Human Exposure Assessment Document for Carbaryl

HS-1788

by

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TABLE OF CONTENTS

TABLES

ABBREVIATIONS AND ACRONYMS

ADD	absorbed daily dosage
AADD	annual average daily dosage
AI	active ingredient
APHIS	Animal and Plant Health Inspection Service
ARB	California Air Resources Board
CAC	County Agricultural Commissioner
CAS No.	Chemical Abstracts Service Number
CCR	California Code of Regulations
CFAC	California Food and Agriculture Code
CFR	Code of Federal Regulations
CFWAP	California Farm Worker Activity Profile
DFR	dislodgeable foliar residue
DPR	California Department of Pesticide Regulation
HIARC	Hazard Identification Assessment Review Committee
LADD	lifetime average daily dosage
LOD	limit of detection
LOQ	limit of quantitation
M/L	mixer/loader
M/L/A	mixer/loader/applicator
PCO	pest control operator
PHED	Pesticide Handler Exposure Database
PHI	preharvest interval
PISP	Pesticide Illness Surveillance Program
PPE	personal protective equipment
PUR	Pesticide Use Report
RED	Reregistration Eligibility Decision
REI	restricted entry interval
SADD	seasonal average daily dosage
STADD	short-term absorbed daily dosage
TC	transfer coefficient
TWA	time-weighted average
UCL	upper confidence limit
U.S. EPA	U.S. Environmental Protection Agency
WHS	Worker Health and Safety Branch

ABSTRACT

Carbaryl is a carbamate insecticide with multiple uses in both agricultural and non-agricultural settings. Several formulations of carbaryl are registered for use in California, including aqueous concentrates, flowable concentrates, suspensions, dusts, granulars, baits, and ready-to-use liquids. Carbaryl products have uses in both occupational and residential settings.

This human health exposure assessment was prepared for inclusion in the risk characterization document for carbaryl because of adverse effects resulting from acute inhibition of acetylcholinesterase activity and tumorigenesis reported in laboratory studies. Thus, the exposures that are potentially of most concern include short-term exposures approaching levels when acetylcholinesterase inhibition might occur, and lifetime exposures approaching the level implicated in tumorigenesis.

Twelve of 29 occupational handlers, listed below, were identified as having the highest level of concern with respect to exposure. The Short-Term Absorbed Daily Dosage (STADD) exposure estimate for each scenario is given in parentheses:

- Mixer/loaders (M/L) handling liquid products in support of aerial and chemigation applications to citrus (60.8 mg/kg/day)
- Rights-of-Way applicators (48.8 mg/kg/day)
- Mixer/loader/applicators (M/L/A) using high-pressure handwands (42.6 mg/kg/day)
- Aerial applicators making high-acre applications of liquids (26.0 mg/kg/day)
- M/L handling liquid products in support of airblast (6.99 mg/kg/day)
- M/L supporting high-acre groundboom applications (5.82 mg/kg/day)
- M/L/A using backpack sprayers (5.35 mg/kg/day)
- Open-cab airblast applicators (4.04 mg/kg/day)
- M/L supporting groundboom applications (2.33 mg/kg/day)
- M/L supporting Rights-of-Way applications (1.46 mg/kg/day)
- Loading granular products into broadcast spreader in support of high-acre applications (0.207 mg/kg/day)
- Aerial applicators making high-acre applications of granulars (0.189 mg/kg/day)

Nine of 17 occupational reentry scenarios have the highest level of concern with respect to exposure:

- Citrus pruning (6.84 mg/kg/day)
- Corn detasseling (4.52 mg/kg/day)
- Apple thinning (3.41 mg/kg/day)
- Blackberry pruning (3.23 mg/kg/day)
- Turf maintenance (2.74 mg/kg/day)
- Grape leaf pulling (1.74 mg/kg/day)
- Cabbage scouting (1.38 mg/kg/day)
- Lettuce scouting (1.14 mg/kg/day)
- Potato scouting (0.970 mg/kg/day)

None of the six residential handler scenarios have the highest level of concern with respect to exposure. However, residential reentry is associated with the highest level of exposure concern:

- Reentry onto treated lawns by toddlers (4.33 mg/kg/day)
- Reentry onto treated lawns by adults (2.58 mg/kg/day)

With the exception of trigger sprayer applicator and handlers involved in high-acre aerial and Rights-of-Way applications, all occupational scenarios have been identified as having the highest level of concern for lifetime exposures. With the exception of hand thinning in apples, blackberry pruning, hand harvesting of asparagus and tobacco, and scouting in beans, cucumber, and cabbage, all occupational reentry scenarios have the highest level of concern for lifetime exposures. In contrast, lifetime exposures for residential scenarios have a low level of concern.

INTRODUCTION

Carbaryl is an *N*-methyl carbamate broad-spectrum insecticide that has wide use in agriculture as a foliar treatment for control of numerous insect pests. In addition, it is used in and around the home and for control of insect pests in the garden. Its major recognized mode of action is through inhibition of acetylcholinesterase activity.

REGULATORY STATUS

U.S. EPA

The United States Environmental Protection Agency (U.S. EPA) classifies carbaryl as "likely to be carcinogenic in humans," based on the incidence of hemangiocarcinomas in mice (Chuzel, 1999). The U.S. EPA classifies the acute oral toxicity of carbaryl as Category II, the acute dermal toxicity as Category III, and the acute inhalation toxicity as Category IV (U.S. EPA, 2010). In available animal studies, carbaryl was not a dermal or eye irritant, nor was it a dermal sensitizer, although dermal irritation and allergic reactions have been reported in humans, according to U.S. EPA (2010).

U.S. EPA assessed carbaryl during its reregistration assessment process, which culminated in a Reregistration Eligibility Decision, or RED (U.S. EPA, 2008). In addition to the chemical-specific risk assessment, U.S. EPA also assessed the effects of exposure to the N-methyl carbamates, multiple chemicals sharing a common mechanism of toxicity with carbaryl (U.S. EPA, 2007). U.S. EPA initiated registration review for carbaryl, as required every 15 years under the Food Quality Protection Act, on September 22, 2010 (U.S. EPA, 2010).

California

Under the California Code of Regulations Title 3, Section 6400 (3 CCR 6400), most products containing carbaryl are classified as Restricted Materials, due to concerns over toxicity to bees (Rutz, 1997). Exceptions that are not classified as Restricted Materials include products formulated as baits, or carbaryl-containing products "labeled only for one or more of the following uses: use directly on livestock or poultry, home use, structural pest control, industrial use, institutional use, or use by public agency vector control districts pursuant to Section 116180 of the Health and Safety Code." A Restricted Material can only be applied by or under the direct supervision of a certified applicator, under a permit from the County Agricultural Commissioner (3 CCR 6406).

DPR is charged with protecting individuals and the environment from potential adverse effects that may result from the use of pesticides in the State. This is codified in the California Food and Agriculture Code (CFAC), Sections 11501, 12824, 12825, 12826, 13121-13135, 14102, and 14103. As part of DPR's effort to meet this mandate, pesticide active ingredients (AIs) are prioritized for assessment of exposure and risk potential. A description of the risk prioritization process can be found at DPR's website (http://www.cdpr.ca.gov/docs/risk/raprocess.pdf). When comprehensive risk assessments are initiated for particular AIs, the evaluations are conducted in accordance with California regulations (3 CCR 6158).

Carbaryl is being reviewed under the Birth Defect Prevention Act of 1984 (California Food and Agriculture Code, Sections 13121-13135), in part because of adverse effects reported in laboratory studies. Reported adverse effects included cholinergic signs; liver, kidney, and vascular tumors; cataracts; and increased chromosomal aberration in Chinese hamster ovary cells (Gee, 2002). This exposure assessment is the first prepared by the California Department of Pesticide Regulation (DPR) for carbaryl.

PHYSICOCHEMICAL PROPERTIES

Carbaryl, *1*-naphthyl *N*-methylcarbamate, is a tan colored crystalline solid (molecular formula $C_{12}H_{11}NO_2$; molecular weight 201.2; CAS No. 63-25-2). The structure is shown in Figure 1 and selected physical properties of carbaryl are listed in Table 1.

Figure 1. Carbaryl Chemical Structure.

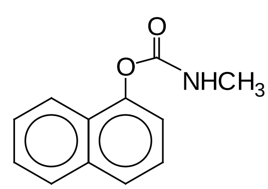


Table 1. Physical and Chemical Properties of Carbaryl

Property [a]	Value
Melting Point (°C)	142
Water Solubility (mg/liter, 25 °C)	104
Octanol/Water Partition Coefficient (log K_{ow})	2.36
Vapor Pressure (mm Hg, 25°C) [b]	1.36×10^{-6}
Henry's Law Constant (atm-m^3/mole, 25°C)	2.74×10^{-9}

[a] Properties taken from summary in the Department of Pesticide Regulation's environmental fate review of carbaryl (Gunasekara, 2007), unless otherwise indicated.
[b] From NLM (2011).

FORMULATIONS AND USES

Carbaryl is available in California in several formulation types, including those designed to be mixed with water before spraying, such as aqueous concentrates, liquid suspensions, and flowable concentrates; and ready-to use (RTU) products in dust, granular, bait, and liquid formulations. For exposure assessment purposes, baits and non-bait granular formulations are considered together. Five of the bait products contain metaldehyde (2%); however, estimating metaldehyde exposure is beyond the scope of this exposure assessment. Metaldehyde is on DPR's list of AIs that have been prioritized for risk characterization (DPR, 2011c).

Currently, there are 24 registered products containing carbaryl in California, excluding one product intended solely for manufacturing use. That product is outside the scope of this exposure assessment because manufacturing uses are not regulated by DPR. The other 23 products are summarized in Table 2.

Table 2. Carbaryl Formulations Registered in California

Formulation Type	Number of Products [a]	Carbaryl Concentration Range (%)	Signal Word(s)
AC, FC, and Suspension [b]	7	22.5 – 44.1	Caution
Dust	1	5	Caution
Granular/Bait [c]	13	2 – 10	Caution
Ready-to-Use Liquid [d]	3	0.126 – 22.5	Caution
Total	24		

[a] One product intended for manufacture use only was omitted.
[b] AC: aqueous concentrate. FC: flowable concentrate. All three formulations (AC, FC, and suspension) are considered to be liquids in this exposure assessment, and all are mixed with water before application.
[c] Includes four non-bait granular products containing 2 – 10% carbaryl; three bait products containing 5% carbaryl; and five bait products containing 5% carbaryl and 2% metaldehyde.
[d] One ready-to-use product contains 22.5% carbaryl and is diluted during hose-end application. The other two products are sprays containing 0.126% carbaryl.

Carbaryl is used in both agricultural and non-agricultural situations. The non-agricultural uses of carbaryl include applications to landscapes and home gardens. Some product labels also allow application for grasshopper suppression programs by the U.S. Department of Agriculture; California is one of 17 Western states participating in such programs (USDA, 2002). Agricultural uses are numerous; they include field crops, vegetables, fruit, nuts, nursery/greenhouse crops and forest/rangelands.

PESTICIDE USE AND SALES

California requires reporting of all agricultural uses of pesticides, as well as other uses when pesticides are applied by a licensed applicator. These data are collected in the Pesticide Use Report (PUR) database (DPR, 2012a). California also collects a fee for all pesticides sold in the state, including products sold for home/garden use (DPR, 2011b). By dividing the pounds of carbaryl sold in California by the pounds used in agriculture, it is possible to get a rough indication of the percentage of carbaryl used for agricultural vs. non-agricultural uses. These databases were intended for different purposes, and the data are not directly comparable (e.g., pesticides sold in one year may be used in a different year, and sales data include sales to distributors). With these caveats in mind, examination of sales and use data for 2010 (the most recent year for which data are available) suggests that about 44% of the pounds of carbaryl sold (255,005 lbs; 115,668 kg) was used in agriculture (113,050 lbs; 51,279 kg).

Table 3 shows PUR data for top crops and use sites for carbaryl in 2006 – 2010, based on pounds applied. Carbaryl was used most often in citrus; 24% of the pounds of carbaryl recorded in the PUR during the 5-year interval were applied to citrus crops. The crops and use sites in Table 3 represent an average of 93% of total reported use each year.

Table 3. Agricultural and Commercial Use of Carbaryl by Crop/Site for 2006- 2010

Crop or Use Site	Pounds Applied [a]					
	2006	2007	2008	2009	2010	5-year Average (% Total)
Citrus [b]	33,249	32,583	29,852	24,979	16,520	27,436 (20.5)
Tomatoes (all types)	11,826	27,269	31,468	41,641	21,302	26,701 (20.0)
Pome Fruit [c]	17,196	17,530	14,170	14,215	11,985	15,019 (11.2)
Stone Fruit [d]	13,219	9,846	11,958	9,648	4,450	9,824 (7.3)
Nut Crops [e]	14,736	10,654	8,832	5,862	8,941	9,810 (7.3)
Cucurbits [f]	14,846	12,032	8,138	8,482	4,147	9,529 (7.1)
Olives	3,940	3,345	1,344	5,938	17,330	6,439 (4.8)
Corn (all types)	5,978	4,728	3,024	2,540	3,295	3,913 (2.9)
Structural Pest Control	13,046	603	1,993	1,810	148	3,520 (2.6)
Landscape Maintenance	5,150	3,939	2,608	1,944	2,217	3,172 (2.4)
Strawberries	2,564	2,689	1,054	2,891	1,775	2,195 (1.6)
Asparagus	1,979	2,515	248	906	2,709	1,671 (1.2)
Grapes (all types)	4,771	1,022	89	242	1,529	1,531 (1.1)
Potatoes	628	1,833	723	1,112	2,322	1,324 (1.0)
Peppers (all types)	781	1,682	1,581	1,023	580	1,129 (0.8)
Regulatory Pest Control	270	88	7	0	5,159	1,105 (0.8)
Total of listed crops	144,964	130,080	117,922	122,060	104,409	124,319
Total in PUR	156,939	142,010	126,076	130,982	113,050	133,811
Listed crops % of total	92.4%	91.6%	93.5%	93.2%	92.4%	92.9%

[a] From (DPR, 2007; 2008; 2009; 2010; 2011a). Arranged in descending order by 5-year average.
[b] Includes grapefruit, lemons, oranges, tangelos, tangerines and unspecified citrus fruit.
[c] Includes apples, loquats, crabapples, pears and Oriental pears.
[d] Includes apricots, cherries, nectarines, peaches, plums and prunes.
[e] Includes almonds, chestnuts, pecans, pistachios and walnuts.
[f] Includes cantaloupes, cucumbers, melons, pumpkins, squash and watermelons.

REPORTED ILLNESSES

DPR's Worker Health and Safety Branch (WHS) includes a Pesticide Illness Surveillance Program (PISP). PISP maintains a database of all reports of illness and injury potentially related to pesticide exposure in California. The PISP database contains information about the nature of the pesticide exposure and the subsequent illness or injury. DPR uses the database to identify high-risk situations and to evaluate the effectiveness of DPR's pesticide safety regulatory programs (WHS, 2007).

PISP defines a “case” as the program’s representation of a pesticide exposure and its apparent effects on one individual's health (WHS, 2007). PISP scientists evaluate investigations of each case and record a qualitative assessment of the likelihood that pesticide exposure caused or contributed to the reported symptoms. Cases are considered to be associated with exposure to a pesticide as follows: they are evaluated as “definite” (both physical and medical evidence support exposure and consequent health effects), “probable” (incomplete or circumstantial evidence supports a relationship to pesticide exposure) or “possible” (available evidence neither supports nor contradicts a relationship). When the weight of evidence is against pesticide contribution to health effects, scientists may classify cases as “unlikely,” “indirect,” “asymptomatic,” or “unrelated.” They also have the option of declining to classify cases that lack critical information.

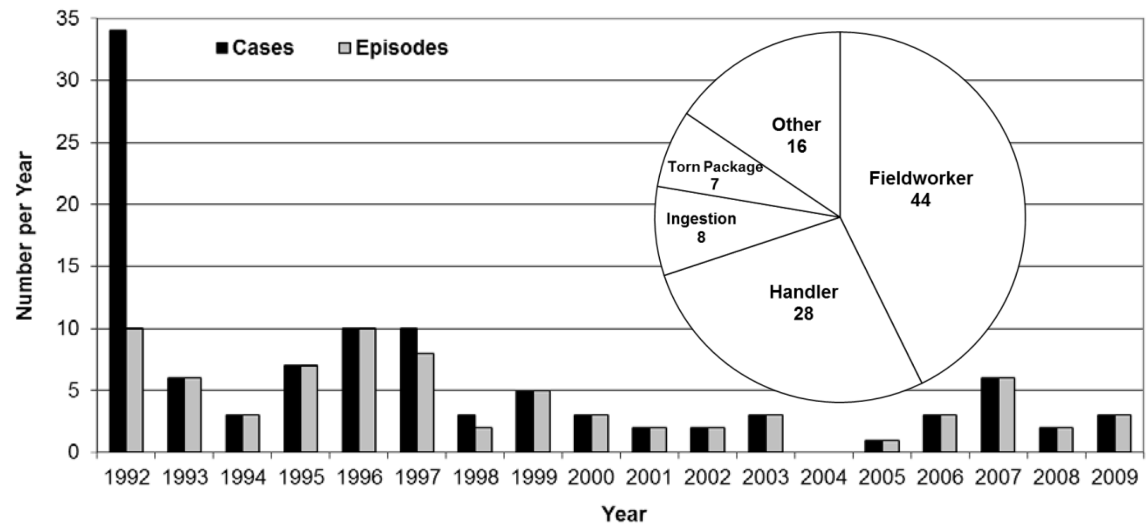
PISP defines an “episode” as an incident in which one or more people experience pesticide exposure from a particular source with subsequent development or exacerbation of symptoms. Occasionally, a single episode gives rise to a large number of cases.

A total of 103 illness cases in 76 episodes were reported during the years 1992 through 2009 (Mehler, 2011; DPR, 2012b). Figure 2 summarizes numbers of cases and episodes reported annually. With the exception of 1992, 1997, and 1998, numbers of cases equal numbers of episodes; that is, each episode involved a single person. In 1992, multiple illnesses occurred in each of three episodes. In the first of these episodes, four employees unloading a van had itching or redness of skin after exposure to carbaryl dust leaking from a box. In the second episode, seven pesticide handlers working for a pest control operator were removed from exposure to organophosphates and carbamates because of low cholinesterase levels (their plasma cholinesterase activities had decreased 37 – 83% relative to their baseline values, and red blood cell cholinesterase activities decreased 3 – 46%). In the third episode, a crew of orange harvesters working in a grove that had been treated with carbaryl and petroleum oil complained of nausea, dizziness, headache, and other symptoms; carbaryl residues were detected on leaves that were later sampled in the orange grove.

The pie chart inset to Figure 2 summarizes conditions under which illnesses were reported. Most illnesses (72 cases) were reported by fieldworkers and handlers. Six fieldworker illnesses were associated with drift, in which a worker smelled an odor or received spray from a nearby application. The other fieldworker illnesses reported symptoms after working in treated crops, and illnesses were potentially associated with carbaryl residues on the crops.

In addition to illnesses reported by handlers and fieldworkers, four episodes (seven cases) involved exposure to carbaryl dust from torn packaging (three torn bags, as well as the leaking box mentioned above), and eight cases ingested carbaryl. U.S. EPA (2008) prohibited agricultural applications of carbaryl, for which the larger package sizes were used, decreasing the likelihood of future illnesses happening this way. Currently, only one carbaryl dust product is registered in California, and it's only available in a small shaker can.

Figure 2. Numbers of Illnesses (Cases) and Episodes Reported in California, 1992 – 2009, Evaluated by the California Pesticide Illness Surveillance Program as Definitely, Probably, or Possibly Related [a] to Carbaryl Exposure



[a] "Definite" means that both physical and medical evidence document exposure and consequent health effects, "probable" means that limited or circumstantial evidence supports a relationship to pesticide exposure, and "possible" means that evidence neither supports nor contradicts a relationship (Mehler, 2011). More than one case can be associated with each episode. Pie chart (inset) summarizes conditions under which illnesses were reported, either by activity (fieldworker or handler) or manner of exposure (ingestion or exposure to dust from torn packaging). Numbers in the pie chart represent numbers of cases reported in each category.

Five of the eight ingestions were determined to be intentional, one appeared intentional, and the other two were mistaken ingestions from carbaryl that had been transferred to inappropriate containers (an unlabeled bag and a salt shaker). Five ingestion cases resulted in hospitalization lasting 1 – 18 days; these were the only hospitalizations reported among carbaryl-associated illnesses.

Table 4 summarizes types of symptoms reported. Handlers and fieldworkers reported different types of illnesses from one another. For example, handlers complaining of eye effects, such as irritation, pain, and blurry vision, did not have other types of symptoms. Furthermore, all seven cases had direct contact with carbaryl into their eyes. Three cases were not wearing eye protection (two of these were homeowners spraying around their own residences), and two were splashed behind protective eyewear. The remaining two cases did not say whether they were wearing eye protection.

In contrast to handlers, fieldworkers rarely had eye effects; only two cases had eye irritation, and in both cases skin rashes also occurred. Skin effects were more common among fieldworkers and individuals encountering torn packages than among handlers or others with carbaryl-associated illnesses.

Table 4. Types of Illness Cases Reported in California (1992 – 2009) [a]

Types of Symptoms Reported [b]	Activities and Exposure Conditions					Total
	Handler	Field-worker	Torn Package	Ingest	Other	
Skin	2	14	5	0	1	22
Eye	7	0	0	0	1	8
Skin, Eye	0	2	0	0	0	2
Respiratory	1	2	0	0	0	3
Skin, Respiratory	0	1	1	0	0	2
Systemic	8	21	0	5	1	35
Skin, Systemic	4	3	0	0	0	7
Respiratory, Systemic	4	1	0	3	8	16
Skin, Respiratory, Systemic	2	0	0	0	1	3
Eye, Respiratory, Systemic	0	0	0	0	4	4
Skin, Eye, Respiratory, Systemic	0	0	1	0	0	1
Total	28	44	7	8	16	103

[a] Illness cases that were definitely, probably, or possibly associated with carbaryl exposure. "Definite" means that both physical and medical evidence document exposure and consequent health effects, "probable" means that limited or circumstantial evidence supports a relationship to pesticide exposure, and "possible" means that evidence neither supports nor contradicts a relationship (Mehler, 2011; DPR, 2012b).

[b] Eye effects include irritation, pain, and blurry vision. Respiratory illnesses include sore throat, congestion, coughing, wheezing, and shortness of breath. Systemic illnesses include symptoms such as symptoms such as nausea, dizziness, headache, confusion, and weakness. Skin effects include irritation, rashes, itching, and blisters.

LABEL PRECAUTIONS AND CALIFORNIA REQUIREMENTS

Label Precautions

Warning statements on product labels differ according to the AI concentration in each formulation. WP formulations containing 80% carbaryl have the signal word of Warning; all other formulations have the signal word, Caution.

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

Products for Use in Agriculture

Following requirements in U.S. EPA (2008), label precautions were revised on all product labels. The following information occurs on the agricultural use product, Sevin® SL Carbaryl Insecticide, which contains 43% AI (California label approval date: 04/29/2010).

Precautionary Statement: CAUTION
Hazards to Humans & Domestic Animals: Harmful if absorbed through the skin, inhaled, or if in eyes. Avoid breathing vapors or spray mist. Avoid contact with eyes, skin or clothing. Keep out of reach of children and domestic animals.

PPE: Some materials that are chemical-resistant to this product are barrier laminate, nitrile rubber, neoprene rubber, or viton. lf you want more options, follow the instructions for category E on an EPA chemical resistance category selection chart.

Handlers applying with open cab airblast equipment at application rates equal to or greater than 5 quarts of product per acre must wear:

- Coveralls over long-sleeved shirt and long pants,
- Chemical-resistant gloves,
- Chemical-resistant footwear plus socks,
- Chemical-resistant headgear, and
- NIOSH-approved dust/mist filtering respirator with NIOSH/MSHA approval number prefix TC-21C or NIOSH-approved respirator with any N, R, P or HE filter

All other mixers, loaders, applicators, and handlers must wear:

- Long-sleeved shirt and long pants,
- Shoes plus socks,
- Chemical-resistant gloves, and
- Chemical-resistant apron, when mixing, loading, or cleaning up spills or equipment

In addition, mixers and loaders supporting aerial or chemigation applications must wear:

- NIOSH-approved dust/mist filtering respirator with NIOSH/MSHA approval number prefix TC-21C or NIOSH-approved respirator with any N, R, P or HE filter.

