in crack-and-crevice fashion, usually around structural perimeter and along pest crawl and hide trails. It is likely that the treated surface area is much smaller than the areas an adult or child may play on. Because this assessment assumes that fipronil levels on outdoor surfaces are lower than on indoor surfaces, the potential exposure from contaminated surfaces can be adequately covered by the indoor scenario.

C. Pet spray and spot-on products

Fipronil products for cats and dogs are available in two formulations, i.e., spray and spot-on. Because pesticide exposure potential is associated with the product formulation (Beauvais *et al.*, 2007), groomer, home user and post-application exposures for adults and children were assessed for each of the formulations.

Applicator, groomer. The number and size of dogs/cats treated by each handler per day is expected to vary greatly among different handlers. This assessment assumed each groomer treated 10 dogs per day, which is the average number of dogs and cats treated by a commercial groomer based on a registrant submitted survey (Irwin, 1997). Irwin (1997) also found that veterinary groomers treated fewer dogs/cats per day than commercial groomers (Irwin, 1997). Therefore, this assessment used 10 dogs/cats for professional groomers per day as well as two dogs once per month for pet owners. This agrees with findings from the recent AVMA surveys as well as the number of treated dogs/cats selected in the US EPA SOP (AVMA, 2012; AVMA, 2019; US EPA, 2012).

Applicator, home user. The product labels suggest repeated applications of fipronil on pets to maintain satisfactory tick and flea controls. The suggested application frequency is monthly, i.e., home users only need to apply fipronil once every month. Accordingly, the intermediate- and long-term home user exposures were not assessed because the once-a-month use pattern is not consistent with the definitions of intermediate and long-term exposures as defined in Kwok (2017).

Post-application, resident. As stated earlier, this assessment did not evaluate fipronil transfer from treated pet to indoor surfaces and the associated human exposure, rather relied on an indoor monitoring study that evaluated various residential fipronil uses. One study attempted to quantify fipronil transfer after pet treatment (Bigelow-Dyk *et al.*, 2012). Researchers placed cotton cloths in areas frequently visited by the treated dogs/cats (beds, furniture, play areas, and cat trees), collecting them after 2 weeks to measure the concentrations of fipronil and three degradates (desulfinyl, sulfone and sulfide). This study also measured fipronil transfer to humans by asking pet owners to wear cotton socks 2 hours per night for seven consecutive days.

There were several reasons results from Bigelow-Dyk, et al., were not used, most of which center on the location and duration of the testing and the representativeness of indoor fipronil levels. For example, the levels of fipronil transferred to socks was 0.18-16 µg per hour of activity. Because the socks were worn for one week, it is difficult to calculate fipronil daily transferable amount. In addition, only transfer rates per hour can be calculated, but not the amount deposited per unit of indoor surface area; the latter is needed for this assessment.

Another potential post-application exposure scenario considered in this assessment is exposure from bathing treated dogs/cats. No data were available to evaluate fipronil exposure during bathing dogs/cats for either groomers or owners. The US EPA SOP recommends using handler exposure studies as surrogate scenarios, as handlers are expected having more vigorous contact with the treated animals (US EPA, 2012).

This assessment conducted a preliminary evaluation of fipronil exposure during dog bathing using US EPA's Swimmer Exposure Assessment Model as the surrogate scenario, but only considered dermal exposure on hands and forearms, assuming that these two body parts contact the bathing water (US EPA, 2003). Dermal permeability coefficient required by this model was calculated following the US EPA summary on dermal exposure assessment (US EPA, 2007). Fipronil concentration in the bathing water of a treated dog was based on data from Teerlink *et al.* (2017). In this study dogs were treated with fipronil spot-on products and washed at different days after treatments. The dermal STADDs, as shown in Table 35, were estimated based on the concentrations of fipronil and four fipronil degradates (amide, sulfide, sulfone and desulfinyl) in the bathing water. The finding is in agreement with US EPA in that the STADDs from bathing dogs are lower than handler STADDs.