See engineering controls for additional requirements and exceptions.

ENGINEERING CONTROLS: Pilots must use an enclosed cockpit in a manner that is consistent with the WPS for Agricultural Pesticides [40 CFR 170.240(d)(6)].

Applicators using airblast equipment for application to citrus in California must use an enclosed cab that meets the definition in the Worker Protection Standard for Agricultural Pesticides [40 CFR 170.240(d)(5)] for dermal protection. In addition, such applicators must:

- wear long-sleeve shirt, long pants, shoes, and socks;
- either wear NIOSH-approved dust/mist filtering respirator with NIOSH/MSHA approval number prefix TC-21C or NIOSH-approved respirator with any N, R, P or HE filter or use an enclosed cab that is declared in writing by the manufacturer or by a

government agency to provide at least as much respiratory protection as this type of respirator;
- ♦ be provided and have immediately available for use and wear in an emergency when they must exit the cab in the treated area coveralls, chemical-resistant gloves, chemical-resistant footwear, and chemical-resistant headgear (if overhead exposure) plus - if not already using one - the respirator specified above;
- ♦ take off any PPE that was worn in the treated area before reentering the cab, and
- ♦ store all such PPE in a chemical-resistant container, such as a plastic bag, to prevent contamination of the inside of the cab.

Human flagging is prohibited, except for flagging to support ultra-low volume aerial applications for Rangeland Grasshopper and Mormon Cricket Suppression through the Animal and Plant Health Inspection Service (APHIS) Program or affiliated state program.

Flagging to support aerial application for all other use patterns is limited to use of the Global Positioning System (GPS) or mechanical flaggers.

Flaggers supporting ultra-low volume aerial applications for Rangeland Grasshopper and Mormon Cricket Suppression through the Animal and Plant Health Inspection Service (APHIS) Program or affiliated state program must use an enclosed cab that meets the definition in the Worker Protection Standard for Agricultural Pesticides [40 CFR 170.240(d)(5)] for dermal protection. In addition, flaggers must:
- ♦ wear long-sleeve shirt, long pants, shoes, and socks,
- ♦ either wear NIOSH-approved dust/mist filtering respirator with NIOSH/MSHA approval number prefix TC-21C or NIOSH-approved respirator with any N, R, P or HE filter or use an enclosed cab that is declared in writing by the manufacturer or by a government agency to provide at least as much respiratory protection as this type of respirator;
- ♦ be provided and have immediately available for use and wear in an emergency when they must exit the cab in the treated area coveralls, chemical-resistant gloves, chemical-resistant footwear, and chemical-resistant headgear, and, if using an enclosed cab that provides respiratory protection, a respirator of the type specified above,
- ♦ take off any PPE that was worn in the treated area before reentering the cab, and
- ♦ store all such PPE in a chemical-resistant container, such as a plastic bag, to prevent contamination of the inside of the cab.

When applicators use enclosed cabs in a manner that meets the requirements listed in the Worker Protection Standard (WPS) for agricultural pesticides [40 CFR 170.240(d)(5)], the handler PPE requirements may be reduced or modified as specified in the WPS.

Do not enter or allow worker entry into treated areas during the restricted-entry interval (REl). The REI for carbaryl is 12 hours unless otherwise specified in the directions for use associated with each crop.

PPE required for early entry to treated areas that is permitted under the Worker Protection Standard and that involves contact with anything that has been treated, such as plants, soil, or water is coveralls over short-sleeve shirt and short-pants, chemical-resistant footwear plus socks, chemical-resistant gloves made of any waterproof material, and chemical-resistant headgear if overhead exposure.

Residential-Use Products

The following precautionary statements came from the residential-use product, GardenTech® Sevin Ready-To-Spray Bug Killer, which is labeled for the control of pests on vegetables, fruits, and ornamentals (California label approval date: 8/25/2011).

Precautionary Statement: **Caution**
Hazards to Humans and Domestic Animals. Harmful if swallowed. Harmful if absorbed through skin. Harmful if inhaled. Avoid contact with skin, eyes or clothing. Avoid breathing vapor or spray mist. Wear long-sleeved shirt, long pants, shoes plus socks and household latex or rubber gloves when mixing and applying this product. Wear a hat and eye protection when making overhead applications. Remove clothing immediately if pesticide soaks clothing. Change clothing as soon as possible after use. Wash the outside of gloves before removing. Wash thoroughly after handling and before eating, drinking, chewing gum, using tobacco or using the toilet.

Restrictions

- Do not apply this product in a way that will contact any person or pet, either directly or through drift. Keep people and pets out of the area during application.
- Do not allow people or pets to enter the treated area until sprays have dried.
- For outdoor use only.
- Not for use on plants grown for sale, commercial use, or for commercial seed production.
- Use on lawns is prohibited.

In contrast, most labels on granular products and baits have user safety recommendations rather than requirements for residential users. As users can legally choose not follow the recommendations, exposure estimates for residential handlers of these products do not assume that protective clothing or PPE are used.

California Requirements

The product labels contain most of the requirements of the California regulations. However, 3 CCR 6738(b) requires that protective eyewear be worn during most mixing, loading and application activities. This requirement is not stated on product labels.

EXPOSURE SCENARIOS

An exposure scenario describes a situation where people may contact pesticides or pesticide residues, and in which the nature of the exposure as well as its magnitude (apart from variability among individuals and occasions) is relatively homogeneous. This exposure assessment is intended to address all exposure scenarios, and some scenarios for which exposure estimates are provided may represent many scenarios.

Occupational Handler

Occupational activities are categorized into agricultural (involved in production agriculture) and non-agricultural handlers. These activities reflect uses permitted on current labels registered in California. Occupational agricultural handler activities include mixer/loader (M/L), applicator, mixer/loader/applicator (M/L/A), loader/applicator (L/A), and flagger. On current carbaryl product labels, human flaggers are prohibited except to assist aerial applicators (pilots) during APHIS applications, when they are required to be in a closed cab and must wear label-specified PPE. Agricultural handler scenarios are listed in Table 5.

Table 5. Agricultural Handler Scenarios for Carbaryl

Activity [a]	Formulation	
	Liquid [b]	Granular/Bait [c]
Aerial M/L [d]	x	x
Aerial Applicator [d]	x	x
Flagger [d]	x	x
Airblast M/L	x	
Airblast Applicator	x	
Airblast M/L/A	x	
Groundboom M/L [d]	x	
Groundboom Applicator [d]	x	
Groundboom M/L/A	x	
Chemigation M/L [e]	x	
Right-of-Way M/L	x	
Right-of-Way Sprayer	x	
Low Pressure Handwand M/L/A	x	
Backpack M/L/A	x	
High Pressure Handwand M/L/A	x	
Broadcast Spreader L/A		x
Push-Type Spreader L/A		x

[a] Based on product labels approved by the California Department of Pesticide Regulation. No agricultural use of the dust formulation is allowed (U.S. EPA, 2008). L/A is loader/applicator. M/L is mixer/loader. M/L/A is mixer/loader/applicator.
[b] Includes aqueous suspension, aqueous concentrate, and flowable concentrate, all of which are diluted before use.
[c] Granular/bait products are not mixed with water before use, but are applied in solid form.
[d] These activities involve treatment of typical field sizes, as well as high-acre applications, which are considered as separate scenarios.
[e] Chemigation is allowed through either a center pivot or a solid set sprinkler (not hand-move irrigation).

Handlers may be growers treating their own crops or custom applicators; custom applicators may treat crops for many different growers (Haskell, 1998). Handler exposures are assumed to be generally independent of crop and to be dependent upon formulation, application method and amount handled. Separate exposure scenarios were assessed for each unique combination of application method and formulation; liquid formulations were grouped together.

Non-agricultural handler scenarios are listed in Table 6. Some applicator scenarios involve ready-to-use liquid and dust products, which do not require mixing and loading before application; hand spread of bait does not require mixing and loading, either.

Occupational non-agricultural handlers include M/L, applicator, M/L/A for rights-of-way, invertebrate control, turf and landscape maintenance, residential properties, office buildings, and other handler activities not involved in production agriculture.

Table 6. Non-Agricultural Occupational Handler Scenarios for Carbaryl

Activity [a]	Formulation			
	Liquid [b]	Granular and Bait [c]	Dust [c]	Ready-to-Use Liquid
Groundboom M/L	x			
Groundboom Applicator	x			
Groundboom M/L/A	x			
Broadcast Spreader L/A		x		
Right-of-Way M/L	x			
Right-of-Way Sprayer	x			
Low Pressure Handwand M/L/A	x			
Backpack M/L/A	x			
High Pressure Handwand M/L/A	x			
Push-Type Spreader L/A		x		
Shaker Can Applicator		x	x	
Hose End Sprayer M/L/A				x
Trigger Spray Applicator				x

[a] Based on product labels registered by DPR. L/A is loader/applicator. M/L is mixer/loader. M/L/A is mixer/loader/applicator.
[b] Includes aqueous suspension, aqueous concentrate and flowable concentrate, all of which are diluted before use.
[c] Granular/bait and dust products are not mixed with water before use, but are applied in solid form.

Occupational Post-Application

Occupational reentry scenarios are considered differently depending on whether or not the reentry is regulated under 3 CCR 6760–6778. California requirements are at least as strict as, and consistent with, the Worker Protection Standard (WPS) in Title 40 of the Code of Federal Regulations (40 CFR), Parts 156 and 170. The WPS regulates "occupational exposures to pesticides used in the production of agricultural plants on farms or in nurseries, greenhouses, and forests, and also from the accidental exposure of workers and other persons to such pesticides" (40 CFR 170.1). Under 3 CCR 6772–6774, reentry into treated fields and other production agricultural areas is restricted for a specific interval (the restricted entry interval, or REI) following pesticide applications. Because of the REI, agricultural reentry regulated under 3 CCR 6181-6182 is assessed differently than non-agricultural reentry.

Agricultural Reentry Scenarios (Activities in Production Agriculture)

Agricultural reentry activity information was obtained from several sources, including the California Farm Worker Activity Profile (CFWAP; Edmiston *et al.*, 1999); a survey of growers in California and surrounding states (Thompson, 1998); crop profiles published by the University of California (UCCE, 2012); and consultation with scientists from DPR's Exposure Monitoring and Health Investigation Program. Agricultural reentry exposure scenarios considered in this exposure assessment are listed in Appendix 1.

Carbaryl is registered for use on numerous crops, and many reentry activities are possible in each crop. It would be desirable to have exposure estimates for each of these crop/activity combinations (scenarios). However, little information is available for many scenarios, and several scenarios are likely to result in similar exposures. For these reasons, representative reentry exposure scenarios were selected based on available information about the extent of foliar contact for each activity, and the resulting potential for residue transfer.

Use sites listed on carbaryl product labels registered in California are given in Appendix 1, along with reentry activities expected to occur in each. Also, the maximum application rate allowed for each use site, and the shortest preharvest interval (PHI; for assessing occupational exposure during harvest) for each crop, are given in Appendix I. Reentry activities other than harvesting were assessed at the expiration of the REI, which is 12 hours for most crops.

For agricultural reentry scenarios, representative scenarios were determined by first grouping application sites, then by selecting activities within each group that would be anticipated to have the highest potential for exposure. Crops were grouped by growth form (e.g., tree) and by similar cultural practices. For example, pome and stone fruit crops were grouped together, as were olives and tree nut crops. Field crops such as alfalfa and corn were considered together. Lettuce and other leafy vegetables that are close to the ground were assessed as a group. Tomatoes, eggplants and peppers, which have fruit above ground, were considered together, as were crops such as potatoes, carrots, and peanuts, which are underground. Berries were grouped together, except strawberries, which were considered separately because they are low to the ground and other berries are not. These crop groups are summarized in Table 7. Reentry into treated forests, rangeland and pastures is not anticipated to result in appreciable exposure to carbaryl.

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

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

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

Table 7. Crop Groups for Selecting Representative Scenarios

Category [a]	Representative Crop	Crops Included [b]
FC	Corn	Field crops (e.g., alfalfa, clover, field corn, popcorn, rice, sorghum, soybean, sweet corn)
FN	Olive	Tree nuts and tree plantations (e.g., almond, chestnut, Christmas tree, filbert, pecan, pistachio, walnut)
FN	Apple	Pome and stone fruits (e.g., apricot, crabapple, loquat, nectarine, pear, peach, persimmon, prune, plum)
FN	Blackberry	All berries except strawberries (e.g., blueberry, Boysenberry, cranberry, Loganberry, Marionberry, raspberry)
FN	Citrus	All citrus (e.g., lemon, lime, grapefruit, orange, tangerine)
M	Turf	Sod and lawns (including residential and public areas such as parks and golf courses)
OT	Ornamental Plants	Ornamental trees, shrubs, and flowers; also, vegetables for transplant
V	Beans	Beans and peas (e.g., dried beans, succulent beans, dried peas)
V	Cabbage	Crucifers (e.g., broccoli, Brussels sprouts, cauliflower, Chinese cabbage, celery, kohlrabi)
V	Lettuce	Leafy greens (e.g., collards, head lettuce, kale, leaf lettuce, mustard greens, parsley, spinach)
V	Cucumber	Cucurbits (e.g., melons, pumpkin, squash)
V	Potato	Root vegetables (carrots, garden beets, horseradish, parsnip, peanut, potato, radish, sugar beet, sweet potato, turnip)
V	Tomato	Fruiting vegetables (e.g., eggplant, peppers, pricklypear cactus)

[a] FC = Field Crops; FN = Fruits and Nuts; OT = Ornamentals, Nursery/Greenhouse; V = Vegetables.
[b] Crops addressed separately (i.e., no other crops in group) include asparagus, grape, strawberry, and tobacco (which is grown in university and small farm plots in California).

Table 8 summarizes representative occupational reentry scenarios for carbaryl. Exposure estimates generated for representative scenarios are anticipated to be the best available for other scenarios as indicated. The last column in Table 8 lists activities and crops covered by the representative scenario. Scenarios grouped under a representative scenario are not all expected to have identical exposures; however, the representative scenario is anticipated to involve exposures similar to or greater than all scenarios covered by it. In other words, representative scenarios might overestimate exposure for other scenarios, but should not underestimate exposure. For example, detasseling in corn is the representative scenario that covers all activities in alfalfa, clover, corn, rice, sorghum, and soybeans. Because of the height and foliar density of corn as it matures, reentry into a treated cornfield is likely to result in more exposure than reentry in alfalfa, soybeans, or most other field crops. Additionally, many activities in these crops, such as irrigating or mechanical harvesting, would be anticipated to result in lower exposures per full workday than detasseling corn. Hand harvesting is not done in most commercial field crops, and is specifically prohibited for field corn and sweet corn treated with carbaryl.

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

Table 8. Representative Occupational Reentry Scenarios for Carbaryl

Crop [a]	Rate [b]	Activity [c]	Represents [d]
Apple	3	Thinning (REI)	All activities in pome and stone fruits
Asparagus	2	Hand Harvest (PHI: 1)	All activities in asparagus
Beans	1.5	Scouting (REI)	All activities in beans and peas
Blackberry	2	Pruning (REI)	Activities in all berries except strawberry
Cabbage	2	Scouting (REI)	All activities in crucifers
Citrus	8	Pruning (REI: 3 d)	All activities in citrus
Corn	2	Detasseling (REI: 21 d)	All activities in field crops
Cucumber	1	Scouting (REI)	All activities in all cucurbits
Grape	2	Leaf Pulling (REI)	All activities in grapes
Lettuce	2	Scouting (REI)	All activities in leafy greens
Olive	7.5	Pruning (REI: 3)	Activities in tree nuts and tree plantations
Ornamental Plants	1	Hand Harvest (PHI: 0)	Activities in all nursery and greenhouse plants, and working with quarantined treated commodities.
Potato	2	Scouting (REI)	All activities in root vegetables
Turf	8	Maintenance (PHI: 0)	Sod growing, harvesting, and installation; turf maintenance on lawns, golf courses, etc.
Strawberry	2	Scouting (REI)	All activities in strawberry
Tobacco	2	Hand Harvest (PHI: 2)	All activities in tobacco
Tomato	2	Staking/Tying (REI)	All activities in tomato, eggplant, etc.

[a] Representative crops from Table 7.
[b] Maximum application rate allowed on crop in pounds of active ingredient per acre (lbs AI/acre).
[c] PHI: preharvest interval; number of days. REI: restricted entry interval; REI is 12 hours (i.e., on Day 0) unless otherwise stated as number of days. Exposures in crops with PHI = 0 are assessed at the day the REI expires.
[d] All scenarios covered by the representative crop and activity are anticipated to have exposure equivalent or less than that of the representative scenario. See Table 7 for specific crops covered by each scenario.

<u>Non-Agricultural Occupational Reentry Scenarios</u>

Non-crop occupational use sites include adult mosquito control; fire ant control; applications to rights-of-way; ornamental and residential turf; and quarantine uses. Reentry into areas treated for adult mosquito control is anticipated to involve minimal exposure, and to be similar to reentry into areas treated for fire ants and rights-of-way.

Reentry activities in treated turf would include landscape and golf maintenance activities such as mowing and weeding. Installation of sod onto private or commercial lawns is a high-contact activity in which pieces of sod are carried by hand, and often held against the body, then placed on the ground and moved into position. During sod installation, workers laying sod will crawl across newly laid pieces to position them and to trim excess.

Finally, reentry into areas where carbaryl was applied for quarantine uses involves handling treated commodities and is considered to be covered by reentry into greenhouse or nursery ornamentals listed in Table 7.

Residential Handler

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

Table 9. Residential Handler Scenarios for Carbaryl

Activity [a]	Formulation Type			
	Liquid [b]	Granular/Bait [c]	Dust [c]	Ready-to-Use Liquid
Backpack M/L/A	x			
Low Pressure Handwand M/L/A	x			
Trigger Sprayer Applicator				x
Hose End Sprayer M/L/A	x			
Push-type Spreader L/A		x		
Shaker Can Applicator		x	x	

[a] Based on product labels registered by DPR. L/A is loader/applicator. M/L/A is mixer/loader/applicator.
[b] Includes aqueous concentrate, suspension, and flowable concentrate, all of which are diluted before use.
[c] Granular/bait and dust products are not mixed with water before use, but are applied in solid form.

Residential Post-Application

Residential reentry exposures include reentry onto treated turf (e.g., lawns or golf courses), activities in gardens where carbaryl has been applied, thinning and harvesting of fruit from trees treated with carbaryl, and swimming in waters such as farm ponds, canals, or rivers receiving agricultural inflows. Each of these scenarios includes exposures via non-dietary ingestion as well as by the dermal route. These components are summarized in Table 10.

Post-application exposures following carbaryl use on gardens or residential or commercial orchards open to the public are anticipated to be less than exposure for the corresponding occupational scenarios.

Table 10. Representative Residential Reentry Scenarios for Carbaryl

Scenario [a]
LAWNS
Post-application dermal exposure from pesticide residues on turf following residential use (adult and toddler)
Post-application exposure among toddlers from incidental nondietary ingestion of pesticide residues on residential lawns via hand-to-mouth transfer, object-to-mouth transfer, and soil ingestion
SWIMMING IN RECEIVING WATERS AFTER AGRICULTURAL USE
Post-application exposure from incidental nondietary ingestion of pesticide residues while swimming
Post-application dermally absorbed dose from swimming in receiving water containing pesticide residues

[a] Adapted from (U.S. EPA, 1997b).

Ambient Air, Bystander, and Swimmer

Bystanders include individuals, working or not, who are not directly involved with a pesticide application but who may be exposed to airborne pesticide during or after the application, by drift or volatilized pesticide. Bystanders can be exposed from agricultural and public pest control applications. Ambient air monitoring was conducted by the California Air Resources Board (ARB) in three counties with relatively high carbaryl use (Fresno, Tulare, and Kings), during times when peak use was anticipated. Results of these studies suggest that airborne carbaryl exposures to the public are possible in areas that are far from application sites. Pesticide residues in surface waters such as lakes, rivers, and canals, may result in exposure for swimmers. Representative scenarios for ambient air and bystander exposures include infants and adults. Representative scenarios for swimmer exposures include children and adults. Infants or children are included as potential worst-case scenarios, and exposure estimates are included for adults to allow comparison with other types of scenarios.

PHARMACOKINETICS

Dermal Absorption

Dermal absorption is a major exposure route for pesticide handlers and for individuals contacting treated plants and other surfaces (Durham and Wolfe, 1962). For most pesticides, including carbaryl, only part of the amount contacting the skin is absorbed (Feldmann and Maibach, 1974); dermal absorption is factored into the exposure estimates in this exposure assessment. Several *in vivo* and *in vitro* studies investigating the dermal penetration of carbaryl have been conducted; studies available to DPR were discussed in detail and reviewed by Beauvais (2006a).

In Vivo Studies

The dermal absorption of carbaryl has been investigated in humans, rats, and mice. These studies are summarized in Table 11.

Table 11. Summary of *In Vivo* Dermal Absorption Studies for Carbaryl

Subjects	N [a]	Label Position [b]	Dose [c]	Vehicle	Exposure Duration [d]	Total Duration [d]	Absorption (%) [e]
Human, Male [f]	6	Not specified	4	Acetone, 0.1 ml	24	120	73.9
Rat, Male [g]	**3**	**Naphthyl-1**	**4**	**Acetone, 0.1 ml**	**4 – 120**	**120**	**72.1**
Mouse, Female [h]	3	Methyl	1 mg/kg	Acetone, 0.1 ml	< 1 – 48	< 1 – 48	88.5
Rat, Male [i]	4	Naphthyl-1	43.5	Acetone, 0.2 ml	0.5 – 168	0.5 - 168	NR
Rat, Female [j]	3	Naphthyl-1	31/37	Acetone, 0.1 ml	72	72	NR
Rat, Female [k]	2-5	^{3}H, Ring	0.9	Benzene	< 1 – 24	< 1 – 24	NR
Rat, Male [l]	3	Methyl	0.19	Ethyl alcohol	4	20	NR
Rat, Male [m]	4	Naphthyl-1	35.6	CMC [n]	0.5 – 24	0.5 – 24	21.2

[a] Number of replicates per dose and duration. Studies were discussed in detail by Beauvais (2006a).

[b] Position of radiolabel on molecule. Radiolabel was ^{14}C and the radiopurity of all labeled chemicals was > 99%, unless otherwise specified.

[c] Lowest applied dose of carbaryl, reported in µg/cm² unless otherwise specified.

[d] Exposure duration and total test duration in hours. Total test duration includes exposure and subsequent observation, until test termination.

[e] Dermal absorption at intervals up to 24 hours, reported as percent of applied dose, including bound skin residues. Estimated dermal absorption for carbaryl of 70% used in exposure assessment was based on the 8-hour dose in the study shown in bold (Shah and Guthrie, 1983). Reasons for not relying on other studies are given in footnotes below. NR: Not reported; no result reported within first 24 hours.

[f] Feldmann and Maibach (1974). Because results were based on portion of radiolabel recovered from urine, and only 7.4% was recovered following an IV dose, this result was not used to estimate absorption. Radiopurity was not reported. Result shown is from 24 hours, after administered dose was washed off.

[g] Shah and Guthrie (1983). Doses were not washed off until animals were euthanized at 4, 8, 12, 24, 48, and 120 hours post-dose; result shown is at 12 hours, as measured by direct method (summed radiolabel recovered from carcass and excretions). The estimated dermal absorption of 70% was based on this study.

[h] Shah *et al.* (1981). Dose was reported as mg/kg, applied to 1-cm² area. Doses were not washed off until animals were euthanized at 1, 5, 15, 60, 480, and 2880 minutes post-dose. Because applied doses were not washed off, were not protected, and might have been ingested during grooming, these data were not used to estimate absorption. Result shown is 8-hour geometric mean penetration, based on disappearance of radiolabel from application site.

[i] Knaak *et al.* (1984). Radiopurity was > 98%. Doses were not washed off until animals were euthanized at 0.5, 1, 4, 8, 12, 24, 48, 72, 96, 120, 144, and 168 hours post-dose. Because the material balance was poor (65% of applied radioactivity recovered) and results were not reported for intervals shorter than 165 hours, these data were not used to estimate absorption.

[j] Shah *et al.* (1987). Lowest dose was 31 µg/cm² applied to 33 day-old rats and 37 µg/cm² applied to adult rats; the high dose in this study was 3,450 µg/cm². Because of relatively high applied doses and the overly long 72-hour exposure duration, these data were not used to estimate absorption.

[k] O'Brien and Dannelley (1965). Radiolabel was ^{3}H; doses were applied to shaved belly of each animal. Doses were not washed off until animals were euthanized at 3 minutes and 1, 3, 4, 6, 18, and 24 hours post-dose. In another experiment, vehicle was 0.1 ml of either acetone, benzene, or corn oil; test duration was 3 hours. Results were reported as amount of radioactivity remaining in skin, rather than as recovered radioactivity, and it is unclear whether doses were washed for before analysis. These data were not used to estimate absorption.

[l] Tos-Luty *et al.* (2001). Tails were soaked in a solution of carbaryl dissolved in ethyl alcohol. Because of the non-standard test method (in particular the application site), these data were not used to estimate absorption.

[m] Cheng (1995). Vehicle was 1.0% carboxymethyl cellulose. Doses were not washed off until animals were euthanized at 0.5, 1, 2, 4, 10, and 24 hours post-dose. Because of relatively high applied doses, these data were not used to estimate absorption.

[n] CMC: carboxymethyl cellulose.

Results from a well-conducted human study would be anticipated to predict dermal absorption in persons exposed to carbaryl. However, the only human study available (Feldmann and Maibach, 1974) was conducted with an inappropriate solvent vehicle (acetone) and had low recovery of the radiolabel in urine samples (average of just 7.4% of an IV dose). Conversely, the dose applied in this study was realistic with regard to anticipated exposure levels. This study is discussed below.

Feldmann and Maibach (1974) measured dermal penetration of carbaryl in six human subjects. Applications were on the ventral side of the forearm at a dose of 4 µg/cm² over an area of 2.8 – 20 cm² with ^{14}C-carbaryl in 0.1 ml acetone (the position of the radiolabel on the molecule was unspecified). The dose site was not protected, and subjects were asked not to wash the area for 24 hours. Urine collections lasted 120 hours. To correct the dermal absorption for incomplete elimination, an intravenous (IV) dose of carbaryl was administered to the subjects at another time; an average of just 7.4% of the IV dose was excreted in urine. Mean urinary excretion of the dermally applied dose, corrected for urinary excretion of the IV-applied dose, was 73.9% (5.5% uncorrected), with a standard deviation of 21.0%. However, the absorption estimate is predominantly influenced by the correction used to address the low recovery of the radiolabel in urine. This study provides limited support for an estimate of carbaryl's dermal absorption.

In addition to the single study conducted in humans, six studies were conducted in rats and one study was conducted using female mice. Of the seven animal studies, four used acetone as a vehicle (Shah *et al.*, 1981; Shah and Guthrie, 1983; Knaak *et al.*, 1984; Shah *et al.*, 1987), and two others also used organic solvents as vehicles, benzene and ethyl alcohol (O'Brien and Dannelley, 1965; Tos-Luty *et al.*, 2001). The seventh study used an appropriate vehicle consistent with a formulated product, but applied elevated doses of one to three orders of magnitude above anticipated exposure levels, which can result in an underestimate of penetration (U.S. EPA, 1998a; Thongsinthusak *et al.*, 1999). Beauvais (2006a) compared results across studies and showed that the relatively high doses used by Shah *et al.* (1987) and Cheng (1995) resulted in relatively low penetration compared with studies using lower doses; for this reason estimated dermal was not based on these studies. The use of an acetone vehicle did not correlate with higher absorption (Beauvais, 2006a). Four other studies were not used because of non-standard test methods that confound interpretation of results (O'Brien and Dannelley, 1965; Shah *et al.*, 1981; Knaak *et al.*, 1984; Tos-Luty *et al.*, 2001).

Shah and Guthrie (1983) applied 1 µCi carbaryl in acetone intraperitoneally to six male rats. Urine and feces were collected at several time intervals up to 120 hours post-dose. For dermally dosed animals, ^{14}C-carbaryl was applied to the midback region (shaved 24 hours earlier), at a dose of 4 µg/cm² in 0.1 ml acetone. Groups of three rats were euthanized at 4, 8, 12, 24, 48, and 120 hours post-dose; urine and feces were collected separately. Blood, liver, application site (skin patch), and carcass were assayed for ^{14}C. Total radioactivity recovered in all treatment groups was > 90%; results were reported as % of recovered dose. After 120 hours, mean excretion of ^{14}C from IP-dosed rats was 83.52%; time for 50% urinary clearance of the total dose was about 6.5 hours. A correction factor of 1.2 was based on the IP dose. Applying the correction factor to the indirect dermal dose, at 12, 24, and 120 hours the mean dermal absorption was 65.1%, 76.0%, and 91.3 %, respectively. In comparison, the direct dermal absorption at 12, 24, and 120 hours was 72.1%, 75.1%, and 95.7 %, respectively. The direct dermal absorption estimate at 12 hours (72.1%) supports a single-day estimated dermal absorption of 70%.

In Vitro Studies

Three studies are available, two using porcine skin sections as membranes (Chang *et al.*, 1994; Baynes and Riviere, 1998) and one using rodent skin (MacPherson *et al.*, 1991). These studies were reviewed by Beauvais (2006a), and results pertinent to exposure estimates in the carbaryl risk assessment are briefly summarized in Table 12. Although the dosing vehicles and receptor solutions varied, as well as membrane sources and other test conditions, all of the studies applied the same dose of 40 µg carbaryl/cm². The portion of applied carbaryl penetrating rat skin varied depending on the receptor solution used (MacPherson *et al.*, 1991).

Chang *et al.* (1994) assessed the dermal penetration of carbaryl dissolved in an ethyl alcohol solution across a perfused porcine skin flap at a dose rate of 40 µg/cm². Monitoring of the absorption from the afferent venous system took place for 8 hours, after which an average of 4.22% of the applied carbaryl dose had crossed the membrane; 45% was recovered from the membrane itself, and 21% was recovered from the dosing patch.

Table 12. Summary of *In Vitro* Dermal Absorption Studies for Carbaryl

Membrane Source	N [a]	Dose (µg/cm²)	Vehicle	Receptor Solution [b]	Test Duration [c]	Absorption (%) [d]	Penetration (%) [e]
Porcine Skin [f]	4	40	Ethanol, ~0.1 ml	Perfusate	0.5 – 8	4.22	49
Porcine Skin [g]	4	40	40% Acetone, 0.01 ml	Perfusate	1 – 8	9.46	20
Porcine Skin [g]	4	40	80% Acetone, 0.01 ml	Perfusate	1 – 8	6.51	18
Porcine Skin [g]	4	40	40% DMSO, 0.01 ml	Perfusate	1 – 8	2.94	37
Porcine Skin [g]	4	40	80% DMSO, 0.01 ml	Perfusate	1 – 8	2.14	29
Rat, Male [h]	8	40	Acetone, 0.01 ml	50% Ethanol	0.5 – 7.5	2.76	34
Rat, Male [h]	8	40	Acetone, 0.01 ml	0.9% Saline	0.5 – 7.5	0.77	42

[a] Number of replicates per duration. Studies were discussed in detail by Beauvais (2006a). All studies used ^{14}C radiolabel at the 1-naphthyl position of the molecule.

[b] Radiolabel recovered from receptor solution was considered absorbed. Perfusate solutions are described in footnotes f and g below.

[c] Test duration in hours. Sampling was done at half-hour or hour intervals.

[d] Dermal absorption, reported as percent of applied dose recovered in the receptor cell. The cumulative absorption for 7.5 – 8 hours is reported.

[e] Dermal penetration, reported as total percent of applied dose recovered in the receptor cell and membrane (included as bound skin residues). The cumulative absorption for 7.5 – 8 hours is reported.

[f] Chang *et al.* (1994). Specific activity of the radiolabel was 10.9 mCi/mmol, with radiopurity > 98%. Skin flap was perfused with oxygenated (95% O_2, 5% CO_2) Krebs-Ringer bicarbonate buffer spiked with glucose and bovine serum albumin. On average, a total of 69.4% of the applied dose was recovered.

[g] Baynes and Riviere (1998). Specific activity of the radiolabel was 8.4 mCi/mmol. Radiopurity was not reported. Perfusate was oxygenated (95% O2, 5% CO2) Krebs-Ringer bicarbonate buffer spiked with glucose and bovine serum albumin. Dosing vehicle was either 40% or 80%, either acetone or dimethyl sulfoxide (DMSO). A flow-through diffusion cell was used, and each treatment was replicated 4 – 7 times (replication was not specified for individual treatments).

[h] MacPherson *et al.* (1991). Specific activity of the radiolabel was 58 mCi/mmol. Radiopurity was not reported. Hourly sampling was conducted from 0.5 to 7.5 hours.

Baynes and Riviere (1998) examined penetration of 40 µg/cm² of ^{14}C-carbaryl applied in two solvent vehicles, acetone and dimethyl sulfoxide (DMSO). Vehicle (acetone or DMSO) concentrations were 40% or 80%. Porcine skin disks (removed from the dorsal surface of weanling pigs) with an exposed area of 3.2 cm² and approximately 150 – 200 µm thickness were perfused at a flow rate of 4.0 ml/hour with Krebs-Ringer bicarbonate buffer. Perfusate samples were collected hourly for 8 hours; at the end of the 8-hour interval skin sections were swabbed twice with a soapy solution and tape-stripped six times. Absorption, defined as the portion of applied dose recovered from the receptor cell, was on average 2.14% – 9.46% of carbaryl applied in acetone and DMSO vehicles. Penetration was defined as the sum of applied radiolabel recovered from the receptor cell, the stratum corneum, and the skin, which effectively includes bound skin residues in the estimate. After 8 hours, mean dermal penetration of carbaryl in acetone ranged from 18% to 20%. Mean dermal penetration of carbaryl in DMSO ranged from 29% to 37%.

MacPherson *et al.* (1991) investigated dermal penetration and metabolism of carbaryl in the dorsal skin of rats, using an open-top static *in vitro* system. Square sections of dorsal skin about 2 cm² were mounted in a diffusion cell, with about 1.18 cm² exposed to the air in the donor cell. The exposed portion received 40 µg/cm² of ^{14}C-carbaryl in 0.01 ml of acetone. In various trials, receptor solutions were either 50% ethyl alcohol in water, 0.9% sterile saline, or tissue culture medium prepared from Earle's salt base. Receptor fluid was sampled (0.05 ml) and replaced with fresh solution at intervals ranging between 0 and 7 hours after carbaryl application. At 7.5 hours post-application, the test was terminated and skin and receptor solution analyzed. Of the three receptor solutions, ethyl alcohol acquired the most ^{14}C, with a mean of 2.76% of the applied dose. Saline acquired 0.77% of the applied dose and Earle's culture medium acquired an average of 0.95% of the applied dose. Conversely, bound-skin residues of carbaryl were lower when the receiving solution was ethyl alcohol, 31% of the applied dose compared to 41% and 35.5% for saline and Earle's medium. Including bound-skin residues as potentially absorbable would result in dermal absorption estimates from this study of 34% – 42%.

Data from *in vitro* studies were not used to determine dermal absorption for the purpose of exposure assessment. One reason they were not used is that the applied dose in all available *in vitro* studies was 40 µg/cm², which was likely too high for most anticipated carbaryl exposures. This dose is similar to the 35.6 µg/cm² applied in the *in vivo* study by Cheng (1995). Dermal absorption (including bound skin residues) reported at that dose in the *in vivo* study was 21.5%, which was in the range of the 20% – 42% estimated from *in vitro* data, suggesting that an *in vitro* study with lower dose levels might confirm the approximately 70% dermal absorption estimated from *in vivo* studies with an applied dose of 4 µg/cm² (Feldmann and Maibach, 1974; Shah and Guthrie, 1983). Another reason is that the various methods used in the studies summarized in Table 12 yielded a range of values, although the applied dose was the same. As noted by Frank (2009c), no standardized methodology exists for the conduct of *in vitro* studies. It is unclear which *in vitro* methods would yield the best estimate of dermal absorption. These concerns are discussed in the Exposure Appraisal.

U.S. EPA Estimate of Dermal Absorption of Carbaryl

U.S. EPA's Hazard Identification Assessment Review Committee (HIARC) established a dermal absorption value to be used in the carbaryl risk assessment of 12.7% (Dobozy, 2002). HIARC determined that value based on the absorption of the low dose from Cheng (1995), following 10 hours exposure. U.S. EPA excluded bound skin residues in estimating dermal penetration; had U.S. EPA included those residues, the resulting dermal absorption estimate would have been 21.2% (for the calculation see Table 2 in Beauvais, 2006a).

Following submission of an *in vitro* comparative dermal penetration study using rat skin and human skin (a study which was not submitted to DPR), U.S. EPA later determined that rat skin was approximately 2.8 times more permeable than human skin (Shah, 2007). Rather than divide 12.7% by 2.8 (which would give an estimated human dermal absorption of 4.5%), U.S. EPA (2008) instead adjusted its dermal toxicity estimate 2.8-fold. See the Exposure Appraisal for a discussion of *in vitro* dermal absorption data.

In its risk assessment for carbaryl, Health Canada's Pest Management Regulatory Agency (PMRA) used a dermal absorption value of 21% (PMRA, 2009). PMRA (2009) did not discuss how its dermal absorption estimate was determined.

Dermal Absorption Estimate Used in Exposure Assessment

The dermal absorption estimate used in the exposure assessment is 70%, based on the dermal absorption in rats following 12 hours exposure to carbaryl (Shah and Guthrie, 1983).

Inhalation Absorption

In addition to dermal absorption, inhalation is the other major route of exposure in the scenarios considered in this exposure assessment. No inhalation absorption studies are available. However, results of a laboratory study suggest that carbaryl is readily absorbed from the lungs when instilled intratracheally (Hwang and Schanker, 1974). The absorption of 0.1 ml of a carbaryl solution (2.5 – 5.0 µM) injected into the trachea of rats (three rats per treatment) was determined in 2-minute intervals. About 50% of the carbaryl was absorbed after 2.6 minutes. The absorption rate was similar for solution concentrations of 2.5 µM and 5.0 µM, suggesting that at these concentrations saturation was not occurring (Hwang and Schanker, 1974).

In the absence of inhalation absorption data, and with the difficulty of extrapolating the methodology of Hwang and Schanker to an inhalation model, a default inhalation absorption value of 100% was used for calculations of doses absorbed via inhalation in accordance with DPR policy (Frank, 2008).

Animal Metabolism/Pharmacokinetics

Data on pharmacokinetics are useful if biomonitoring studies are available. Preliminary studies have investigated the feasibility of biomonitoring to assess human exposure to carbaryl; these are discussed below. Carbaryl metabolism has been investigated in many animal species, from mammals (including humans) to birds. These studies are too numerous to address comprehensively in this exposure assessment; discussion is limited to pertinent data on carbaryl metabolites found in urine of humans and monkeys.

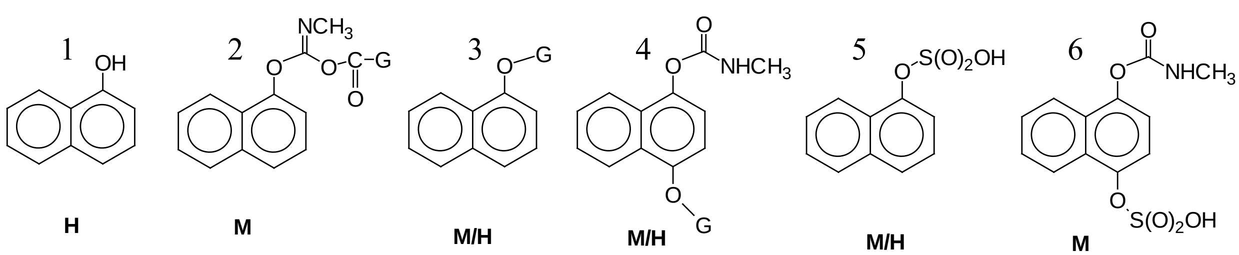
Human

Knaak *et al.* (1968) examined the metabolism of carbaryl after an oral administration in humans with unlabeled carbaryl, and in monkeys, pigs and sheep with ^{14}C-ring and *N*-methyl labeled carbaryl. Figure 3 illustrates the metabolites isolated from monkey and human urine. In the part of the study using human subjects, two men weighing 81.5 and 86.5 kg swallowed a carbaryl dose of 2.0 mg/kg in a gelatin capsule. Urine was collected from them in 4-hour intervals over 24 hours post-dose, then four 24-hour pooled urine samples were collected. Analysis of the urine by a colorimetric method indicated the presence of 1-naphthol (structure number 1 in Figure 3), which accounted for 37.8% of the administered dose. Other metabolites identified in urine included 1-naphthyl sulfate (5), 1-naphthyl glucuronide (3), and 4-(methylcarbamoyloxy)-1-naphthyl glucuronide (4). With only two subjects, lack of material balance, and older analytical methods, this study is of limited usefulness.

Monkey

Knaak *et al.* (1968) used a 4.59 kg-female rhesus monkey for two metabolism studies. In the first study, ^{14}C ring-labeled carbaryl (specific activity 11.1 µCi/mmole) was orally administered at a dose of 300 mg/kg. In the second study, conducted four days later, Knaak *et al.* (1968) administered ^{14}C methyl-labeled carbaryl orally at the same dose. The monkey was held in a cage for two days for collection of urine and feces. The authors provided no indication of the proportion of the radioactivity excreted in urine versus feces. Chromatography of the urine over a DEAE-cellulose column provided metabolite speciation data. The major metabolites identified in this study were 1-naphthyl methylimidocarbonate glucuronide (2), 1-naphthyl sulfate (5), and 4-(methylcarbamoyloxy)-1-naphthyl sulfate (6).

Figure 3. Carbaryl Metabolites from Human and Monkey Urine (Knaak *et al.*, 1968)



Key: H – Human; **M** – Monkey; G – glucuronide.

Animal and human metabolism studies - Role of biomonitoring in exposure assessment

These metabolism data suggest that it may be possible to estimate carbaryl exposure via assessment of the titer of 1-naphthol in the urine. However, before execution of any human exposure studies, a study of the pharmacokinetics after dermal administration of carbaryl is required to evaluate the pharmacokinetics following dermal absorption and determine the length of time after exposure that urine samples should be collected to ensure a representative estimate of the absorbed dose. Additionally, as 1-naphthol is also a metabolite of other compounds such as polycyclic aromatic hydrocarbons, concurrent analysis of samples for other carbaryl metabolites, or for biomarkers such as 2-naphthol that are not major metabolites of carbaryl, might help differentiate the source of 1-naphthol (Hecht, 2002). Petropoulou *et al.* (2006) proposed an analytical method that would allow source differentiation by simultaneous analysis of multiple carbaryl metabolites to estimate exposure.

A few preliminary studies show potential promise, as well as the potential for confounding in estimating carbaryl exposure from urinary biomonitoring. For example, Shealey *et al.* (1997) conducted a pilot study with a farmer who applied carbaryl and his family, in which environmental and dermal measurements of carbaryl were correlated with urinary excretion of 1-naphthol. In another pilot study, sampling of five pesticide applicators who had applied carbaryl using a handheld sprayer and ten controls who had not applied pesticides, both 1- and 2-naphthol were found in samples from applicators (Petropoulou *et al.*, 2006). Samples from non-applicators who were heavy smokers also had these metabolites, but in smaller proportions to other analytes, and neither metabolite was found in samples from non-smoking non-applicators. In a third study, 1-naphthol levels in urine samples from greenhouse pesticide applicators increased after they had sprayed carbaryl (Bouchard *et al.*, 2008). Finally, Putnam *et al.* (2008) used 1-naphthol levels in urine to estimate carbaryl exposure; as noted above, however, other compounds also have 1-naphthol as a metabolite.

Borzelleca and Skalsky (1980) also suggest that it may be possible to use saliva for non-intrusive biomonitoring of carbaryl, based on data from rats receiving doses of ^{14}C-carbaryl (0, 50, 100, or 200 mg/kg) dissolved in corn oil and directly injected into the stomach. Following the dose, the ^{14}C radiolabel was detected in saliva for up to 24 hours; urinary excretion of the radiolabel also occurred rapidly.

Studies that have been conducted indicate biomonitoring may be used to estimate exposures to carbaryl. Nevertheless, adequate data are lacking to correlate measurements of specific metabolites with exposure levels.

ENVIRONMENTAL CONCENTRATIONS

Dislodgeable Foliar Residues

Dislodgeable foliar residue (DFR) is defined as the pesticide residue that can be removed from both sides of treated leaf surfaces using an aqueous surfactant. DFR is assumed to be the portion of an applied pesticide available for transfer to humans from leaf and other vegetative surfaces. Measurements of DFR can be used, along with an appropriate transfer coefficient (TC), to estimate the amount of pesticide adhering to clothing and skin surfaces following entry into a previously treated field. The DFR is reported as residue per leaf area (µg/cm^2).

Studies used for exposure estimates were evaluated for acceptability based on criteria described in Iwata *et al.* (1977) and U.S. EPA (1996). For example, each was performed under climate conditions typical of California growing season; there were no rain events during the study (or if rain occurred, subsequent days were not used); samples were collected for several days extending at least through the REI; replicate samples were collected; residues were dislodged from leaf surfaces with a detergent solution (rather than an organic solvent);

and the application rate was at or near the maximum stated on the product label for the crop (although application rates might not affect the dissipation rate, the relationship has not been studied for carbaryl). Day 0 refers to the day of application, Day 1 is the first post-application day, and subsequent post-application days are similarly identified.

DFR values used in exposure estimates were back-calculated from equations using daily means of study data, as explained in Andrews (2000). Where possible, data from California were used. Field spike recoveries in all studies exceeded 84%. With the exception of strawberries, for which only a range of field spike recoveries was reported (84.9% – 97.3%; Zweig *et al*., 1984), samples were corrected for field spike recoveries less than 90%.

DFR Dissipation Studies on Field Crops and Vegetables

Table 13 summarizes DFR studies done on field crops and vegetables. Two studies conducted on cotton in Arizona, in which residues were dislodged with either acetone or methylene chloride instead of a detergent solution, are not included in Table 13 (Ware *et al*., 1978; Estesen *et al*., 1982).

Most of the application rates used in studies summarized in Table 13 are close to the maximum application rate listed on product labels (see Appendix 1 for maximum application rates allowed on each crop). Maximum application rates on product labels registered in California are 2.0 lbs AI/acre for cabbage and tobacco, and 1.0 lb AI/acre for cucumber. Use of carbaryl on sunflowers is not allowed in California. Carbaryl residues in the field and vegetable crops studied had a dissipation half-life of less than a week.