Table 35. Post-application dermal STADDs for pet owner and groomer from bathing treated dogs

Occupation	Human receptor	STADD[a] (µg/kg/d)
Professional groomer	Adult	2.3
Pet owner	Child, 7-10 years old	0.58
	Teen, 11-14 years old	0.66
	Adult	0.45

a: short-term absorbed daily dose (STADD) = Exposure time (200 and 40 minutes for groomer and pet owner respectively) × Surface area of exposed skin (0.10, 0.19 and 0.19 m^2 for child, teen and adult respectively) × Dermal permeability coefficient (0.0028 cm/h) × Water concentration (8.9 µg/mL) ÷ Body weight (30, 48 and 72 kg for child, teen and adult respectively) (US EPA, 2003; US EPA, 2007; Frank, 2009);

The calculated STADDs in Table 35 might overestimate fipronil exposure from dog bathing. Fipronil water concentrations used in the calculation (8.9 µg/mL) was the maximum measured concentration of total fipronil compounds in the bathing water, but this value already exceeded fipronil water solubility (2 µg/mL) (Teerlink *et al.*, 2017). As discussed in this paper, dog bathing water contained 1.6-76.2 g/L suspended solids. Therefore, the water concentration used in the calculation includes fipronil amount associated with suspended solids, which does not have the same dermal uptake as the freely soluble fipronil. This assessment did not evaluate post-application inhalation exposures for pet products, and there is no study that monitored fipronil air concentrations shortly after pet product use. As stated previously in the Exposure Assessment section, due to the low volatility of fipronil and the small amount applied, the inhalation exposures were determined minimal. Using the ideal gas law, the maximum concentration dictated by the saturation vapor pressure of fipronil after application is 0.065 $\mu g/m^3$ at 25 ºC. However, using this concentration will significantly overestimate the inhalation exposures because of the assumptions of immediate volatilization loss after application and no mass transfer limitations (e.g., surface-to-air) during the volatilization. In fact, in a study from Honeycutt and Kennedy (2001) that monitored fipronil air concentrations during and after applications of structural LC products, the 24-hr average air concentration was 0.021 $\mu g/m^3$ (Table 12). Given the lower use rates and frequencies of pet products than structural LC products, the post-application inhalation exposures for pet products are expected to be low.

This assessment also did not evaluate post-application incidental oral exposure for long-term exposure duration. Data revealed detections of radiolabeled fipronil in the stratum corneum and viable epidermis of the application zone (neck) of beagle dogs up to 56 days post-application (Cochet et al., 1997). The persistence of the active ingredient combined with regular 30-day applications indicates the possibility of long-term fipronil exposures, but the exposure levels are expected to be much lower than the short- and intermediate-term exposures estimated in this assessment, since the transferable amount of fipronil on cats and dogs rapidly decreased within 28 days after treatments (de Fontenay et al., 1997a; de Fontenay et al., 1997b; de Fontenay et al., 1997c; de Fontenay et al., 1997d; Hughes, 1997a; Hughes, 1997b; Hughes, 1997c; Hughes, 1997d). Post-application object-to-mouth exposure following indoor applications is generally considered short-term in duration (US EPA, 2012). Product-specific dose estimates can be refined to reflect a more accurate multi-day or multi-episode exposure profile when more data, such as long-term monitoring of transferable residues on pets, becomes available.

D. Turf granule products

<u>Post-application, resident.</u> Exposure monitoring data is usually considered as the best information to assess post-application exposure from treated-turf for a particular pesticide and formulation. No monitoring data were available for post-application fipronil exposure from treated turf. Therefore, this assessment followed US EPA SOP (2012) to assess post-application turf exposure, and assumed the dermal exposure is proportional to the TTR value (US EPA, 2012).

Besides TTR, DPR may also use monitoring of other pesticides as surrogate data when exposure monitoring data are not available. For instance, carbaryl post-application exposure on treated turf was estimated using a study that monitored exposure instead of TTR (Beauvais, 2014). In another example, dithiopyr exposure was monitored after turf treatment with a granular formulation product (Baugher *et al.*, 2004). In Table 36, adult and child fipronil dermal exposures were calculated using this dithiopyr study as surrogate and compared with those calculated using TTR. The calculated fipronil exposure using both methods is the same order of magnitude, but STADDs from the TTR method are about three times higher than STADDs from monitoring data for both the adult and child.