Table 13. Dissipation of Carbaryl on Field Crops and Vegetables

Crop	Formulation [a]	Location	Application rate (lb AI/acre)	DFR [b] Equation R^2	Day 0 DFR [b] (µg/cm²)	Half-Life (Days) [c]
Cabbage [d]	F	California	2.0	0.94	4.31	3.2
Cabbage [e]	F	California	2.07	0.83	2.36	3.9
Cucumber [f]	F	North Carolina	1.0	0.92	3.51 [g]	0.8
Sunflower [h]	F	North Dakota	1.5	0.81	5.81	6.4
Tobacco [i]	EC	North Carolina	2.0	0.91	4.86	3.4

[a] EC: emulsifiable concentrate; F: flowable concentrate; All formulations were mixed with water.
[b] Dislodgeable foliar residue (DFR) values were calculated using the linear regression generated from study data: $\ln DFR_t = \ln (DFR_0) - kt$ (Andrews, 2000). Unless otherwise indicated, reported Day 0 value was predicted from the regression. See Appendix 2 for measured and predicted DFR values. R^2: coefficient of determination; the closer to 1 R^2 is, the better the linear regression fits the data.
[c] Half-life calculated from the following equation: $T_{1/2} = (\ln 0.5)/k$, where k is the slope of the linear regression generated from study data: $\ln DFR_t = \ln (DFR_0) - kt$ (Dong *et al*., 1992).
[d] Klonne *et al.* (2001a); data following second application with tractor-driven ground boom sprayer.
[e] Klonne *et al.* (2000c); data following second application with tractor-driven ground boom sprayer.
[f] Klonne *et al.* (2001b); data following second application with tractor-driven ground boom sprayer.
[g] Measured Day 0 exceeded predicted Day 0; exposure assessment was based on the measured Day 0 DFR.
[h] Klonne *et al.* (1999b); data following second aerial application.
[i] Klonne *et al.* (1999a); data following second application with tractor-driven ground boom sprayer.

DFR Dissipation Studies on Fruit Crops

Table 14 summarizes DFR studies done on fruit crops, including apple, citrus (grapefruit, lemon and orange), olive, and strawberry. On all the tree crops, dissipation half-life was longer than for carbaryl field crops and vegetables, ranging from 6.6 days on olive foliage to 23.1 days on grapefruit leaves. The dissipation half-life for carbaryl on strawberry foliage was 4.1 days. Dissipation half-lives were similar among studies conducted in citrus orchards in California (14 – 22 days) and those done in Florida or Oregon (17 – 23 days). Initial DFR estimates (Day 0 DFR) tended to be lower for studies done in California than for studies done outside California, regardless of application rates. This difference is certainly due in part to the fact that the California studies involved a single application, while DFR sampling followed multiple applications in the Florida studies. Although the difference is substantial, it may be an artifact of how few studies are available (i.e., the apparent trend might not continue if additional studies were done in California). As multiple application are allowed on citrus, exposure estimates were based on data from Klonne and Merrick (2000).

Table 14. Dissipation of Carbaryl on Fruit Crops

Crop	Formulation [a]	Location	Application rate (lb AI/acre)	DFR [b] Equation R^2	Day 0 DFR [b] (µg/cm²)	Half-Life (Days) [c]
Apple [d]	F	Oregon	3.0	0.98	9.49	13.9
Grapefruit [e]	F	Florida	7.7	0.98	27.5 [f]	23.1
Lemon [g]	WP	California	11.5	0.94	2.8	21.6
Orange [g]	WP	California	11.5	0.98	7.2	13.9
Orange [h]	F	Florida	7.07	0.90	28.9 [f]	16.9
Olive [i]	F	California	7.65	0.81	3.94	6.8
Strawberry [j]	F	Oregon	2.0	0.90	8.08	4.1

[a] F = flowable concentrate; WP = wettable powder. Both formulations were mixed with water.

[b] Dislodgeable foliar residue (DFR) values were calculated using the linear regression generated from study data: $\ln DFR_t = \ln(DFR_0) - kt$ (Andrews, 2000). Unless otherwise indicated, reported Day 0 value was predicted from the regression. See Appendix 2 for measured and predicted DFR values. R^2 is the coefficient of determination; the closer R^2 is to 1, the better the linear regression fits the data.

[c] Half-life calculated from the following equation: $T_{1/2} = (\ln 0.5)/k$, where k is the slope of the linear regression generated from study data: $\ln DFR_t = \ln(DFR_0) - kt$ (Dong *et al.*, 1992).

[d] Klonne *et al.* (2001c); data following second airblast application.

[e] Klonne *et al.* (2000b); data following second airblast application.

[f] Measured Day 0 is reported, as it exceeded the predicted Day 0.

[g] Iwata *et al.* (1979); single application with oscillating boom spray rig. Dissipation curves and R were reported, but not measured data. Dissipation on lemon: $\ln DFR_t = \ln(2.8) - 0.032t$ (R = 0.97). Dissipation on orange: $\ln DFR_t = \ln(7.2) - 0.050t$ (R = 0.99).

[h] Klonne and Merricks (2000); data following second airblast application.

[i] Klonne *et al.* (2000a); data following second airblast application. Trace rainfall after sampling on Day 4.

[j] Zweig *et al.* (1984); application by airblast. No sampling was conducted on application day (Day 0). The measured Day 1 value was substituted for predicted Day 0, as it exceeded predicted Day 0.

All but one study used a liquid carbaryl product. Iwata *et al.* (1979) reported a DFR study for a wettable powder formulation (Sevin 80WSP) applied to orange and lemon foliage. The dissipation curves followed first order kinetics over the 61 days of the study. The authors observed half-lives of 14 and 22 days on orange and lemon foliage; similarly long half-lives occurred in the two other studies applying liquid carbaryl products to citrus (Klonne *et al.*, 2000b; Klonne and Merricks, 2000).

DFR Studies with Spot Sampling of Crop Foliage

Three studies are available in which spot samples of crop foliage were collected and DFR analyzed; all were done in California. Carman *et al.* (1972) compared foliar residues in mature navel orange trees treated with a low volume sprayer and treated with dilute sprays from an oscillating boom sprayer. The product used was Sevin 80WSP, and the application rate was 24 lbs AI/acre (twice the maximum rate currently allowed on California citrus, which is 12 lbs AI/acre). Mean DFR values 5 days after application were 9,700 and 1,200 µg/cm², respectively, on foliage treated with low volume and dilute sprays. The methods used to dislodge and analyze foliar residues were not reported, preventing meaningful comparison of these results with results obtained in other studies.

As part of a large study of pesticide residues encountered by reentering fieldworkers, Hernandez *et al.* (1998) collected and analyzed 939 foliar samples in sixteen counties in California's Central Valley and coastal regions. No information was available about pesticide applications, and samples were tested for multiple pesticides. Carbaryl was detected in 78 samples, at levels ranging from 0.001 to 1.314 µg/cm². Reported detection limits (RDL) for carbaryl in leaf disc extract samples ranged from 2 – 12 µg/sample (RDL were sometimes limits of quantitation rather than limits of detection). Each sample contained residues dislodged from either 405 or 423 cm² of leaf surface, depending on the leaf punch used (Hernandez *et al.*, 1998); thus, the RDL for carbaryl ranged from 0.005 – 0.030 µg/cm².

In another study, DFR samples were collected at the expiration of the REI following known pesticide applications (Hernandez *et al.*, 2002). Table 15 summarizes results of the study for carbaryl. Hernandez *et al.* (2002) did not report application rates in fields where they sampled, and it is possible that some applications were made at lower rates; if so, this might explain the variability between samples in oranges. It may also explain lower DFR results for apple and orange in Table 15 compared to results summarized in Table 14.

Table 15. Dislodgeable Foliar Residues of Carbaryl from Spot Sampling

Crop [a]	Sampling Date [b]	Number of Detects/Total Samples	Minimum detected DFR [c] (µg/cm²)	Maximum DFR (µg/cm²)	Mean DFR [c] (µg/cm²)	SD DFR [c] (µg/cm²)
Apple	4/23/1998	12/12	2.675	4.95	3.912	0.743
Grape, table	10/4/2000	2/6	0.0033	3.09	1.27	1.53
Orange	6/13/2000	8/8	2.12	4.73	3.521	0.776
Orange	6/15/2000	2/4	0.0013	0.0029	0.0021	0.0011
Orange	10/4/2000	6/6	0.0122	0.0268	0.0174	0.0049
Pummelo	11/3/1998	8/8	0.278	1.36	0.711	0.317

[a] Data from Table 1 and Appendix 1 in Hernandez *et al*. (2002).
[b] Samples collected within 24 hours of expiration of the 12-hour restricted entry interval for carbaryl.
[c] Non-detects excluded from range and statistics. Reported detection limits ranged 2 – 12 µg/sample.

In a study comparing variable dislodging techniques, the Agricultural Reentry Task Force measured DFR on treated cabbage and lettuce plots 1 day post-application of 2 lbs AI/acre (Bruce *et al*., 2006a). The four lettuce DFR samples dislodged using the standard technique had mean $\pm$ standard deviation of 6.195 $\pm$ 0.615 μg/cm², and four cabbage DFR samples had mean of 0.908 $\pm$ 0.091 μg/cm². As the application rates and other conditions in the study were the same between crops, the 6-fold difference in mean DFR suggests that cabbage DFR might generally underestimate dislodgeable residues on lettuce.

Transferable Turf Residue (TTR)

Available data do not appear to support a consistent relationship between TTR and exposure. As an alternative to TTR-based estimations, surrogate chemical data were used to estimate post-application dermal exposure to turf-applied pesticides, as chemical specific exposure data are not available. If needed, residue dissipation on turf can be estimated from TTR studies. TTR data are also used to estimate reentry exposure by non-dietary ingestion.

Carbaryl residues were measured on treated turf in two studies (Mester, 1999; Krolski, 2005). Mester (1999) diluted and applied a liquid formulation of carbaryl (21.3%) twice to a mixed tall fescue turf plot in California, at a target rate of 8.17 lbs AI/acre (actual rates were 8.39 and 8.19 lbs AI/acre). Following each application, the plots were irrigated with 0.3 to 0.71 inches of water. Only the range of irrigation amounts across sites was reported, not the amount applied to each site. TTR samples were collected before and after each irrigation. The California site was mowed twice, once before the second application and once before the Day 14 samples were collected. Additional irrigation was applied during the study, for a total of 2.70 inches of water at the California site; the exact dates and amounts of irrigation were not reported. Rain added another 0.20 inches of water during the study.

Transferable residues on turf were estimated using the modified California roller method, and the limit of quantitation (LOQ) for carbaryl was 2.0 μg/dosimeter sheet. None of the controls (collected from an untreated plot) had carbaryl residues above the LOQ. Following the second application, samples were collected on the day of application (pre- and post-irrigation), and at day 0.5, day 1, day 2, day 3, day 5, day 7, day 10, and day 14. Mean TTR pre-irrigation was 0.9 μg/cm², and mean TTR post irrigation was 0.290 μg/cm². Dissipation for TTR was determined from a first-order regression, which gave an equation of $\ln TTR_t = -0.717 - 0.302t$ ($r^2 = 0.90$). The half-life for carbaryl dissipation was calculated to be 2.3 days, according to the following equation: $T_{1/2} = (\ln 0.5)/(-0.302)$.

Krolski (2005) applied a granular formulation of carbaryl (2% AI) at a target rate of 0.18 lb AI/1000 ft^2. Field trials were done at three sites in Florida, Kansas and California. Only the California data are discussed here. Two treated plots were included in each trial, one designated as the non-irrigated plot while the other designated as the irrigated plot. Each plot was subdivided into 3 subplots from which the 3 replicate samples were collected at each time point (0, 4, 10, 24, 48, 72, 120, and 168 hours post application). Immediately following application, the designated irrigated plot was irrigated with 0.48 inches of water. The plots were not mowed during the course of sample collection. TTR was estimated using the modified California roller method, with an LOQ of 1.0 μg carbaryl/dosimeter sheet. None of the controls (collected from untreated plots) had carbaryl residues above the LOQ. No rainfall or additional irrigation occurred during the study. Mean TTR on the non-irrigated plot immediately after application was 0.45 µg/cm², and dissipation determined from a first-order regression gave an equation of ln TTR = -3.08 – 0.513t (r^2 = 0.99).

DFR Values Used in Exposure Estimates

Table 16 summarizes DFR values that were used in short-term reentry exposure estimates. DFR values shown in Table 16 are predicted values from Appendix 2.

Table 16. Carbaryl Dislodgeable Foliar Residue (DFR) Values Used in Reentry Exposure Estimates

Crop [a]	Rate [b]	DFR for Reentry at REI (µg/cm²) [c]	DFR for Short-Term Harvester (µg/cm²) [d]	DFR for Seasonal and Annual Exposure [e]		DFR from Crop [f]
				Non-Harvest (µg/cm²)	Harvest (µg/cm²)	
Apple	3	14.2	Covered by thinning	8.62 (10)	NA	Apple
Asparagus	2	9.49	4.54 (PHI: 1)	NA	NA	Apple
Beans	1.5	6.06	Covered by scouting	NA	NA	Strawberry
Blackberry	2	8.08	Covered by pruning	NA	NA	Strawberry
Cabbage	2	4.31	Covered by scouting	NA	NA	Cabbage
Citrus [g]	8	28.5	Covered by pruning	19.0 (13)	NA	Orange
Corn	2	3.32	Covered by detasseling	2.01 (31)	NA	Apple
Cucumber [h]	1	3.51	Covered by scouting	0.002 (7)	NA	Cucumber
Grape	2	2.18	Covered by leaf pulling	0.399 (16)	NA	Strawberry
Lettuce	2	9.49	Covered by scouting	5.75 (10)	NA	Apple
Olive [i]	7.5	2.84	Covered by pruning	1.02 (13)	NA	Olive
Ornamental Plants	1	4.09	4.09 (PHI: 0)	2.67 (10)	2.67 (10)	Orange
Potato	2	8.08	Covered by scouting	1.11 (10)	NA	Strawberry
Strawberry	2	8.08	Covered by scouting	1.11 (10)	NA	Strawberry
Tobacco	2	4.73	4.73 (PHI: 2)	NA	NA	Tobacco
Tomato	2	8.08	Covered by staking/tying	1.11 (10)	NA	Strawberry

[a] Representative crops from Table 7. Reentry exposures involving treated sod and turf are estimated directly from exposure monitoring data, rather than from residues on turf, and turf is not included in this table.
[b] Maximum application rate allowed on crop in pounds of active ingredient per acre (lbs AI/acre), from Table 8. Multiply value by 1.12 to get application rate in kg AI/ha. If DFR came from a study with a different application rate, then DFR values used in exposure estimates were adjusted for the rate difference (i.e., DFR was multiplied by the ratio of maximum rate allowed on crop to rate used in study).
[c] DFR values (µg/cm²) used for short-term exposure estimates for workers entering at expiration of restricted entry interval (REI); the REI is 12 hours for most crops, except 1 day for sod and corn (21 days for detasseling); 2 days for tobacco; 3 days for citrus and olive; and 6 days for grapes.
[d] DFR estimated for expiration of preharvest interval (PHI in days), used to estimate short-term harvester exposure.
[e] DFR estimated for long-term re-entry activities as described by Beauvais (2008). Assumes reentry at post-application day in parentheses. NA = not applicable.
[f] Surrogate crops were chosen to match representative crops as closely as possible. DFR from Appendix 2.
[g] Citrus has a maximum application rate of 12 lbs AI/acre in California, but only one application per year is allowed at that rate. Higher DFR is associated with multiple applications, which are allowed at 8 lbs AI/acre.
[h] Cucumber DFR data are available only through 7 days post-application.
[i] Olive DFR data are available only through 14 days post-application.

Exposure estimates for reentry on treated turf and sod are based on surrogate exposure monitoring data rather than on carbaryl residues on turf, and turf is omitted from Table 16.

Air

California has laws that limit ambient air concentrations of pesticides, including the Toxic Air Contaminants (TAC) Act (California Health and Safety Code, Sections 39650-39761), which codified the state program to evaluate and control toxic air contaminants. Carbaryl is on the TAC list (3 CCR 6860) because it is listed federally in the Clean Air Act as a Hazardous Air Pollutant (United States Code Title 42, Section 7412). Carbaryl concentrations have been monitored in the ambient air away from applications (ambient air monitoring), and in the air surrounding application sites (application site monitoring). These studies are discussed below.

Ambient Air

Carbaryl has been detected in ambient air at both urban and rural sites. In 1996 and 1997, the U.S. Geological Survey monitored atmospheric concentrations of several pesticides, including carbaryl, at three locations in Sacramento County (Majewski and Baston, 2002). Two of the sites were rural, at airports northwest and southeast of Sacramento; the third site was in downtown Sacramento (about 10 m above ground). The rural sites were approximately 10 and 20 miles (16 and 32 km) northwest and southeast, respectively, of the downtown site. Sample devices mounted 3 m above ground consisted of 119-cm^3 polyurethane foam plugs in Teflon cartridges, connected to high-volume blowers flowing at approximately 100 liters/min. Weekly whole-air (particulates were not filtered out) composite samples were collected at each site throughout the study. Sampling was triggered when 15-min mean wind speeds exceeded 1 m/sec in a northerly or southerly direction, and continued until the directional wind speed decreased below the trigger velocity, up to 20 minutes each hour. Carbaryl was reported in samples at all sites (LOQ = 0.00015 $\mu g/m^3$), at concentrations up to 0.0306 $\mu g/m^3$.

The California Air Resources Board (ARB) conducted ambient air monitoring for methomyl and carbaryl in Fresno, Tulare and Kings Counties during July and August 2007 (ARB, 2008). Six different sample locations were selected, and 24-hour samples were collected in July and August, 2007. Sample devices consisted of XAD-2 resin tubes mounted 1.5 meters above the ground (one site) or above the rooftop (five sites), connected to sample pumps calibrated at 2.0 liters per minute. Carbaryl was not detected in any of the 182 samples; detection limits were 0.020 µg/sample, which corresponded to 0.00068 $\mu g/m^3$.

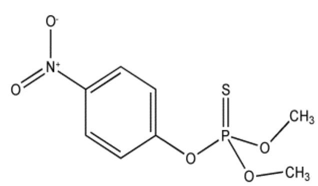
Application Site Air Monitoring: Agricultural Applications

Application site air monitoring provides data that are used to estimate bystander exposures during application. No site monitoring has been reported for agricultural applications in California. Carbaryl concentrations in air associated with agricultural applications were monitored in two studies involving airblast and aerial applications of carbaryl to an orchard in Vermont (Currier *et al.*, 1982; MacCollom *et al.*, 1986). However, the studies had limited sampling and did not provide sufficient information about application and monitoring conditions to allow reliance on them for concentrations used to estimate exposure.

The Spray Drift Task Force has assembled a large data set that included field studies with multiple active ingredients and application methods, as well as laboratory and wind-tunnel studies (SDTF, 1997). When evaluated together, these studies supported a conclusion that drift is affected more strongly by application method and physical factors such as droplet size than by the active ingredient (U.S. EPA, 1997c). This implies that exposure estimates could rely on monitoring of an airblast application of an AI other than carbaryl, as long as that study was conducted under conditions under which carbaryl might be applied (Barry, 2006).

Exposure estimates were based on surrogate data from an airblast application of methyl parathion, at a rate of 2 lbs AI/acre, to a walnut orchard in San Joaquin County (Barry, 2006). This application is briefly described in Wofford and Ando (2003). This study has previously been used as an appropriate surrogate for estimating air concentrations used to calculate bystander exposures to methidathion (Beauvais, 2007; Froines, 2007). Barry (2006) argued that this study would be an appropriate surrogate for that purpose, because of similarity of equipment used, timing of applications, and similar vapor pressures of both methyl parathion and methidathion. These reasons also apply to carbaryl. The vapor pressure reported for methyl parathion, 1.7×10^{-5} mm Hg at 25°C (Spencer *et al.*, 1979), is about 10-fold greater than the vapor pressure of 1.36×10^{-6} mm Hg at 25°C reported for carbaryl (Gunasekara, 2007). The structure of methyl parathion is given in Figure 4.

Figure 4. Methyl parathion.



The surrogate study was conducted in a 100-acre (40-ha) walnut orchard; trees were 24 feet (8 m) tall with full canopies. Methyl parathion was applied at a rate of 2 lbs AI/acre with two airblast applicators on July 17, 2003. The predominant wind direction at the site was reported to be generally from the northwest to the southeast (Wofford and Ando, 2003). Wind speeds during the application interval ranged <0.5 – 7.8 mph, with a mean of 3.9 mph (personal communication from P. Wofford, November 13, 2006).

Samplers consisted of foil-covered clear glass tubes containing XAD-4 adsorbent. Sampler height was 4 –5 feet (1.2 – 1.5 m), and sampler flow rate, calibrated at the beginning and end of each sampling interval, was 2 liters/min (Wofford and Ando, 2003). Samplers were positioned 22 – 171 feet (6.7 – 52.1 m) from the edges of the orchard, along the eastern, southern, and western sides. No samplers were placed north of the orchard because of "resource considerations" (Wofford and Ando, 2003). Samplers were, however, placed at the northwest and northeast corners (Samplers 11 and 12, respectively). These samplers, and others positioned at the orchard edge, were not set up until the application was completed to avoid sample contamination by drip off the tree canopy. Sampling lasted five days, beginning with the application. Each sample interval spanned about 10 – 12 hours. Samples were analyzed for methyl parathion and for its degradation product, methyl paraoxon. Quality assurance was acceptable and consisted of background samples prior to application (in which neither methyl parathion nor methyl paraoxon was detected), and fortified laboratory samples with recoveries in the range of 69% - 125% for methyl parathion and 75% - 141% for methyl paraoxon. Results were not corrected for laboratory spike recoveries. Reporting limits for methyl parathion and methyl paraoxon were 0.1 µg/sample and 0.2 µg/sample, respectively. Table 17 summarizes the highest methyl parathion concentration measured at each sample interval and the concurrent methyl paraoxon concentration. These concentrations were summed over each interval and used to estimate bystander exposures.

Table 17. Selected Concentrations of Surrogate Methyl Parathion and Methyl Paraoxon Near a Walnut Orchard Receiving an Application [a]

Sample Interval	Sample Date	Start Time	Selected Sampler Location [b]	Flow Rate (l/min)	Sample Time (min)	Sample Volume (m^3) [c]	Methyl Parathion (µg/m^3) [d]	Methyl Paraoxon (µg/m^3) [e]	Total (µg/m^3) [f]
1 [g]	7/17/03	22:01	17	2.04	634	1.292	7.25	*0.077*	**7.32**
2	7/18/03	9:00	16	1.99	590	1.176	3.09	0.27	3.36
21-hour Time-Weighted Average [h]									**5.41**
3	7/18/03	19:01	4	2.06	732	1.508	1.94	*0.066*	2.01
4	7/19/03	6:54	3	2.01	751	1.507	0.637	*0.066*	0.703
5	7/19/03	19:02	14	1.98	719	1.425	1.19	*0.070*	1.26
6	7/20/03	7:04	14	2.10	708	1.490	0.557	*0.067*	0.624
7	7/20/03	19:04	16	2.01	720	1.449	0.649	*0.069*	0.718
8	7/21/03	7:04	16	2.02	714	1.439	0.334	*0.070*	0.404
9	7/21/03	19:02	14	1.96	691	1.354	0.244	*0.074*	0.318
10	7/22/03	6:59	1	1.96	734	1.439	0.076	*0.070*	0.146
5-day Time-Weighted Average [i]									**1.59**

[a] Methyl parathion applied with two airblast applicators in San Joaquin County on July 17, 2003. Application began at 22:00 (10:00 PM) and ended at 7:15 the next morning. Orchard size was 100 acres (40 ha) and walnut trees were 24 feet (8 m) tall with full canopies. Study briefly described in Wofford and Ando (2003); interval-specific data from P. Wofford (personal communication, August 31, 2006). Concentrations used to calculate exposure estimates are bolded.

[b] Sampler with highest total (methyl parathion and methyl paraoxon) concentration during the sampling interval. Sampler locations given in Wofford and Ando (2003).

[c] Sample volume calculated by multiplying flow rate by sample time; 1 liter = 0.001 m^3.

[d] The highest concentration in each sample interval is reported (P. Wofford, personal communication, August 31, 2006).

[e] Methyl paraoxon was only detected in a few samples, during the second sampling interval; concentrations ranged 0.12 – 0.27 µg/m^3 (Wofford and Ando, 2003). With the exception of sample interval 2, all methyl paraoxon concentrations reported in this table were based on ½ the reporting limit of 0.2 µg/sample, divided by the sample volume (values based on the reporting limit are italicized).

[f] Sum of methyl parathion and methyl paraoxon for interval.

[g] Concentrations reported from Sampler 17 during sample interval 1 were used to estimate 1-hr acute bystander exposure to carbaryl, as this interval contained the highest methyl parathion concentration measured in the study.

[h] The 21-hr time-weighted average (TWA) concentrations from intervals 1 and 2 were used to estimate the acute daily absorbed dose, with the estimated methyl paraoxon concentration during interval 1 based on the reporting limit (0.155 µg/m^3).

[i] TWA across all ten sample intervals (5 days) used to estimate seasonal and annual bystander exposures.

Methyl paraoxon was only detected in a few samples during the second sampling interval, with concentrations in the range of 0.12 – 0.27 μg/m^3. With the exception of sample interval 2, all methyl paraoxon concentrations reported in Table 17 were estimated based on half of the reporting limit, as methyl paraoxon was not detected in those samples. For example, the calculation for sample interval 1 is (0.1 μg/sample)/(1.292 m^3) = 0.077 μg/m^3. This concentration was included in time-weighted averages used to estimate seasonal and annual exposures.

For short-term exposures, the nominal concentration based on the reporting limit for methyl paraoxon was used (instead of half the limit), to provide health-protective estimates of acute exposure. The oxon concentration for sample interval 1 used in calculating acute exposure estimates is (0.2 μg/sample)/(1.292 m^3) = 0.155 μg/m^3. Values calculated this way are italicized in Table 17.

Application Site Air Monitoring: Applications in Urban Areas

DPR monitored air for carbaryl during several applications to control gypsy moths and glassy winged sharpshooters in California (Neher *et al.*, 1982; Segawa *et al.*, 1982; Weaver *et al.*, 1983; Franz *et al.*, 1985; Walters *et al.*, 2003). Distances of air sampling stations from carbaryl applications were not reported, but probably varied considerably as air monitoring occurred in residential neighborhoods where trucks drove through while spraying carbaryl (with exception of Segawa *et al.* (1982), where carbaryl was applied by helicopter). These studies provide the only available data on carbaryl air concentrations during ground and aerial applications in California. Results of monitoring conducted in the spray zone (i.e., on-site air monitoring) during these studies are summarized in Table 18.

In most studies, a single air sampler was located at each site. Exceptions are noted in Table 18. Samples were typically collected with high volume samplers using XAD-2 or XAD-4 resin and a high-volume pump operating at 30 – 40 ft^3/min (0.85 – 1.1 m^3/min). Walters *et al.* (2003) collected samples with high volume samplers using XAD-4 resin and a high-volume pump operating at 1 m^3/min, and with SKC samplers using XAD-2 resin and a pump operating at 0.003 m^3/min. Sampling intervals are summarized in Table 18; in most cases, samples were collected prior to spraying (with sampling intervals ranging 40 minutes – 24 hours), during spraying, and post-spraying (sampling intervals ranging 40 minutes – 24 hours). Results were reported as time-weighted average concentrations. Quality assurance consisted of one trip spike and one field spike, and lab spikes included with each set of one to twelve samples being extracted and analyzed. The trip spike and field spike had recoveries of 55% and 65%, respectively; no explanation was given for the relatively low recoveries. In contrast, lab spikes had average recoveries of 83.5% for XAD-2 resin and 95.6% for XAD-4 resin.

Table 18. On-Site Application Urban Air Monitoring of Carbaryl in California

Date	Formulation [a]	Location [b]	Concentration (μg/m³) [c]		
			Pre-Spray	Application	Post-Spray
3/1982 [d]	SP	Santa Barbara County, Site 1	ND (0.04) [e]	**12.00**	0.120
4/1982 [d]	SP	Santa Barbara County, Site 2	ND (0.04)	0.160	0.160
4/1982 [d]	SP	Santa Barbara County, Site 3	0.016	**2.318**	0.306
3/1983 [f]	SP	Alameda County	ND (0.0098)	**2.33**	0.95
3/1983 [f]	SP	Los Angeles County	ND (0.0098)	**0.91**	0.34
4/1983 [f]	SP	Marin County	0.04	**0.13**	0.04
3/1983 [f]	SP	San Mateo County	ND (0.011)	**1.14**	0.15
3/1983 [f]	SP	Santa Clara County	ND (0.0077)	**9.02**	0.44
3/1984 [g]	SP	Alameda County	0.02	**4.10**	0.43
3/1984 [g]	SP	San Diego County	ND (0.0097)	**0.55**	0.05
11/2000 [h]	EC	Butte County	ND (0.046)	**ND (0.74)**	ND (0.046)
10/2000 [h]	EC	Contra Costa County	ND (0.046)	**ND (0.74)**	ND (0.046)
6/2000 [h]	EC	Fresno County	ND (0.046)	**0.39**	0.19
8/2000 [h]	EC	Sacramento County	ND (0.046)	**0.77**	0.60
6/2000 [h]	EC	Tulare County	0.013	**0.52**	0.31
11/1982 [i]	EC	Tulare County	**ND (0.098)**	**2.80**	**ND (0.098)**
11/1982 [j]	EC	Tulare County	**ND (0.098)**	**2.19**	NS [k]

[a] EC: emulsifiable concentrate; SP: soluble powder. Both formulations were mixed with water.
[b] Monitoring of ground applications in residential neighborhoods where carbaryl was applied by a truck-mounted sprayer, unless otherwise stated. All air samples were collected in the neighborhoods being sprayed.
[c] Each concentration is reported as a time-weighted average of a single sampler at each site, unless otherwise stated. Bolded values represent concentrations from shorter sampling intervals, up to 4 hours.
[d] Neher *et al.* (1982). Application rate not specified on a per-acre basis; spray contained 0.12% carbaryl. Sampling intervals for pre- and post-spray samples were 24 hours; application intervals ranged 8 – 330 minutes (0.13 – 5.5 hours); highest value occurred during an 80-minute application. Detection limit: 50 μg/sample.
[e] ND: Not Detected. Detection limit (μg/m³) in parentheses.
[f] Weaver *et al.* (1983). Application spray contained 0.125% carbaryl. Sampling intervals were 6 hours pre-and post-spray; application intervals ranged 35 – 81 minutes (0.57 – 1.35 hours).
[g] Franz *et al*. (1985). Application spray contained 0.120% carbaryl. Sampling intervals and detection limits were the same as in Weaver *et al.* (1983); the application monitoring interval was 57 minutes.
[h] Walters *et al.* (2003). Hand-held sprayer with 0.11 – 0.21% carbaryl spray. Sampling intervals spanned at least 12 hours pre-spray; application plus 1 hour (1.5 – 4 hours total); and two sequential 24-hour samples post-spray. Post-spray results in this table include the first 24-hour samples only; detections were frequently reported in the second 24 hour samples. Reporting limit: 0.2 μg/sample, which ranged 0.0007 – 0.05 μg/m³ for samples of varying duration with different sampling volumes. Fresno County results are means of six samples; Sacramento County results are means of three samples; Tulare County results are means of six samples.
[i] Segawa *et al.* (1982). Monitoring of carbaryl applied at the rate of 1 lb AI/acre by a helicopter 250 feet (76 m) above ground. Results are means of three samplers. Sampling intervals were 40 minutes pre-spray, 20 minutes during the application and 40 minutes beginning ½ hour post-spray. Detection limit: 0.098 μg/m³.
[j] Segawa *et al.* (1982). Monitoring of carbaryl applied at the rate of 1 lb AI/acre by a helicopter 120 feet (37 m) above ground. Results are means of three samplers. Sampling intervals were 40 minutes pre-spray and 40 minutes during the application. Detection limit: 0.098 μg/m³.
[k] NS: Not Sampled. No sample was collected during this interval.

Table 19 summarizes off-site air monitoring conducted in association with pest control programs in California. Two studies are available, one monitoring drift from an aerial application (Segawa *et al.*, 1982) and one monitoring a mist blower application (Weaver *et al.*, 1983).

Table 19. Off-Site Urban Application Air Monitoring of Carbaryl

	Distance from	Sampling Interval (minutes)			Concentration (µg/m³)		
	Spray Area (m)	Pre-Spray	Application	Post-Spray	Pre-Spray	Application	Post-Spray
Ground Application [a]							
Mist blower [b]	< 10	360	245	120	0.058	0.362	0.148
Mist blower [c]	76	360	245	120	0.079	0.214	0.241
Aerial Applications [d]							
250 ft height [e]	80	40	15	NS [f]	ND [f]	0.199	NS
250 ft height [e]	550	40	15	NS	ND	ND	NS
120 ft height [g]	310	40	15	NS	ND	4.52 [h]	NS

[a] Application in Contra Costa County of Sevin 80SP on April 8, 1983 (Weaver *et al.*, 1983). Spray contained 0.125% carbaryl. Detection limit: 3 µg/sample (0.013 – 0.032 µg/m³).
[b] Results are means of five samplers. The highest measured concentration during this application was 0.540 µg/m³.
[c] Results are means of six samplers. The 95th percentile of post-spray concentration is 1.32 µg/m³, which is the highest estimated concentration associated with this application.
[d] Sampling associated with aerial applications of Sevin XLR in Tulare County on November 10, 1982 (Segawa *et al.*, 1982).
[e] Application made at 250 feet above ground over a 15-minute interval (1250 – 1305 hours). Results from single sampler at each location, north of spray area. Detection limit: 0.098 µg/m³.
[f] ND: Not Detected. NS: Not Sampled.
[g] Application made at 120 feet above ground over a 15-minute interval (1600 – 1615 hours). Results from single sampler at each location, south of spray area (sampler was moved from its position during the earlier application, due to a wind shift). Detection limit: 0.098 µg/m³.
[h] This concentration is used to estimate 1-hour bystander exposures associated with urban pest control.

Segawa *et al*. (1982) monitored carbaryl concentrations in association with two aerial applications to a county park in Tulare County in 1982. Both applications applied at a rate of 1 pound carbaryl per acre using a helicopter with a 45 foot-long spray boom. Air monitoring was done at five sites in the application area and two downwind. Each site had three air samplers, with three different types of sample media connected to a high-volume pump operating at 40 ft³/min (1.1 m³/min). Sample media included a dual stage cascade impactor to collect particles (one stage for diameters < 3.5 µm and the other for diameters > 3.5 µm); a glass fiber filter for total suspended particulates; and a glass cartridge packed with 125 ml of XAD-2 resin. The cascade impactors and glass fiber filters had a detection limit of 4.4 µg/m³; no carbaryl was detected by either media.

Water

With a reported water solubility of 104 mg/liter at 25°C (Gunasekara, 2007), carbaryl is fairly water soluble. In national monitoring of surface waters conducted by the U.S. Geological Survey, carbaryl was the third most frequently found insecticide in agricultural watersheds, and the second most frequently detected in urban watersheds (Gilliom *et al*., 2007). Carbaryl has been monitored in both surface and ground water in California; it has also been detected in rainwater samples collected in the state (Vogel *et al*., 2008). Although carbaryl has been detected numerous times in surface water, and has been detected in low concentrations in ground water in other states, it has not been detected in California ground water (Gunasekara *et al.*, 2008).

The persistence of carbaryl in water is affected by pH (Chapman and Cole, 1982). When dissolved in sterile aqueous buffers with pH ranging from 4.5 to 8.0, the calculated half-life varied more than 1000-fold, from 0.27 to 300 weeks. Above pH 7, hydrolysis is the major degradation pathway for carbaryl, and degradation rates increase with microbial activity (Gunasekara, 2007). Stanley and Trial (1980) monitored carbaryl concentrations in Maine rivers and streams contaminated by forest spraying, and found a dissipation rate constant of 0.028/hour for carbaryl, regardless of stream size or starting concentration; the half-life was about 25 hours. In laboratory experiments using water collected from the Sacramento River in California and spiked with pesticide mixtures, carbaryl decayed rapidly, with a calculated half-life in the range of 1 – 2 days at 25°C and 16 – 22 days at 10°C; shorter half-lives would be anticipated in water with higher pH, as carbaryl degrades more readily under alkaline conditions (Starner *et al.*, 1999).

Pesticide residues in surface water may result in exposure for swimmers. Reported concentrations of carbaryl in surface water were used in calculating swimmer exposure estimates.

Surface Water Monitoring: Ambient

Ambient surface water monitoring in California for carbaryl has been done in both the Sacramento and San Joaquin River basins. Carbaryl has been detected numerous times in California surface waters. Guo (2000) summarized monitoring data for carbaryl in surface water in California between 1990 and 1998. Carbaryl was detected in 150 of 2,744 samples analyzed during that time, for a detection frequency of 5.5%. The 50th percentile of reported concentrations was 0.1 µg/liter, and the 95th percentile was 1.7 µg/liter (Guo, 2000).

Ross *et al.* (1996) monitored concentrations of organophosphate and carbamate insecticides in the San Joaquin River during two consecutive winters in 1991-1992 and 1992-1993. Of 108 samples collected, 12% had detectable levels of carbaryl; nearly all detections coincided with rain events. Concentrations ranged between 0.06 and 3.95 µg/liter (Ross *et al.*, 1996).

The U.S. Geological Survey assessed surface water quality in the Sacramento River basin, which spans much of northern California. River and stream samples were collected in urban and agricultural areas, and in streams draining mixed land-use areas, between 1994 and 1998, an interval that included above-average precipitation and a major flood (Domagalski *et al.*, 2000). Carbaryl was detected in nine of 21 samples collected from agricultural streams (43%), in concentrations ranging from approximately 0.01 to 0.2 µg/liter. All thirty urban stream samples contained carbaryl (100%), in concentrations ranging from approximately 0.03 to 1.3 µg/liter. Carbaryl was detected in seven of 26 samples (27%) collected from streams draining areas with mixed land use, in concentrations ranging from approximately 0.02 to 0.09 µg/liter.

From April 2008 through August 2009, DPR staff monitored concentrations of several pesticides, including carbaryl, in water sampled at 25 urban sites in Placer, San Diego, and

Orange counties and in the San Francisco Bay area (Ensminger and Kelley, 2011a). The reporting limit for carbaryl in the study was 0.05 µg/liter. This reporting limit was exceeded in two of 32 samples in Placer County, with concentrations of 0.065 and 0.129 µg/liter; in seven of 59 Bay Area samples, with concentrations ranging 0.069 – 0.369 µg/liter; in 15 of 39 samples in Orange County, with concentrations ranging 0.057 – 0.682 µg/liter; and in four of 31 samples in San Diego County, with concentrations ranging 0.05 – 0.066 µg/liter. Higher carbaryl concentrations occurred during rain runoff than during dryflow sampling.

As a continuation of the urban surface waters sampling project, DPR staff monitored pesticide concentrations at 13 sites, including both storm drain outflows and urban streams, in the Sacramento and San Francisco Bay areas (Ensminger and Kelley, 2011b). Samples were collected during the dry season and during rain events. Carbaryl concentrations were above the reporting limit of 0.05 µg/liter in nine of the 42 samples collected; the highest reported concentration was 0.399 µg/liter. All nine samples in which carbaryl was reported were collected during rain events.

A report from the California Department of Fish and Game compared carbaryl concentrations measured during surface water monitoring to concentrations found to be toxic to aquatic organisms in laboratory studies, and determined that carbaryl concentrations in the Sacramento-San Joaquin River system can present acute and chronic hazards to aquatic life (Siepmann and Jones, 1998). An assessment by DPR staff concurred (Starner, 2007).

<u>Surface Water Monitoring: Application Site</u>

DPR conducted surface water monitoring in association with several carbaryl applications to control gypsy moths, Japanese beetles, and glassy winged sharpshooters (Neher *et al.*, 1982; Segawa *et al.*, 1982; Weaver *et al.*, 1983; Segawa, 1988; Walters *et al.*, 2003). Post-spray concentrations were used to estimate exposure of individuals swimming in surface waters. Several studies also sampled runoff following rain events; those results are mentioned below but are not pertinent to swimmer exposures.

Neher *et al.* (1982) collected surface water samples from Sycamore Canyon Creek in Santa Barbara County. During the sampling interval, 1,630 pounds of carbaryl were applied over 276 acres. No carbaryl was detected in any background samples collected downstream or within the treatment area. Runoff samples were also collected from the creek at locations upstream, downstream, and within the spray area during a rain event occurring two days post-application. Carbaryl concentrations in the runoff samples ranged from 3.1 – 47.0 µg/liter. The lowest concentration occurred in a sample collected within the spray site. An upstream sample contained 33.0 µg/liter, suggesting that carbaryl was also being used by individuals not involved with the pest eradication project.

Segawa *et al.* (1982) collected duplicate surface water samples from a river about 50 miles north of the area being sprayed by helicopter (1 lb/acre on 14 acres, Tulare County). No carbaryl was detected in pre-spray samples. In samples collected during the two applications, carbaryl concentrations ranged from 2.0 – 6.0 µg/liter. Differences between replicates were greater than between applications. Within the ability of the study to determine, neither application height nor wind direction (which varied between the applications) affected drift from the aerial spray.

Weaver *et al.* (1983) collected samples from Pleasanton Canal and Arroyo del Valle Creek in Alameda County, from Mount Diablo Creek in Contra Costa County, from Westlake Village Reservoir in Los Angeles County, from a small creek draining the treatment area in Marin County (also a stock pond the creek flowed into), from Atherton Channel and Laurel Creek in San Mateo County, and from four creeks draining treatment areas in Santa Clara County. Carbaryl was generally not detected in pre-spray samples, nor in several of the runoff samples collected in the first rain event post-application. When multiple rain events were sampled, as in Marin County, carbaryl concentrations tended to increase with each one, and were as high at 295 µg/liter in runoff (samples collected up to 3 weeks post-application). The application rate was not specified.

Segawa (1988) monitored water concentrations from creeks within a treatment area after two rain events following ground spraying in 1983 – 1986 for Japanese beetle control in Sacramento County. Carbaryl concentrations ranged from below detection limits (1.0 or 5.0 µg/liter) to a high of 13.0 µg/liter.

Walters *et al*. (2003) monitored carbaryl concentrations in surface water and runoff following ground spraying for glassy-winged sharpshooter. The highest concentration in rain runoff was 1,737 µg/liter in Contra Costa County. Walters *et al*. (2003) also measured the highest carbaryl concentration in a swimmable body of water, 6.94 µg/liter in a fishpond in Sacramento County; this concentration was used to estimate swimmer exposure.

<u>Ground Water</u>

Carbaryl is on the list of chemicals that are considered to have the potential to contaminate ground water (Clayton, 2005). Carbaryl is on this list based on its fairly high water solubility, its fairly low soil adsorption coefficient (K_{oc} = 326 cm^3/g), and the relatively long half-life reported for anaerobic soil metabolism of 87 days (Clayton, 2005). Although carbaryl has certain physicochemical properties that might predispose it to leach into ground water, extensive monitoring has resulted in no detections of carbaryl in California's ground water.

DPR has a well monitoring program that samples numerous wells each year to determine the presence and geographical distribution of agriculturally applied pesticides in groundwater. The program, including criteria for selection of wells and sampling and analytical methods, is described by Troiano *et al.* (2001). Between 1986 and 2003, a total of 5,152 well water samples were collected and tested for the presence of carbaryl residues in 52 California counties, out of total 58 counties (Schuette *et al.*, 2003). Carbaryl was detected in four samples, at concentrations ranging from 2 – 55 µg/liter. All four detections were classified as "unverified," meaning that follow-up sampling failed to detect carbaryl. In groundwater monitoring conducted between 2004 and 2010, a total of 3,264 wells were sampled; carbaryl was not detected in any of the samples (Schuette *et al.*, 2005; Nordmark *et al*., 2006; Nordmark *et al*., 2008; GWPU, 2009; GWPU, 2010; GWPU, 2011).

As part of the U.S. Geological Survey's National Water Quality Assessment (NAWQA), 29 domestic and two monitoring wells were sampled in the southeastern Sacramento Valley in 1996 (Dawson, 2001). Carbaryl was not detected in any sample. Detection limits were not reported by Dawson (2001).

The U.S. Geological Survey also assessed ground water quality in the Sacramento River basin, in samples collected between 1994 and 1998 (Domagalski *et al.*, 2000). Carbaryl was not detected in shallow ground water samples collected in either urban (28 samples) or agricultural (19 samples) areas, nor was carbaryl detected in any of 31 aquifer samples. Detection limits were not reported by Domagalski *et al.* (2000).

EXPOSURE ASSESSMENT

Exposure to carbaryl is anticipated to include occupational handlers exposed during applications in agricultural and non-agricultural settings; occupational reentry scenarios; residential handlers; residential reentry; airborne exposures of bystanders; and ambient air exposures. For each exposure scenario, estimates are provided for short-term (defined in this exposure assessment as acute and up to one week), intermediate-term (seasonal, one week to one year), and long-term (annual and lifetime) exposures.

For short-term exposures, WHS estimates the highest exposure an individual may realistically experience while performing a label-prescribed activity. In order to estimate this "upper bound" of daily exposure, WHS generally uses the estimated population 95th percentile of daily exposure. A population estimate is used instead of a sample statistic because sample maxima and upper-end percentiles, in samples of the sizes usually available to exposure assessors, are both statistically unstable and known to underestimate the population values. The population estimate, on the other hand, is more stable because it is based on all the observations rather than a single value; moreover, it is adjusted, in effect, for sample size, correcting some of the underestimation bias due to small samples. A high percentile is estimated, rather than the maximum itself, because in theory, the maximum value of a lognormal population is infinitely large. In practice, exposures must be bounded because a finite amount of active ingredient (AI) is applied. The use of a high percentile acknowledges that the assumed lognormal distribution is probably not a perfect description of the population of exposures, especially at the upper extremes. The population 95th percentile is estimated rather than a higher percentile, because the higher the percentile the less reliably it can be estimated and the more it tends to overestimate the population value (Chaisson *et al.*, 1999).

To estimate intermediate- and longer-term exposures, the average daily exposure is of interest because over these periods of time, a worker is expected to encounter a range of daily exposures (i.e., WHS assumes that with increased exposure duration, repeated daily exposure at the upper-bound level is unlikely). To estimate the average, WHS uses the arithmetic mean of daily exposure. The arithmetic mean is used rather than the geometric mean or the median because, although it can be argued that the latter statistics better indicate the location of the center of a skewed distribution, it is not the center that is of interest in exposure assessment, but the expected magnitude of the long-term exposure. While extremely high daily exposures are low-probability events, they do occur, and the arithmetic mean appropriately gives them weight in proportion to their probability. In most instances, the mean daily exposure of individuals over time is not known, and the mean daily exposure of a group of persons observed in a short-term study is believed to be the best available estimate.

Occupational Handler Exposure

Estimates for occupational agricultural and non-agricultural commercial handlers are grouped according to application method (e.g., aerial, airblast, groundboom, chemigation, etc.). Aerial, airblast and groundboom M/L/A were assumed to have exposures in the range of M/L and applicators (exposure estimates are normalized to an 8-hour day, and M/L/A would mix/load part of the day, and apply for the remainder). For this reason, separate M/L/A scenarios were not prepared for these scenarios.

Exposure Monitoring Studies

Handler exposure to carbaryl in agricultural and non-agricultural settings has been monitored in numerous studies, most of which involve hand-held spray equipment (Leavitt *et al.*, 1982; Waldron, 1985; Leonard and Yeary, 1990; Lavy *et al.*, 1993; Merricks, 1997). With the exception of Merricks (1997), these studies could not be used to estimate exposure. Leavitt *et al.* (1982) monitored exposure of five professional M/L/A using a power sprayer to spray trees; in addition to the small sample size, monitoring times were quite short (25 minutes). Waldron (1985) measured air concentrations of carbaryl during hand spray (power sprayer and backpack sprayer) applications in greenhouses; no dermal exposure monitoring was done, and there is no known relationship between air concentration and dermal exposure in workers. Leonard and Yeary (1990) monitored carbaryl concentrations (but not dermal exposure) in the breathing zone of commercial tree and shrub applicators using hand-held spray guns. Lavy *et al.* (1993) reported results of dermal exposure monitoring using patches and biomonitoring of nursery workers; however, because of high detection limits, these data were not used for exposure assessment.