Table 36. Comparison of adult and child dermal STADD calculated using TTR method or exposure monitoring data

STADD (µg/kg/d)	US EPA SOP TTR[a]	Exposure monitoring study
Adult	0.0068	0.0017[b]
Child	0.0098	0.0024[c]

a: short-term absorbed daily dose (STADD) (dermal, normal physical activity) = TTR (0.0368 ng/cm^2) × transfer coefficient (200000 and 54000 cm^2/h for adult and child respectively) × exposure time (1.5 h) ÷ Body weight (70 and 13 kg for adult and child respectively) × dermal absorption rate (0.043);
b: short-term absorbed daily dose (STADD) (adult dermal, monitoring data) = monitored exposure (24.1 µg/20-min) × exposure time (1.5 h) ÷ application rate ratio (40) ÷ body weight (70 kg) × dermal absorption rate (0.043);
c: short-term absorbed daily dose (STADD) (child dermal, monitoring data) = monitored adult exposure (24.1 µg/20-min) × exposure time (1.5 h) ÷ adult body surface area (1.95 m^2) × child body surface area (0.53 m^2) ÷ application rate ratio (40) ÷ child body weight (13 kg) × dermal absorption rate (0.043);

For a 1–2 year old child, the calculated oral exposure through episodic granular ingestion was 4–5 orders of magnitude higher than the exposure through other oral routes. This assessment calculated episodic granular ingestion exposure assuming fipronil concentration on the ingested granules equals the concentration in the product. The product labels suggest the lawn be irrigated after the treatment, so the actual exposure may be lower due to loss of fipronil from granules. However, there is no information on fipronil residue remaining on the formulation granules after irrigation. This assessment assumed 100% fipronil remained on granules after irrigation, based on the hydrophobicity of fipronil.

For similar reasons as for pet products, post-application inhalation exposures were not assessed for turf products and are expected low.

E. Structural bait gel/strip products

Post-application, resident. no fipronil-specific study was found, so this assessment used a registrant submitted study on abamectin as a surrogate to calculate fipronil deposition (Rosenheck and Schuster, 1995). Abamectin was applied in two formulations, flowable dust and gel. Flowable dust applications were used to calculate 95th percentile value of surface deposition because there were only two gel applications. This may overestimate the surface deposition as flowable dust formulation is more prone to transfer off-site and generate higher indoor deposition.

In this study from (Rosenheck and Schuster, 1995), abamectin application rate at each room was vastly different (Rosenheck and Schuster, 1995). This assessment assumed abamectin deposition level was proportional to the application rate. But factors other than application rates also affect indoor deposition levels, and pesticide concentrations on indoor surfaces are often found not correlated to application rates. According to the US EPA SOP, there is no correlation between application rate and post-application indoor residue for crack and crevice applications (US EPA, 2012).

F. Structural dust products

Applicator. Handler exposure was assessed using the US EPA SOP scenario for a handler using the plunger dust application method. Instead of using the SOP default values directly, this assessment used the raw data on which this scenario relies (Merricks, 1997). This study is the best available information with which to assess the dust handler exposure scenario. However, using these data may overestimate the handler exposure for the following reasons. First, the package of fipronil dust product is directly connected to a specially designed duster, so the exposure during loading and unloading the product from the duster is expected to be lower than that measured in the study. Second, fipronil is applied by inserting duster outlet tip into a pre-drilled hole, therefore drift during the application is less likely and inhalation exposure is expected to be lower than measured in the study. Third, the fipronil dust product was applied into structural voids, and air flow generated in each pump is unlikely to cause additional handler exposure through re-suspension of already-applied product.

G. Drinking water

Because of the available data, it is difficult to accurately identify the surface water-derived drinking water sources which have the highest contamination rates. This assessment identified a large number of sampling points that include heavy use regions, so the sampling values could be considered a reasonable worst case scenario. It is possible that there are drinking water extraction sites that might have a higher fipronil concentration than the highest sampled value from free flowing waterways. Nevertheless, insufficient information exists to determine if such sites exist or to determine the exact fipronil concentration would be. Since sampling in storm drains in neighborhoods of high use showed fipronil concentrations less than an order of magnitude greater than the highest samples in free flowing waterways, this assessment assumes that any drinking water contamination would be much less than the storm drain samples and thus closer to the recommended concentration values.

VI. CONCLUSION

This analysis assessed fipronil exposures for 18 occupational handler, home user (i.e., pet owners) and re-entry scenarios. The assessment covered exposures for both adults and children and considered four exposure periods (short-term, seasonal, annual and lifetime). For adults, assessed exposure routes were dermal contact and inhalation, and for children, the assessed routes were dermal contact, inhalation and incidental oral ingestion. This analysis generated a total of 74 exposure estimates. This analysis also provided concentration estimates for drinking water exposure assessment. These values were calculated for the development of Risk Characterization Document of fipronil.

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