Merricks (1997) monitored exposure of residential handlers applying multiple carbaryl products: a carbaryl dust product and liquid products using a hand pump sprayer, a hose-end sprayer, and RTU trigger sprayers . This study was reviewed by Beauvais (2011a), and exposure rates based on it are summarized in Table 20. The three liquid application methods (RTU trigger sprayer, hose-end sprayer, and hand-pump sprayer) each involved monitoring of 40 applications (Merricks, 1997). Handlers wore gloves during 20 applications, and did not wear gloves in the other 20 applications. Exposure statistics were calculated with 20 replicates for hand exposure, and 40 replicates for all other exposure matrices (Beauvais, 2011a). In the dust portion of the study, applications used a garden duster. Study subjects did not wear gloves. As the label on the currently registered dust product requires use of gloves, exposure estimates incorporated an assumption that applicators handling dust formulations wear gloves, and an adjustment was made to hand exposures reported by Merricks (1997) to reflect a 90% protection factor for wearing gloves (Aprea *et al.*, 1994; Moody and Nadeau, 1994; Stewart *et al.*, 1999; Creely and Cherrie, 2001).

Three studies monitored applicators using airblast equipment (Simpson, 1965; Comer *et al.*, 1975; Smith, 2005). With the exception of Smith (2005), these studies could not be used to estimate exposure. Simpson (1965) monitored dermal and inhalation exposures of airblast applicators, but did not report the number of workers monitored was not reported, nor was sufficient information given to allow calculation of carbaryl exposure to individual workers. Comer *et al.* (1975) monitored carbaryl exposure of workers in pesticide formulation plants, as well as workers who applied carbaryl solutions in orchards using tractor-drawn airblast equipment. The amount of carbaryl handled by applicators was not reported; neither were application rates and acres treated.

Table 20. Non-Agricultural Handler Exposure Rate Estimates

Scenario [a]	Exposure Route	Short-Term Exposure Rate (µg/lb AI) [b]	Long-Term Exposure Rate (µg/lb AI) [c]
Dust Loader/Applicator [d]	Dermal	136,000	25,300
	Inhalation	8,100	1,140
	Total	144,000	26,400
RTU Trigger Spray Applicator [e]	Dermal	35,700	3,070
	Inhalation	202	50.5
	Total	35,900	3,120
Hose-End Spray Loader/Applicator [e]	Dermal	3,720	347
	Inhalation	3.83	1.21
	Total	3,720	348
Hand-Pump Spray M/L/A [e] (Low-Pressure Handwand)	Dermal	4,170	567
	Inhalation	19.7	5.73
	Total	4,190	573
Push-Spreader Granular Loader/Applicator [f]	Dermal	627	137
	Inhalation	3.18	1.10
	Total	630	138

[a] Data from Merricks (1997) and Klonne and Honeycutt (1999). Handlers are assumed to wear long-sleeved shirts, long pants, and gloves. All values rounded to three significant figures. M/L/A: Mixer/Loader/Applicator. RTU: Ready-to-use liquid formulation.
[b] Short-term exposure rates are 95th percentiles, calculated assuming a lognormal distribution (Frank, 2009a).
[c] Long-term exposure rates are the arithmetic mean.
[d] Data from Merricks (1997); see Beauvais (2011a) for details and calculations. Twenty subjects monitored in the study did not wear gloves, and a 90% protection factor was applied to estimate gloved exposure (Aprea *et al.*, 1994; Moody and Nadeau, 1994; Stewart *et al*., 1999; Creely and Cherrie, 2001).
[e] Data from Merricks (1997); see Beauvais (2011a) for details and calculations. Forty subjects were monitored while handling carbaryl.
[f] Data from Klonne and Honeycutt (1999); see Beauvais (2011b) for details and calculations. Thirty subjects were monitored while handling a granular dimethyl tetrachloroterephthalate product.

Smith (2005) monitored dermal and inhalation exposure of airblast applicators driving open-cab tractors to carbaryl. This study was reviewed by Beauvais (2006b). Applicators wore either Sou'wester rain hats (15 replicates) or hooded rain jackets (10 replicates) as chemical-resistant headgear. Because the jackets provided an extra layer of clothing over the torso and arms, only data from the replicates wearing rain hats were used to estimate exposure. Dermal exposure was monitored with whole-body dosimeters, face/neck wipes, hand washes and patches on the inside and outside of headgear. Inhalation exposure was monitored with breathing zone air samplers consisting of OSHA Versatile Sampler tubes, each containing glass fiber filter and XAD-2 sorbent and connected to a sampler pump calibrated to 2 liters per minute. Applicators were monitored for 5 – 8 hours each, which is about the length of a typical workday for them. Actual spray times ranged 3.3 – 5.7 hours; applicators handled 24 – 90 pounds AI (11 – 41 kg), and treated 12 – 30 acres (5 – 12 ha). Quality assurance samples consisted of laboratory control samples of each matrix, laboratory-fortified samples of each matrix, and field fortified samples of each matrix. Field spikes consisted of each sample matrix spiked with formulated product, and with the exception of socks all field spike recoveries were in the acceptable range (70 – 120%). Results were corrected for field spike recoveries below 90%. Exposure monitoring results for airblast applicators wearing Sou'wester rain hats are summarized in Table 21. Airblast applicators spraying carbaryl are required to wear chemical-resistant headgear, as product labels require chemical-resistant headgear for overhead exposures such as those that occur during airblast application. Airblast applicator exposure estimates were based on these data.

Table 21. Exposure of Open-Cab Airblast Applicators

Statistic [a]	Exposure Rate (µg/lb AI handled)
Dermal Exposure	
Arithmetic Mean	70.2
Arithmetic Mean for Applicator Wearing Coveralls [b]	27.1
Standard Deviation	65.4
95th Percentile [c]	277
95th Percentile for Applicator Wearing Coveralls [b]	111
Inhalation Exposure	
Arithmetic Mean	3.41
Standard Deviation	3.65
95th Percentile [c]	9.54

[a] Summary of data from open-cab airblast exposure monitoring study (Smith, 2005). Only the 15 replicates wearing Sou'wester rain hats were included; carbaryl product labels require chemical-resistant headgear for overhead exposures such as occur during airblast application. Arithmetic mean exposure rates were used to calculate long-term exposures and 95th percentile exposure rates were used to calculate short-term exposures. All estimates were rounded to three significant figures.

[b] Calculated using a 90% protection factor applied to parts of body covered by coveralls (Thongsinthusak *et al.*, 1993).

[c] 95th percentile estimates calculated in Excel, assuming a lognormal distribution (Frank, 2009a). First the natural logarithm (ln) was calculated for each value using the LN function; arithmetic mean and standard deviation was then calculated for the natural logarithms (am(lns) and asd(lns), respectively). The NORMSINV function, with a probability of 0.95, was used to get the inverse of the standard normal cumulative distribution, which was multiplied by asd(lns). This result was added to am(lns), and the sum taken as the power of e with the EXP function.

No chemical-specific monitoring data are available for granular applications using a push-type lawn spreader, but a well-conducted surrogate study by Klonne and Honeycutt (1999) was reviewed by Beauvais (2011b). The surrogate compound was Dacthal® granular herbicide, containing 0.9% dimethyl tetrachloroterephthalate (DCPA). Klonne and Honeycutt (1999) monitored exposures to handlers applying Dacthal® granular herbicide to sod plots with a push-type rotary spreader. This study was reviewed by Beauvais (2011a). Exposure rate estimates from this study are given in Table 20.

Exposure Estimates Using the Pesticide Handler Exposure Database

With the exception of airblast applicators, dust applicators, and handlers applying liquids by trigger sprayer, hand pump sprayer, or hose-end sprayer, exposure estimates were based on the Pesticide Handler Exposure Database (PHED, 1995). PHED was developed by the U.S. EPA, Health Canada and the American Crop Protection Association to provide non-chemical-specific (generic) pesticide handler exposure estimates for specific handler scenarios. It combines exposure data from multiple field monitoring studies using several different AIs.

PHED has limitations as a surrogate database (Beauvais *et al.*, 2007). It combines measurements from diverse studies involving different protocols, analytical methods and residue detection limits. Most dermal exposure studies in PHED use the patch dosimetry method of Durham and Wolfe (1962). To estimate exposure, residues on patches placed on different parts of the body are multiplied by the surface area of the body part. These partial estimates are then summed to provide a total body exposure estimate. Some studies observed exposure to only selected body parts such as the hands, arms and face. As a consequence, dermal exposure estimates for different body parts may be based on a different set of observations. Furthermore, for some handler scenarios, the small number of matching observations in the PHED creates the substantial possibility they do not represent the target scenario. Due to the degree of uncertainty introduced by PHED, WHS calculates upper confidence limits (UCLs) on the exposure statistics to increase the confidence in the estimates of exposure. For short-term exposure estimates, WHS uses the 90% UCL on the 95th percentile. For intermediate or long-term exposure estimates, WHS uses the 90% UCL on the arithmetic mean. Because the sample sizes per body region differ and because the correlations among body regions are unknown, the standard deviation of total dermal exposure cannot be calculated. In order to approximate the confidence limit for the 95th percentile, WHS makes the assumption that total exposure is lognormally distributed and has a coefficient of variation of 100 percent (Frank, 2007; Powell, 2007). The value taken from PHED is adjusted with a multiplier that varies by effective sample size. For non-hand dermal exposure, the effective sample size is estimated as weighted harmonic mean of the numbers of observations for the body parts; this calculation was described by Powell (2007).

Aerial Applications

Carbaryl may be applied aerially on crops or to non-crop areas such as pastures, rangeland, or forests. The maximum application rate for carbaryl applied aerially is on citrus, which in California is 12 lbs AI/acre. For aerial applications, the number of acres treated per day was assumed to be 350 acres/day, based on the default recommended by U.S. EPA (2001). High-acre applications, up to 1,200 acres/day, also occur in California, on pasture and rangeland; such applications are allowed on product labels for Rangeland Grasshopper and Mormon Cricket Suppression through the Animal and Plant Health Inspection Service (APHIS) Program or affiliated state program. These are the only aerial applications allowed for granular products, and for this reason granular products only have high-acre aerial scenarios. Table 22 summarizes exposure rates and short-term exposure estimates for handlers associated with aerial applications.

Appendix 3 summarizes exposure rates for each scenario, based on PHED (Beauvais *et al*., 2007), and adjusted as needed with default protection factors for additional PPE and engineering controls. Aerial applications assumed an open system for M/L and that handlers (M/L, applicators, and flaggers) wore the clothing specified on the product label: long-sleeved shirt and pants, chemical-resistant gloves, and shoes and socks. Chemical-resistant aprons are required when mixing, loading, and cleaning spills or equipment, and M/L working in support of aerial applications are also required to wear respirators. Applicators (pilots) are required to be in enclosed cockpits, and flaggers are required to be in enclosed cabs. As no exposure monitoring data were available for flaggers in closed cabs, flagger exposure was adjusted by applying a default 90% protection factor to data from PHED.

To be health-protective, short-term exposure estimates assume the maximum application rate allowed by product labels, and a reasonable maximum application size. Pesticide uses reported to DPR suggest that application rates of carbaryl on many crops are frequently at or near the maximum allowed. However, smaller application sizes are common. Appendix 4 summarizes annual mean application rates and sizes in a recent 5-year interval for selected crops. For seasonal, annual, and lifetime exposures, the mean application size is a better approximation than the maximum allowed rate of what handlers encounter over longer intervals.

Table 22. Exposure Rates and Short-Term Exposure Estimates for Workers Handling Carbaryl in Support of Aerial Applications

Scenario [a]	# [b]	Short-Term Exposure Rates [c] (µg/lb AI handled)		Long-Term Exposure Rates [d] (µg/lb AI handled)		STADD [e] (mg/kg/day)		
		Dermal	Inhalation	Dermal	Inhalation	Dermal	Inhalation	Total
Aerial (Liquids) [f]								
Mixer/Loader	5	1446	0.734	520.9	0.264	60.8	0.0440	60.8
Applicator	18	12.4	0.0916	4.46	0.0329	0.521	0.00550	0.526
High-Acre Aerial (Liquids) [g]								
Mixer/Loader	5	1446	0.734	NA	NA	26.0	0.0189	26.0
Applicator	18	12.4	0.0916	NA	NA	0.223	0.00236	0.226
Flagger [h]	7	13.302	0.0680	NA	NA	0.239	0.00175	0.241
High-Acre Aerial (Granular) [i]								
Loader	4	29.29	1.10	NA	NA	0.527	0.0283	0.556
Applicator	19	4.061	4.52	NA	NA	0.0731	0.116	0.189
Flagger [h]	8	0.5522	0.0588	NA	NA	0.00994	0.00151	0.0115

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

[b] Scenario numbers from Beauvais *et al.* (2007). See Appendix 3 for summaries of scenarios and exposure rates. Handlers were assumed to wear long-sleeved shirt, long pants, shoes, socks, and chemical-resistant gloves as specified on product labels. Mixer/loaders were assumed to wear respirator and chemical-resistant apron.

[c] These exposure rates were used to calculate STADD, as explained in Footnote [e].

[d] These exposure rates were used to calculate Seasonal Average Daily Dosage and Annual Average Daily Dosage in Table 23. NA = Not applicable; only short-term exposure estimates are needed for this scenario.

[e] Short-Term Absorbed Daily Dosage (STADD) is an upper-bound estimate calculated from the short-term exposure. Application rate is maximum rate on product labels, which varied for each scenario; acres treated per day varies by scenario. Calculation:
STADD = [(short-term exposure) x (absorption) x (acres treated/day) x (application rate)]/(70 kg body weight).
Calculation assumptions include: dermal absorption = 70% (Beauvais, 2006a); body weight = 70 kg (Thongsinthusak *et al*., 1993); inhalation rate 16.7 liters/min (Andrews and Patterson, 2000); and inhalation absorption = 100% (Frank, 2008).

[f] STADD estimates assumed 350 acres (142 ha) treated/day (U.S. EPA, 2001), and a maximum application rate of 12 lbs AI/acre (13.5 kg AI/ha), maximum rate on citrus. Human flaggers are prohibited for this use.

[g] STADD estimates assumed 1,200 acres (486 ha) treated/day (U.S. EPA, 2001), and a maximum application rate of 1.5 lbs AI/acre (1.7 kg AI/ha), maximum rate on rangeland and pastures.

[h] Human flaggers are prohibited, except to support ultra-low volume aerial applications for Rangeland Grasshopper and Mormon Cricket Suppression through the Animal and Plant Health Inspection Service (APHIS) Program or affiliated state program. Flaggers must be in enclosed cabs, and must wear label-required clothing and protective equipment. A default 90% protection factor was applied to both dermal and inhalation for use of closed cab.

[i] STADD estimates assumed 1,200 acres (486 ha) treated/day (U.S. EPA, 2001), and a maximum application rate of 1.5 lbs AI/acre (1.7 kg AI/ha), maximum rate on rangeland and pastures. The only aerial applications allowed of granular carbaryl products are Grasshopper and Mormon Cricket Suppression through APHIS Program or affiliated state program.

Seasonal, annual, and lifetime exposure estimates for occupational handlers of carbaryl in support of aerial applications are summarized in Table 23. Examination of applications reported over a recent 10-year interval (2001 – 2010) suggests that applications larger than 350 acres/day are rare (DPR, 2012a; data not shown). Seasonal, annual, and lifetime exposures are therefore not anticipated for high-acre aerial scenarios.

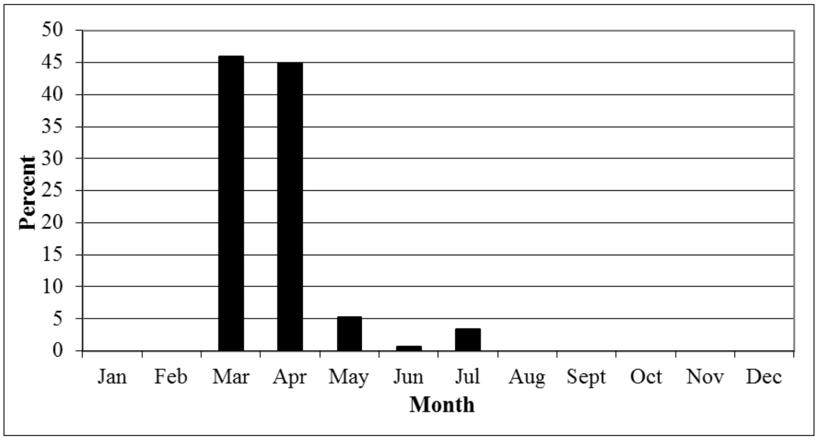
Table 23. Seasonal, Annual, and Lifetime Estimates for Workers Handling Carbaryl in Support of Aerial Applications

Scenario [a]	SADD [b] (mg/kg/day)			AADD [c] (mg/kg/day)			LADD [d] (mg/kg/day)		
	Dermal	Inhalation	Total	Dermal	Inhalation	Total	Dermal	Inhalation	Total
Aerial (Liquids)									
Mixer/Loader	1.25	0.000905	1.25	0.313	0.000226	0.313	0.167	0.000121	0.167
Applicator	0.0107	0.000113	0.0108	0.00268	0.0000282	0.00270	0.00143	0.0000150	0.00144

[a] Exposure estimates are based on data from the Pesticide Handlers Exposure Database (PHED, 1995). Exposure rates are given in Table 22. No seasonal, annual, or lifetime exposure is anticipated for high-acre liquid and granular scenarios, as applications > 350 acres are infrequently reported in the Pesticide Use Report (DPR, 2012a).
[b] Seasonal Average Daily Dosage is a 90% upper confidence estimate calculated from the long-term exposure rates given in Table 22. Calculation assumptions include: dermal absorption = 70% (Beauvais, 2006a); body weight = 70 kg (Thongsinthusak *et al*., 1993); inhalation rate 16.7 liters/min (Andrews and Patterson, 2000); and inhalation absorption = 100% (Frank, 2008). Exposure estimates assumed 120 acres (48.6 ha) treated/day, based on average number of acres treated by each grower daily, as reported in the Pesticide Use Report (DPR, 2012a), and an application rate of 2 lbs AI/acre (2.25 kg AI/ha), the typical rate reported for aerial applications to tomatoes, as summarized in Appendix 4. Calculation:
SADD = [(long-term exposure) x (absorption) x (acres treated/day) x (application rate)]/(70 kg body weight).
[c] Annual Average Daily Dosage = SADD x (annual use months per year)/(12 months in a year). Annual exposure estimate based on high-use period of 3 months, based on data from DPR (2012).
[d] Lifetime Average Daily Dosage = AADD x (40 years of work in a lifetime)/(75 years in a lifetime).

To estimate intermediate and long-term exposures of workers involved in aerial applications of carbaryl, temporal patterns were investigated by plotting percent of annual use based on pounds applied per month for a recent five year interval, 2006 – 2010. Although the highest application rate for carbaryl is on citrus, and short-term exposure estimates assumed applications to citrus, relatively few aerial applications to citrus, or any other tree crop, occurred then (DPR, 2012a; data not shown). Tomatoes, with a maximum allowed application rate of 2 lbs AI/acre, are the crop with the highest application rate and seasonal aerial applications. Data for Fresno County, which has on average the most aerial applications of carbaryl on tomatoes, are summarized in Figure 5. These data are used to estimate application of liquid formulations (aerial application of granular formulations to tomatoes or other crops are not permitted). Aerial applications of carbaryl on tomatoes occurred in the 3 months of March through May. Annual use was estimated to occur during these 3 months.

Figure 5. Aerial Applications of Carbaryl on Tomatoes in Fresno County, 2006 – 2010 [a]



[a] Percent calculations based on pounds applied (DPR, 2012a; queried on April 23, 2012).

Airblast Applications

Exposure estimates for handlers involved in airblast applications assumed an open system, as closed systems are not required for carbaryl products. Product labels require the use of closed cabs for all airblast applications to citrus, and additional PPE consisting of chemical-resistant coveralls, chemical-resistant headgear, and respirator are required for applicators making airblast applications on other crops at or above 5 lbs AI/acre. For this reason, exposures are estimated for three different airblast applicator scenarios: closed-cab applications to citrus; open-cab applications above 5 lbs AI/acre while wearing additional PPE; and open-cab applications at rates below 5 lbs AI/acre. Table 24 summarizes exposure rates and short-term exposure estimates for handlers in support of airblast and groundboom applications.

The maximum application rate for carbaryl applied by airblast is on citrus, which in California is 12 lbs AI/acre (13.5 kg AI/ha); this rate was assumed for closed-cab airblast applications. For open-cab applications having a maximum rate at or above 5 lbs AI/acre, the crop having the allowed maximum application rate is olive, at 7.5 lbs AI/acre (8.4 kg AI/ha); this is the highest allowed application rate on any crop other than citrus. For open-cab applications having a maximum rate below 5 lbs AI/acre, the highest application rate is on pome fruit, at a rate of 3.0 lbs AI/acre (3.4 kg AI/ha). Apple was selected for this scenario as the pome fruit with the most carbaryl applications.

In estimating short-term exposures for all airblast applications, the amount treated was assumed to be 40 acres/day (16 ha/day), the default recommended as a realistic maximum by U.S. EPA (2001). Airblast M/L/A were assumed to have exposures in the range of M/L and applicators (exposure estimates are normalized to an 8-hour day, and M/L/A would mix/load part of the day, and apply for the remainder).

Table 24. Exposure Rates and Short-Term Exposure Estimates for Workers Handling Carbaryl in Support of Airblast and Groundboom Applications

Scenario [a]	# [b]	Short-Term Exposure Rates [c] (µg/lb AI handled)		Long-Term Exposure Rates [d] (µg/lb AI handled)		STADD [e] (mg/kg/day)		
		Dermal	Inhalation	Dermal	Inhalation	Dermal	Inhalation	Total
Airblast								
Mixer/Loader [f]	5	1446	7.34	520.9	2.64	6.94	0.0503	6.99
Applicator, Citrus [f]	10	123.2	1.78	44.3	0.641	0.591	0.0122	0.604
Applicator, 5-7.5 [g]	- -	111	9.54	27.1	3.41	0.333	0.0409	0.374
Applicator, < 5 [h]	9	3340.5	17.6	1201	6.32	4.01	0.0302	4.04
Groundboom [i]								
Mixer/Loader	5	1446	7.34	520.9	2.64	2.31	0.0168	2.33
Applicator	11	85.3	4.12	30.66	1.48	0.136	0.00942	0.146
High-Acre Groundboom [j]								
Mixer/Loader	5	1446	7.34	520.9	2.64	5.78	0.0419	5.82
Applicator	11	85.3	4.12	30.66	1.48	0.341	0.0235	0.365

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

[b] Scenario numbers from Beauvais *et al.* (2007). See Appendix 3 for summaries of scenarios and exposure rates. Handlers were assumed to wear long-sleeved shirt, long pants, shoes, socks, chemical-resistant gloves, and respirator as specified on product labels. Mixer/loaders were assumed to wear chemical-resistant apron.

[c] These exposure rates were used to calculate STADD, as explained in Footnote [e].

[d] These exposure rates were used to calculate Seasonal Average Daily Dosage and Annual Average Daily Dosage in Table 25.

[e] Short-Term Absorbed Daily Dosage (STADD) is an upper-bound estimate calculated from the short-term exposure. Application rate is maximum rate on product labels, which varied for each scenario; acres treated per day varies by scenario. Calculation:
STADD = [(short-term exposure) x (absorption) x (acres treated/day) x (application rate)]/(70 kg body weight).
Calculation assumptions include: dermal absorption = 70% (Beauvais, 2006a); body weight = 70 kg (Thongsinthusak *et al*., 1993); inhalation rate 16.7 liters/min (Andrews and Patterson, 2000); and inhalation absorption = 100% (Frank, 2008).

[f] STADD estimates assumed 40 acres (16 ha) treated/day (U.S. EPA, 2001), and a maximum application rate of 12 lbs AI/acre (13.5 kg AI/ha), maximum rate on citrus. Applicator required to be in an enclosed cab.

[g] Open-cab airblast applying at rates of 5 lbs AI/acre to 7.5 lbs AI/acre; applicator must wear coverall and chemical-resistant headgear in addition to other handler requirements. STADD estimates assumed 40 acres (16 ha) treated/day (U.S. EPA, 2001), and a maximum application rate of 7.5 lbs AI/acre (8.42 kg AI/ha), maximum rate on olive. Exposure estimates based on data from Smith (2005), as summarized in Table 21.

[h] Open-cab airblast applying at rates less than 5 lbs AI/acre. STADD estimates assumed 40 acres (16 ha) treated/day (U.S. EPA, 2001), and a maximum application rate of 3.0 lb AI/acre (3.4 kg AI/ha), maximum rate on apple.

[i] STADD estimates assumed 80 acres (32 ha) treated/day (U.S. EPA, 2001), and a maximum application rate of 2.0 lb AI/acre (2.2 kg AI/ha), maximum rate on tomato.

[j] STADD estimates assumed 200 acres (81 ha) treated/day (U.S. EPA, 2001), and a maximum application rate of 2.0 lb AI/acre (2.2 kg AI/ha), maximum rate on tomato.

Airblast applications are common in tree crops, such as citrus. For the purpose of estimating handler exposure all ground applications to citrus, olive, and apple were assumed to be airblast applications. Table 25 summarizes seasonal, annual, and lifetime exposure estimates.

Table 25. Seasonal, Annual, and Lifetime Estimates for Workers Handling Carbaryl in Support of Airblast and Groundboom Applications

Scenario [a]	SADD [b] (mg/kg/day)			AADD [c] (mg/kg/day)			LADD [d] (mg/kg/day)		
	Dermal	Inhalation	Total	Dermal	Inhalation	Total	Dermal	Inhalation	Total
<u>Airblast</u>									
Mixer/Loader [e]	1.56	0.0113	1.57	0.781	0.00566	0.787	0.417	0.00302	0.420
Applicator, Citrus [e]	0.133	0.00275	0.136	0.0664	0.00137	0.0678	0.0354	0.000733	0.0362
Applicator, 5-7.5 [f]	0.0650	0.0117	0.0767	0.0163	0.00292	0.0192	0.00867	0.00156	0.0102
Applicator, < 5 [g]	0.961	0.00722	0.968	0.160	0.00120	0.161	0.0854	0.000854	0.0860
<u>Groundboom</u> [h]									
Mixer/Loader	0.417	0.00302	0.420	0.104	0.000754	0.105	0.0556	0.000402	0.0560
Applicator	0.0245	0.00169	0.0262	0.00613	0.000423	0.00655	0.00327	0.000226	0.00350
<u>High-Acre GB</u> [i]									
Mixer/Loader	0.573	0.00415	0.577	0.143	0.00104	0.144	0.0764	0.000553	0.0770
Applicator	0.0337	0.00233	0.0361	0.00843	0.000581	0.00901	0.00450	0.000310	0.00481

[a] Exposure estimates are based on data from the Pesticide Handlers Exposure Database (PHED, 1995), unless otherwise indicated. Exposure rates are given in Table 24. Average numbers of acres treated and typical application rates are summarized in Appendix 4, and queried from the Pesticide Use Report (DPR, 2012a),.

[b] Seasonal Average Daily Dosage is a 90% upper confidence estimate calculated from the long-term exposure rates given in Table 24. Calculation assumptions include: dermal absorption = 70% (Beauvais, 2006a); body weight = 70 kg (Thongsinthusak *et al*., 1993); inhalation rate 16.7 liters/min (Andrews and Patterson, 2000); and inhalation absorption = 100% (Frank, 2008). Calculation:
SADD = [(long-term exposure) x (absorption) x (acres treated/day) x (application rate)]/(70 kg body weight).

[c] Annual Average Daily Dosage = SADD x (annual use months per year)/(12 months in a year).

[d] Lifetime Average Daily Dosage = AADD x (40 years of work in a lifetime)/(75 years in a lifetime).

[e] Applicator required to be in an enclosed cab. Exposure estimates assumed 30 acres (12 ha) treated/day, and an application rate of 10 lbs AI/acre (11.2 kg AI/ha), the typical rate reported for ground applications to citrus. Annual exposure estimate assumed a high-use period of 6 months.

[f] Open-cab airblast applying at rates of 5 lbs AI/acre to 7.5 lbs AI/acre; applicator must wear coverall and chemical-resistant headgear in addition to other handler requirements. Exposure estimates assumed 40 acres (16 ha) treated/day, and an application rate of 6 lbs AI/acre (6.74 kg AI/ha), the typical rate reported for ground applications to olives. Exposure estimates based on data from Smith (2005), as summarized in Table 21. Annual exposure estimate assumed a high-use period of 3 months.

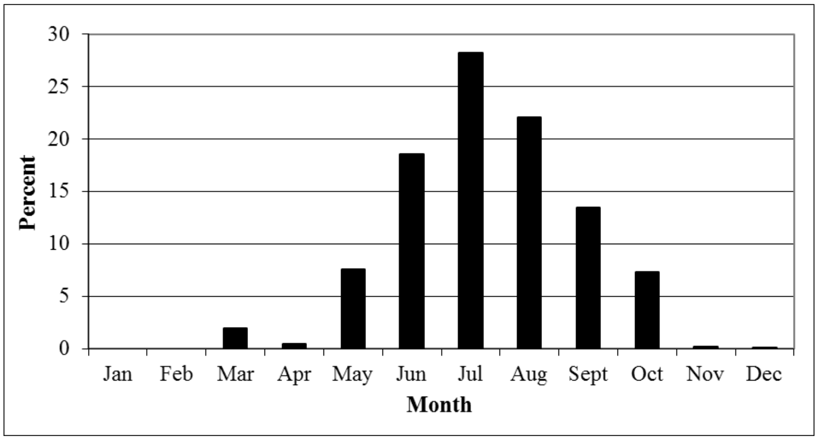
[g] Open-cab airblast applying at rates less than 5 lbs AI/acre. Exposure estimates assumed 40 acres (16 ha) treated/day, and an application rate of 2 lbs AI/acre (2.25 kg AI/ha), the typical rate reported for ground applications to apples. Annual exposure estimate assumed a high-use period of 2 months.

[h] Exposure estimates assumed 80 acres (32 ha) treated/day, and an application rate of 1 lb AI/acre (1.12 kg AI/ha), the typical rate reported for ground applications to tomatoes. Annual exposure estimate assumed a high-use period of 3 months.

[i] GB = groundboom. Exposure estimates assumed 110 acres (44.5 ha) treated/day, and an application rate of 1 lb AI/acre (1.12 kg AI/ha), the typical rate reported for ground applications to tomatoes. Annual exposure estimate assumed a high-use period of 3 months.

For closed-cab airblast, Figure 6 summarizes ground applications of carbaryl to citrus in Tulare County, the county with the highest use on citrus. Applications were > 5% of the annual total in 6 months, May through October. The high-use season was considered to be 6 months for calculating seasonal, annual, and lifetime exposures. The assumed typical application rate and size were 10 lbs AI/acre and 30 acres, based on the highest annual mean values reported for carbaryl applications to citrus in California during a recent 5-year interval (see Appendix 4 for details).

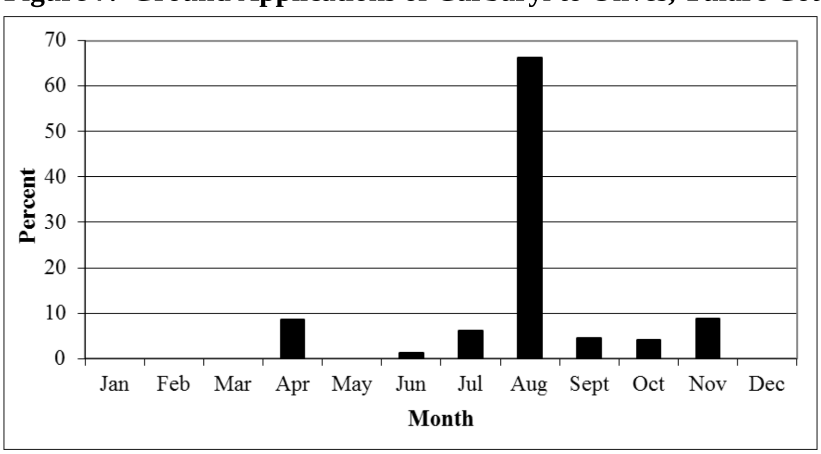
Figure 6. Ground Applications of Carbaryl on Citrus, Tulare County, 2006 – 2010 [a]



[a] Percent calculations based on pounds applied (DPR, 2012a; queried on April 23, 2012).

For open-cab airblast at rates between 5 and 7.5 lbs AI/acre, Figure 7 summarizes ground applications of carbaryl to olives in Tulare County. Applications were > 5% of the annual total in 3 months, July through September (for example, 6.2% of annual applications occurred in July; note that the scale in Figure 7 differs from the scale in Figure 6). Seasonal, annual, and lifetime exposures assume exposure occurs during these 3 months. The assumed typical rate and size were 6 lbs AI/acre and 40 acres, based on the highest annual mean values reported for carbaryl applications to olives in California during a recent 5-year interval (see Appendix 4 for details).

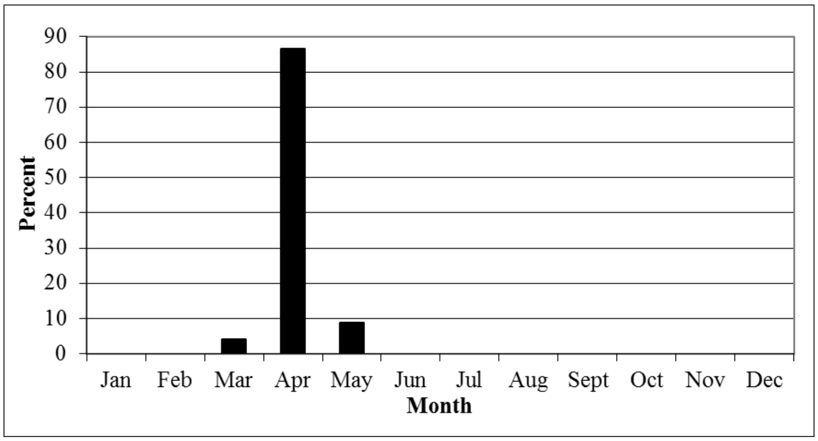
Figure 7. Ground Applications of Carbaryl to Olives, Tulare County, 2006 – 2010 [a]



[a] Percent calculations based on pounds applied (DPR, 2012a; queried on April 23, 2012). Note scale: each line on y-axis represents 10%.

For open-cab airblast at rates < 5 lbs AI/acre, Figure 8 summarizes ground applications of carbaryl to apples in San Joaquin County; applications were > 5% of the annual total in 2 months, April and May. Seasonal, annual, and lifetime exposures assume exposure occurs during these 2 months. The assumed typical rate and size were 2 lbs AI/acre and 40 acres, based on the highest annual mean values reported for carbaryl applications to apples in California during a recent 5-year interval (see Appendix 4 for details).

Figure 8. Ground Applications of Carbaryl to Apples, San Joaquin County, 2006 – 2010 [a]



[a] Percent calculations based on pounds applied (DPR, 2012a; queried on April 24, 2012). Note scale: each line on y-axis represents 10%.

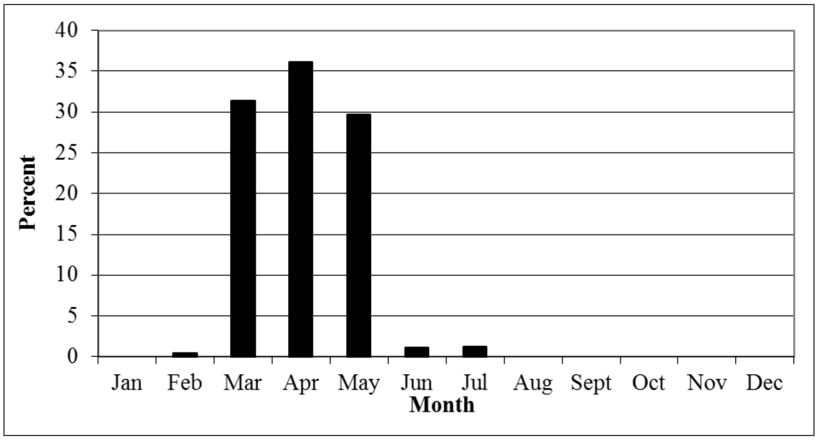
Groundboom Applications

Groundboom applications are common in row crops, such as tomatoes, corn, and strawberries. Exposure estimates assumed an open system for M/L and that all handlers wore the clothing specified on the product label. Exposure estimates assumed open cabs, as there is no requirement for closed cabs. Groundboom M/L/A were assumed to have exposures in the range of M/L and applicators (exposure estimates are normalized to an 8-hour day, and M/L/A would mix/load part of the day, and apply for the remainder).

The maximum application rate for carbaryl applied by groundboom is 2 lb AI/acre (2.2 kg AI/ha). This is the maximum rate allowed on several crops, including tomatoes, corn, and strawberries, and was assumed for short-term exposure estimates. The amount treated for groundboom applications was assumed to be 80 acres/day (32 ha/day), the default recommended by U.S. EPA (2001). High-acre applications of carbaryl occur on tomatoes. For short-term exposures occurring during high-acre groundboom applications, the amounted treated was assumed to be 200 acres (81 ha) treated/day (U.S. EPA, 2001). Seasonal, annual, and lifetime exposures occurring during high-acre groundboom applications assumed 110 acres (44.5 ha), the average number of acres treated by each grower daily (see Appendix 4).

When estimating seasonal, annual, and lifetime handler exposures, all ground applications to tomatoes were assumed to be groundboom applications. Figure 9 summarizes ground applications of carbaryl to tomatoes in Fresno County; applications were ≥ 5% of the annual total in 3 months, March through May. The assumed typical rate and size were 1 lb AI/acre and 80 acres, the highest annual mean values reported for carbaryl ground applications to tomatoes in California during a recent 5-year interval (see Appendix 4 for details).

Figure 9. Ground Applications of Carbaryl to Tomatoes, Fresno County, 2006 – 2010 [a]



[a] Percent calculations based on pounds applied (DPR, 2012a; queried on April 24, 2012).

Chemigation

The representative chemigation scenario is open-pour mixing/loading of liquid carbaryl products. During application, handlers are not present except to inspect and make needed repairs to irrigation lines. Current carbaryl product labels allow application through two kinds of sprinkler irrigation systems: center pivot and solid set. Application is prohibited with any other irrigation system. The maximum application rate listed on product labels with directions for chemigation is on citrus, which in California is 12 lb AI/acre. Handlers involved with chemigation are assumed to treat 350 acres/day (U.S. EPA, 2001). STADD for chemigation is 60.8 mg/kg/day via the dermal route, 0.0440 mg/kg/day via the inhalation route, and a total (dermal and inhalation) exposure of 60.8 mg/kg/day.

For the purpose of estimating long-term handler exposure associated with chemigation, all ground applications to citrus are assumed to be via chemigation. Although this approach likely overestimates long-term exposures due to chemigation (other methods, such as airblast, would also be recorded as ground applications in the PUR), it is the best estimate available. The high-use season was considered to be 6 months for calculating seasonal, annual, and lifetime exposures (see Figure 6). The assumed typical rate and size were 10 lbs AI/acre and 30 acres, based on the highest annual mean values reported for carbaryl applications to citrus in California during a recent 5-year interval (see Appendix 4 for details).

The SADD for chemigation is 1.56 mg/kg/day via the dermal route, 0.00113 mg/kg/day via the inhalation route, and a total exposure of 1.56 mg/kg/day. The AADD is 0.781 mg/kg/day via the dermal route, 0.000566 mg/kg/day via the inhalation route, and a total exposure of 0.782 mg/kg/day. The LADD is 0.417 mg/kg/day via the dermal route, 0.000302 mg/kg/day via the inhalation route, and a total exposure of 0.417 mg/kg/day.

Rights-of-Way Spray Applications

Table 26 summarizes short-term exposure estimates for workers applying carbaryl to rights-of-way; the maximum application rate for this use is 1.0 lb AI/acre. U.S. EPA (2001) recommends a default of 1,000 gallons per day for rights-of-way applications: "Based on PHED application data normalized to an 8 hour day and cultural use patterns. (Typical application rate of 150 gallons/acre. Lower application rates are assumed to have higher total acreage treated per day)." Carbaryl liquid product labels recommend dilution rates of one pound carbaryl to 1 – 39 quarts of water for ground applications, with no specific dilution recommended for rights-of-way applications; in that dilution range, 1 lb AI/acre would result in 2 – 40 quarts/acre, and 1,000 gallons would contain 100 – 2,000 lbs carbaryl. However, the largest carbaryl spray application reported within a recent 10-year interval (2001 – 2010) was 44 lbs AI, suggesting that the low end of that range, 100 lbs AI/day, is a more realistic yet health-protective value for carbaryl applications to rights-of-way in California. Thus, short-term exposure estimates assume 100 acres are treated at 1 lb AI/acre.

Examination of carbaryl use on rights-of-way reported over the same 10-year interval shows that less than 100 pounds of carbaryl have been applied, suggesting that this use is limited and probably does not occur frequently in California. Additional support for this conclusion is found in the PUR: a total of 20 applications were reported between 2006 and 2010, an average of just three each year (DPR, 2012a; data not shown). With so few uses, seasonal, annual, and lifetime exposures are not anticipated for rights-of-way scenarios.

Backpack Sprayer Applications

Table 26 summarizes PHED data and assumptions used in exposure estimates and STADD for handlers applying carbaryl with handheld equipment, including backpack sprayers. The highest exposure for handlers using backpack sprayers is anticipated to be on ornamental plants, which can be treated with a solution containing 5 fluid ounces of a product containing 43.4% or 44.1% carbaryl in each gallon of solution (5 fl. oz. = 148 ml), equivalent to 0.156 pounds (0.0709 kg) AI. In their occupational risk assessment for carbaryl, U.S. EPA refers to this as a 2% solution (Britton, 2007a). Occupational handlers are assumed to mix, load, and apply 40 gallons/day of this solution (150 liters/day; U.S. EPA, 2001).

Table 26. Exposure Rates and Short-Term Handler Exposure Estimates for Hand-Held Applications of Carbaryl Liquids

Scenario [a]	# [b]	Short-Term Rates (µg/lb AI handled) [c]		Long-Term Rates (µg/lb AI handled) [d]		STADD (mg/kg/day) [e]		
		Dermal	Inhalation	Dermal	Inhalation	Dermal	Inhalation	Total
Right-of-Way [f]								
Mixer/Loader	5	1446	0.734	NA	NA	1.45	0.0105	1.46
Applicator	16	48,800	12.3	NA	NA	48.8	0.0176	48.8
Backpack Sprayer [g]								
M/L/A	20	85,640	67.1	30,940	4.43	5.34	0.00598	5.35
High-Pressure Handwand [h]								
M/L/A	21	26,470	565	9,536	203	41.3	1.26	42.6
Low-Pressure Handwand [g]								
M/L/A	- -	4,170 [i]	19.7 [i]	567 [i]	5.73 [i]	0.260	0.00176	0.262
Trigger Spray Applicator [j]								
M/L/A	- -	35,700 [i]	202 [i]	3,070 [i]	50.5 [i]	0.000939	0.00000759	0.000946
Hose-End Sprayer [k]								
M/L/A	- -	3,720 [i]	3.83 [i]	347 [i]	1.21 [i]	0.580	0.000854	0.581

[a] Exposure estimates are based on data from the Pesticide Handlers Exposure Database (PHED, 1995), unless otherwise indicated. Exposure rates and STADD were rounded to three significant figures; dermal exposure rates may have four significant figures as a result of adding together hand and non-hand dermal exposures (see Appendix 3 for details). M/L/A = mixer/loader/applicator. Due to lack of data, dermal exposure estimates for M/L/A do not include label-required use of chemical-resistant apron while mixing and loading.

[b] Scenario numbers from Beauvais *et al.* (2007). See Appendix 3 for summaries of scenarios and exposure rates. Handlers were assumed to wear long-sleeved shirt, long pants, shoes, socks, and chemical-resistant gloves as specified on product labels. Mixer/loaders were assumed to wear chemical-resistant apron.

[c] These exposure rates were used to calculate STADD, as explained in Footnote [e].

[d] These exposure rates were used to calculate Seasonal Average Daily Dosage and Annual Average Daily Dosage in Table 27. NA = Not applicable; only short-term exposure estimates are needed for this scenario.

[e] Short-Term Absorbed Daily Dosage (STADD) is an upper-bound estimate calculated from the short-term exposure. Application rate is maximum rate on product labels, which varied for each scenario; acres treated per day varies by scenario. Calculation:
STADD = [(short-term exposure) x (absorption) x (acres treated/day) x (application rate)]/(70 kg body weight). Calculation assumptions include: dermal absorption = 70% (Beauvais, 2006a); body weight = 70 kg (Thongsinthusak *et al*., 1993); inhalation rate 16.7 liters/min (Andrews and Patterson, 2000); and inhalation absorption = 100% (Frank, 2008).

[f] STADD estimates assumed 100 acres (40.5 ha) treated/day (U.S. EPA, 2001; DPR, 2012a), and an application rate of 1.0 lbs AI/acre (1.12 kg AI/ha), maximum rate on rights-of-way.

[g] STADD estimates assumed handling of 40 gal/day (150 liters/day; U.S. EPA, 2001), containing 0.156 lb AI/gal (0.0187 kg AI/liter), maximum rate on ornamentals.

[h] STADD estimates assumed handling of 1,000 gal/day (3,800 liters/day; U.S. EPA, 2001), containing 0.156 lb AI/gal (0.0187 kg AI/liter), maximum rate on ornamentals.

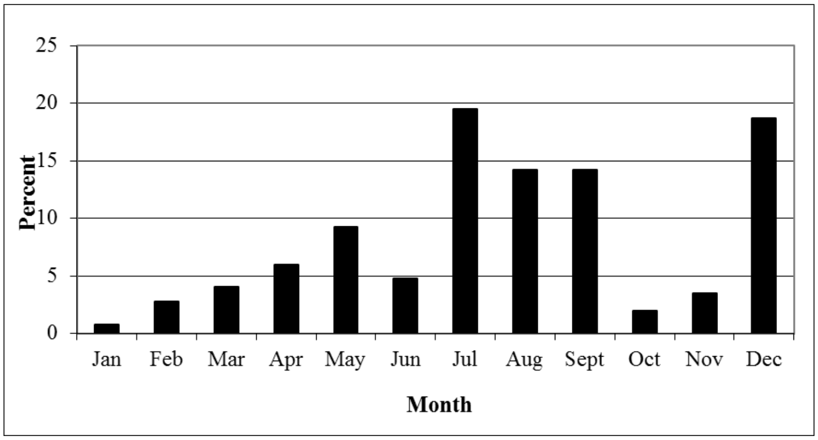
[i] Exposure rates based on data from Merricks (1997), as summarized in Table 20.

[j] STADD estimates assumed handling of one 32-ounce bottle per day (0.946 liters/day; Britton, 2007a), containing 0.00263 lb AI (0.00119 kg AI), maximum rate on ornamentals.

[k] STADD estimates assumed handling of 100 gal/day (379 liters/day; U.S. EPA, 2001), containing 0.156 lb AI/gal (0.0187 kg AI/liter), maximum rate on ornamentals.

For estimating seasonal, annual, and lifetime exposures of handlers applying with backpack sprayers, all ground applications to ornamentals (greenhouse and outdoor nursery-grown cut flowers and container-grown plants) were assumed to be backpack applications. Figure 10 summarizes ground applications of carbaryl to ornamentals in San Diego County; applications were ≥ 5% of the annual total in 7 months, including April through September and December. The assumed typical amount of carbaryl handled daily in this scenario is 2 lbs AI/day, based on the highest annual mean values reported for carbaryl applications to ornamentals in California during a recent 5-year interval (see Appendix 4). Exposure estimates are summarized in Table 27.

Figure 10. Ground Applications of Carbaryl to Ornamentals, San Diego County, 2006 – 2010 [a]



[a] Percent calculations based on pounds applied (DPR, 2012a; queried on April 24, 2012).

<u>High Pressure Handwand Applications</u>

Table 26 summarizes the short-term exposure estimates for M/LA applying carbaryl with a high pressure handwand sprayer. Exposure estimates assumed that applicators wore the clothing specified on the product label, including gloves. For short-term exposures, handlers were assumed to mix, load, and apply 1,000 gallons of a solution containing 0.156 lb AI/gal, maximum rate on ornamentals (U.S. EPA, 2001). Other assumptions used in estimating the exposure, and estimates obtained from PHED, are summarized in Table 26. For seasonal, annual, and lifetime exposures, the same assumptions were applied as for backpack and other hand-held sprayers; estimates are given in Table 27.

<u>Low Pressure Handwand Applications</u>

Exposure estimates for handlers using low-pressure handwand sprayers to apply carbaryl are based on exposure monitoring conducted by Merricks (1997) of individuals using hand-pump sprayers, a common type of low pressure handwand. The study was reviewed by Beauvais (2011a) and is briefly summarized above in Table 20. Data used to estimate exposures and short-term exposure estimates are summarized in Table 26. For seasonal, annual, and lifetime exposures, the same assumptions were applied as for backpack and other hand-held sprayers; estimates are given in Table 27.

Table 27. Seasonal, Annual, and Lifetime Estimates for Mixer/Loader/Applicators Using Hand-Held Sprayers to Apply Carbaryl Liquids

Sprayer Type [a]	SADD [b] (mg/kg/day)			AADD [c] (mg/kg/day)			LADD [d] (mg/kg/day)		
	Dermal	Inhalation	Total	Dermal	Inhalation	Total	Dermal	Inhalation	Total
Backpack [e]	0.619	1.27×10^{-4}	0.619	0.361	7.38×10^{-5}	0.361	0.193	3.94×10^{-5}	0.193
HPHW [e]	0.191	5.80×10^{-3}	0.197	0.111	3.38×10^{-3}	0.114	0.0593	1.80×10^{-3}	0.0611
LPHW [f]	0.0113	1.64×10^{-4}	0.0115	0.00662	9.55×10^{-5}	0.00671	0.00353	5.09×10^{-5}	0.00358
Trigger [f]	0.0000921	2.16×10^{-6}	0.0000943	0.0000537	1.26×10^{-6}	0.0000550	0.0000286	6.73×10^{-7}	0.0000293
Hose-end [f]	0.00694	3.46×10^{-5}	0.00697	0.00405	2.20×10^{-5}	0.00407	0.00216	1.08×10^{-5}	0.00217

[a] Exposure rates are given in Table 26. Exposure estimates assumed handlers used 2 pounds of carbaryl per day, based on the average number of pounds reported used on ornamentals by each grower daily (DPR, 2012a), as summarized in Appendix 4. Trigger sprayer applicators were assumed to use 0.00263 lb AI (0.00119 kg AI) per day, the amount in one spray bottle. High-use season is 7 months/year.
[b] Seasonal Average Daily Dosage is a 90% upper confidence estimate calculated from the long-term exposure rates given in Table 26. Dermal absorption: 70% (Beauvais, 2006a). Inhalation absorption assumed to be 100%. Body weight assumed to be 70 kg (Thongsinthusak *et al*., 1993). Calculation:
SADD = [(long-term exposure) x (absorption) x (acres treated/day) x (application rate)]/(70 kg body weight).
[c] Annual Average Daily Dosage = SADD x (annual use months per year)/(12 months in a year).
[d] Lifetime Average Daily Dosage = AADD x (40 years of work in a lifetime)/(75 years in a lifetime).
[e] Exposure estimates are based on data from the Pesticide Handlers Exposure Database (PHED, 1995). HPHW = high pressure handwand.
[f] Exposure estimates based on data from Merricks (1997), as summarized in Table 20. LPHW = low pressure handwand.

Trigger Sprayer Applications and Hose-End Sprayer Applications

Exposure estimates for handlers using trigger sprayers and hose-end sprayers (including sprayers that are pre-filled and those filled by the user) are based on exposure monitoring conducted by Merricks (1997) of individuals using reusable sprayers into which solution was mixed and loaded before use; this scenario also covers handlers using RTU trigger sprayer products. The study was reviewed by Beauvais (2011a) and is briefly summarized Table 20. Data used to estimate exposures and short-term exposure estimates are summarized in Table 26. For seasonal, annual, and lifetime exposures, the same assumptions were applied as for backpack and other hand-held sprayers; estimates are given in Table 27.

Broadcast Spreader Applications

Table 28 summarizes short-term exposure estimates for loaders and applicators involved in broadcast spreading of carbaryl in granular formulations, including baits. The broadcast spreader scenario includes ground application equipment towed behind a tractor or other vehicle. Exposure estimates assumed open cabs, as there is no requirement for closed cabs.
The maximum application rate for carbaryl applied by broadcast spreader is 2 lb AI/acre (2.2 kg AI/ha). This is the maximum rate allowed on several crops, including tomatoes, corn, and strawberries, and was assumed for short-term exposure estimates. For short-term exposures, the amount treated for broadcast spreader applications was assumed to be 80 acres/day (32 ha/day), and high-acre groundboom applications assumed 200 acres (81 ha) treated per day (U.S. EPA, 2001).

Table 28. Exposure Rates and Short-Term Handler Exposure Estimates for Ground Applications of Carbaryl Dust and Granular Products

Scenario [a]	# [b]	Short-Term Rates (µg/lb AI handled) [c]		Long-Term Rates (µg/lb AI handled) [d]		STADD (mg/kg/day) [e]		
		Dermal	Inhalation	Dermal	Inhalation	Dermal	Inhalation	Total
Broadcast Spreader [f]								
Mixer/Loader	4	35.99	11.0	12.95	3.97	0.0576	0.0251	0.0827
Applicator	14	7.796	0.729	2.802	0.262	0.0125	0.00167	0.0141
High-Acre Broadcast Spreader [g]								
Mixer/Loader	4	35.99	11.0	12.95	3.97	0.144	0.0629	0.207
Applicator	14	7.796	0.729	2.802	0.262	0.0312	0.00417	0.0353
Push-Type Spreader [h]								
L/A	- -	627	3.18	137	1.10	0.259	0.00188	0.261
Dust Applicator [i]								
L/A	- -	136,000	7,100	25,300	1,140	0.136	0.0101	0.146

[a] Exposure estimates are based on data from the Pesticide Handlers Exposure Database (PHED, 1995), unless otherwise indicated. Exposure rates and exposure estimates were rounded to three significant figures; dermal exposure rates may have four significant figures as a result of adding together hand and non-hand dermal exposures (see Appendix 3 for details). L/A = loader/applicator.

[b] Scenario numbers from Beauvais *et al.* (2007). See Appendix 3 for summaries of scenarios and exposure rates. Handlers were assumed to wear long-sleeved shirt, long pants, shoes, socks, and chemical-resistant gloves as specified on product labels.

[c] These exposure rates were used to calculate STADD, as explained in Footnote [e].

[d] These exposure rates were used to calculate Seasonal Average Daily Dosage and Annual Average Daily Dosage in Table 29. NA = Not applicable; only short-term exposure estimates are needed for this scenario.

[e] Short-Term Absorbed Daily Dosage (STADD) is an upper-bound estimate calculated from the short-term exposure. Application rate is maximum rate on product labels, which varied for each scenario; acres treated per day varies by scenario. Calculation:
STADD = [(short-term exposure) x (absorption) x (acres treated/day) x (application rate)]/(70 kg body weight).
Calculation assumptions include: dermal absorption = 70% (Beauvais, 2006a); body weight = 70 kg (Thongsinthusak *et al*., 1993); inhalation rate 16.7 liters/min (Andrews and Patterson, 2000); and inhalation absorption = 100% (Frank, 2008).

[f] Broadcast spreader is towed behind a tractor. STADD estimates assumed 80 acres (32 ha) treated/day (U.S. EPA, 2001), and a maximum application rate of 2.0 lb AI/acre (2.2 kg AI/ha), maximum rate on tomato.

[g] Broadcast spreader is towed behind a tractor; high-acre applications exceed 80 acres/day. STADD estimates assumed 200 acres (81 ha) treated per day (U.S. EPA, 2001), and a maximum application rate of 2.0 lb AI/acre (2.2 kg AI/ha), maximum rate on tomato.

[h] Applicator walks behind a push-type spreader. Estimates were based on data from Klonne and Honeycutt (1999), as summarized in Table 20. STADD estimates assumed treating 5 acres/day (20 ha/day; Britton, 2007b), at a maximum application rate of 8.28 lb AI/acre (9.3 kg AI/ha), maximum rate on turf.

[i] Estimates were based on data from Merricks (1997), as summarized in Table 20. STADD estimates assumed handling of 0.1 lb/day (0.045 kg/day; Britton, 2007a), equivalent to one can.

Seasonal, annual, and lifetime handler exposures are summarized in Table 29; all ground applications to tomatoes were assumed to be broadcast spreader applications. Figure 9 summarizes ground applications of carbaryl to tomatoes in Fresno County; applications were ≥ 5% of the annual total in 3 months. The assumed typical rate and size were 1 lb AI/acre and 80 acres, based on the highest annual mean values reported for carbaryl ground applications to tomatoes in California during a recent 5-year interval (see Appendix 4). Seasonal, annual, and lifetime exposures occurring during high-acre groundboom applications assumed typical daily applications of 110 acres (44.5 ha), based on average number of acres treated by each grower daily as summarized in Appendix 4.

Table 29. Seasonal, Annual, and Lifetime Estimates for Ground Applications of Carbaryl Dust and Granular Products

Scenario [a]	SADD [b] (mg/kg/day)			AADD [c] (mg/kg/day)			LADD [d] (mg/kg/day)		
	Dermal	Inhalation	Total	Dermal	Inhalation	Total	Dermal	Inhalation	Total
Broadcast Spreader [e]									
Mixer/Loader	0.0104	0.00454	0.0149	0.00259	0.00113	0.00372	0.00138	0.000605	0.00199
Applicator	0.00224	0.000299	0.00254	0.000560	0.0000749	0.000635	0.000299	0.0000399	0.000339
High-Acre Broadcast Spreader [f]									
Mixer/Loader	0.0143	0.00624	0.0205	0.00356	0.00156	0.00512	0.00190	0.000832	0.00273
Applicator	0.00308	0.000412	0.00349	0.000770	0.000103	0.000873	0.000411	0.0000549	0.000466
Push-Type Spreader [g]									
L/A	0.0219	0.000251	0.0222	0.0128	0.000147	0.0129	0.00682	0.0000782	0.00690
Dust Applicator [h]									
L/A	0.0253	0.00163	0.0269	0.0148	0.000950	0.0157	0.00787	0.000507	0.00838

[a] Exposure estimates are based on data from the Pesticide Handlers Exposure Database (PHED, 1995), unless otherwise indicated. Exposure rates are given in Table 28. L/A = loader/applicator

[b] Seasonal Average Daily Dosage is a 90% upper confidence estimate calculated from the long-term exposure rates given in Table 28. Dermal absorption: 70% (Beauvais, 2006a). Inhalation absorption assumed to be 100%. Body weight assumed to be 70 kg (Thongsinthusak *et al*., 1993). Calculation:

SADD = [(long-term exposure) x (absorption) x (acres treated/day) x (application rate)]/(70 kg body weight).

[c] Annual Average Daily Dosage = SADD x (annual use months per year)/(12 months in a year).

[d] Lifetime Average Daily Dosage = AADD x (40 years of work in a lifetime)/(75 years in a lifetime).

[e] Exposure estimates assumed 80 acres (32 ha) treated/day, based on average number of acres treated by each grower daily (DPR, 2012a), and an application rate of 1 lb AI/acre (1.12 kg AI/ha), the typical rate reported for ground applications to tomatoes, as summarized in Appendix 4. High-use season is 3 months/year.

[f] Exposure estimates assumed 110 acres (44.5 ha) treated/day, based on average number of acres treated by each grower daily (DPR, 2012a), and an application rate of 1 lb AI/acre (1.12 kg AI/ha), the typical rate reported for ground applications to tomatoes, as summarized in Appendix 4. High-use season is 3 months/year.

[g] Exposure estimates assumed handlers used 16 pounds of carbaryl per day, based on the average number of pounds reported used in landscape maintenance by each grower daily (DPR, 2012a), as summarized in Appendix 4. Estimates were based on data from Klonne and Honeycutt (1999), as summarized in Table 20. High-use season is 7 months/year.

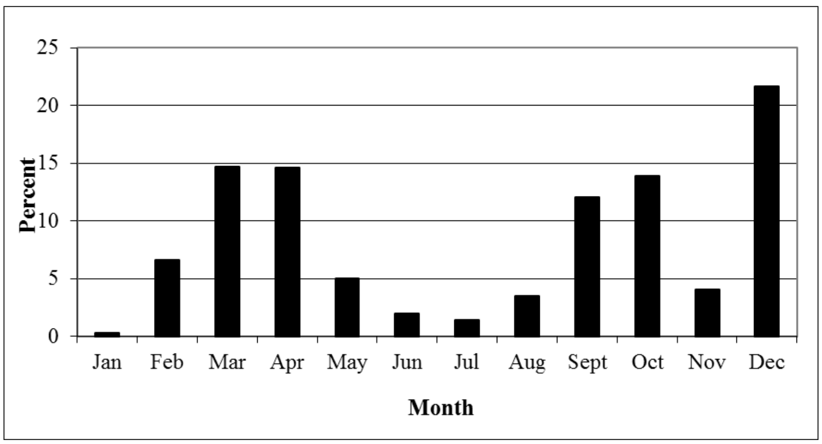
[h] Exposure estimates assumed handling of 0.1 lb/day (0.045 kg/day; Britton, 2007a), equivalent to one can. Estimates were based on data from Merricks (1997), as summarized in Table 20. High-use season is 7 months/year.

Push-Type Spreader Applications

Table 28 summarizes short-term exposure estimates for loader/applicators using a push-type spreader to apply granular carbaryl formulations. Exposure estimates assumed that handlers wore the clothing specified on the product label. The maximum application rate for carbaryl applied by push-type spreader is 8.28 lb AI/acre (9.3 kg AI/ha). This is the maximum rate allowed on turf (0.19 lbs AI/1,000 ft^2 x 43,560 ft^2/acre = 8.28 lbs AI/acre), and was assumed in calculations for short-term exposure estimates. The amount treated for push-type spreader applications was assumed to be 5 acres/day (20 ha/day), the default assumed by U.S. EPA in their carbaryl risk assessment (Britton, 2007b). Exposure estimates for handlers using push-type spreaders to apply carbaryl are based on exposure monitoring conducted by Klonne and Honeycutt (1999). The study was reviewed by Beauvais (2011b) and is summarized above in Table 20. Data used to estimate exposures and short-term exposure estimates are summarized in Table 28.

For the purpose of estimating seasonal, annual, and lifetime handler exposure all ground applications for landscape maintenance were assumed to be broadcast spreader applications. Figure 11 summarizes ground applications of carbaryl to turf in Santa Clara County; applications were ≥ 5% of the annual total in 7 months, February through May, and September, October, and December. The assumed typical amount used was 16 lb AI/day, based on the highest annual mean values reported for carbaryl landscape maintenance applications in California during a recent 5-year interval (see Appendix 4 for details).

Figure 11. Ground Applications of Carbaryl for Landscape Maintenance, Santa Clara County, 2006 – 2010 [a]



[a] Percent calculations based on pounds applied (DPR, 2012a; queried on April 24, 2012).

Dust Applications

Exposure estimates for handlers applying carbaryl dust formulations are based on exposure monitoring conducted by Merricks (1997). The study was reviewed by Beauvais (2011a) and is summarized above in Table 20. Data used to estimate exposures and short-term exposure estimates are summarized in Table 28.

For the purpose of estimating carbaryl exposure of handlers applying carbaryl dust products, all ground applications to ornamentals (greenhouse and outdoor nursery-grown cut flowers and container-grown plants) were assumed to be dust applications. The high-use season was estimated to be 7 months, as shown in Figure 10. Seasonal, annual, and lifetime exposures of handlers applying dust products are summarized in Table 29.

Occupational Post-Application Exposure

<u>Overview</u>

As chemical-specific exposure data were not available for workers reentering crops treated with carbaryl, exposures were estimated from dislodgeable foliar (DFR) values summarized in Table 16 and transfer coefficients (TCs) from studies with surrogate chemicals. An exception to this approach is the turf maintenance scenario; turf exposure estimates are based on surrogate exposure monitoring data rather than environmental residue measures such as DFR.

The major route of pesticide exposure for reentry workers is the dermal route; contact with treated surfaces, especially foliage, causes pesticide residues to be transferred to the skin. The generic TC is a parameter that estimates the rate of contact between the worker and treated surface, based on empirical data from studies in which both DFR and dermal exposure have been measured. The TC for an activity is calculated by dividing DFR from a treated crop into the dermal exposure measured for workers performing reentry activities in the crop: TC (cm^2/hour) = [dermal exposure (µg/hour)]/[DFR (µg/cm^2)]. The extent of worker contact with treated foliage depends on the crop height and fullness of the foliage; thus, the same activity, such as scouting, can have different TCs in different crops.

As the TC is assumed to depend on the intensity of contact with the contaminated surface, it is activity- and surface-specific; however, TCs are only available for a limited number of activities and crops. When specific TCs were not available, TCs from similar crops and activities were used instead. DPR policy documented by Frank (2009b) is to rely on TCs presented in U.S. EPA (2000), with a few exceptions as noted by Frank (2009b) or otherwise justified. No TC was listed for asparagus hand harvesting in either DPR or U.S. EPA (2000); however, in its risk assessment for malathion U.S. EPA used a TC of 1,000 cm^2/hour (Arthur, 2005). That TC was used to calculate exposure of asparagus harvesters to carbaryl.

The absorbed daily dosage (ADD) was calculated as shown in the equation below (Zweig *et al.*, 1984; Zweig *et al.*, 1985), using the dermal absorption rate (DA) of 70% (Beauvais, 2006a); default exposure duration (ED) of 8 hours; and default body weight (BW) of 70 kg (Thongsinthusak *et al*., 1993).

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

Short-term exposure estimates for representative occupational reentry scenarios are summarized in Table 30. Exposure estimates are reported in units of mg/kg/day (calculations included a conversion factor of 1 mg = 1,000 µg).

Reentry workers are not required to wear protective clothing unless entering fields before expiration of the restricted entry interval (REI). Because a lot of reentry work occurs in hot weather and for several hours each day, protective clothing is often not worn by fieldworkers unless required for early reentry. Therefore, fieldworker exposure estimates were based on an assumption that no protective clothing or equipment would be used.

Table 30. Short-Term Exposures to Carbaryl Estimated for Reentry Workers

Exposure Scenario	DFR (µg/cm²) [a]	TC (cm²/hour) [b]	STADD (mg/kg/day) [c]
Apple hand thinning	14.2	3,000	3.41
Asparagus hand harvesting	4.54	1,000	0.363
Beans scouting	6.06	1,500	0.727
Blackberry pruning	8.08	5,000	3.23
Cabbage scouting	4.31	4,000	1.38
Citrus pruning	28.5	3,000	6.84
Corn, detasseling	3.32	17,000	4.52
Cucumber scouting	3.51	2,500	0.421
Grape leaf pulling	2.18	10,000	1.74
Lettuce scouting	9.49	1,500	1.14
Olive pruning	2.84	850	0.193
Ornamental plant hand harvesting	4.09	400	0.131
Potato scouting	8.08	1,500	0.970
Strawberry scouting	8.08	400	0.129
Tobacco hand harvesting	4.73	2,000	0.757
Tomato staking/tying	8.08	1,000	0.363
Turf maintenance [d]	NA	NA	2.74

[a] Dislodgeable foliar residue (DFR) values at the expiration of the restricted entry or pre-harvest interval; see Table 16 for details.

[b] Transfer coefficient (TC) is rate of skin contact with treated surfaces. TC references: asparagus harvesting (Arthur, 2005); olive pruning (Klonne *et al*., 2000a); ornamental hand harvesting (Klonne *et al*., 2000d); all other crops (Frank, 2009b).

[c] Short-term Absorbed Daily Dosage (STADD) calculated as described in text. Exposure estimates are for dermal route, as inhalation route assumed to be insignificant. Calculation assumptions include: dermal absorption = 70% (Beauvais, 2006a); body weight = 70 kg (Thongsinthusak et al., 1993); and exposure duration of 8 hours.

[d] Turf maintenance reentry exposure was not estimated from DFR, but from surrogate exposure monitoring study conducted by Rosenheck and Sanchez (1995). See text for calculation and Beauvais (2012) for study details. NA = Not applicable.

Scouting may occur at any time, and was assumed to occur after all applications. Information about when other reentry activities might occur was obtained from crop profiles prepared by the University of California Cooperative Extension (UCCE, 2012), and from the California Farm Worker Activity Profile (CFWAP; Edmiston *et al.*, 1999). CFWAP is a DPR database compiled from a number of sources, including the California Employment Development Department, U.S. Department of Agriculture, California Department of Food and Agriculture and the University of California Cooperative Extension. CFWAP includes information on harvested acreage, cultural practices necessary to grow a crop, and the dates of peak and overall activity periods for work activities such as harvesting and thinning, based on data from

1994. More recent CFWAP data are not available at the present time, but for some crops typical activity intervals are available in individual reports from UCCE (2012).

Short-term exposures were estimated at the expiration of the REI for all activities except hand harvesting, which was estimated at the expiration of the pre-harvest interval (PHI; Table 8); if PHI was less than the REI, then the REI was used. For seasonal and annual exposure estimates, it was assumed that workers would enter fields at some average time after the expiration of the REI or PHI, based on how frequently specific activities generally occur in general crop types (UCCE, 2012).

Table 31 summarizes seasonal, annual, and lifetime exposures estimates for reentry activities. For longer-term exposure estimates it was assumed that workers would not always enter fields at the expiration of the REI. Seasonal and annual exposures were estimated at an assumed average reentry of REI (or PHI, if longer than REI) plus 7 – 10 days. These assumed averages were not based on data; rather, they were based on the reasonable assumption that workers may enter fields an average of 7 – 10 days after expiration of the REI or PHI. This assumption was examined for endosulfan and found to be health-protective (Beauvais, 2008).

Most reentry activities are not expected to result in pesticide exposure throughout the year. This is true because pesticides like carbaryl are not necessarily applied all year in all crops, and because many activities are performed only seasonally. To estimate when carbaryl applications might occur throughout the year, five-year averages were plotted of monthly PUR data (based on numbers of acres treated) for carbaryl applications to the crops of interest in one or more high-use counties. These average use patterns were compared to information about when reentry activities might occur. Annual exposure to carbaryl is assumed to be limited to the months when activities overlap relatively high use (the high use season is defined as 5% or more of annual use each month).

Apple Hand Thinning

Hand thinning of apples is the representative activity for all reentry activities in pome and stone fruits. Reentry is allowed at expiration of the REI of 12 hours, and the predicted Day 0 for apple trees was used to estimate short-term exposure as summarized in Table 30.

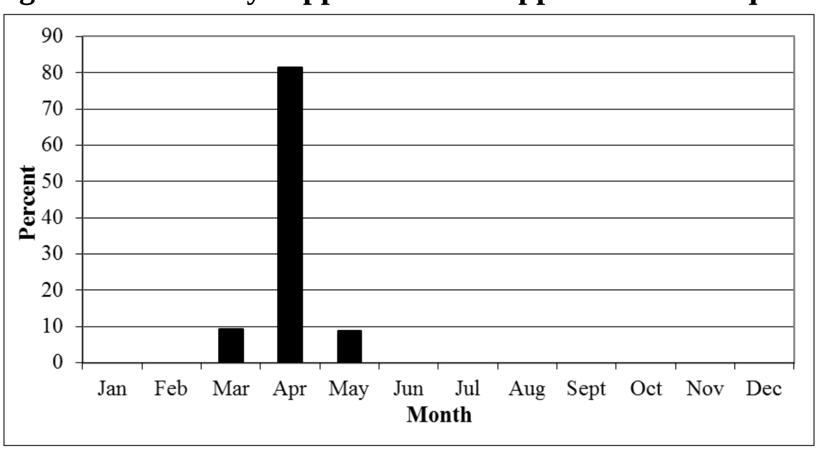
Apples in the Central Valley are typically harvested between July and October, with thinning occurring months earlier, in spring and summer (USDA, 1999). Figure 12 summarizes all applications of carbaryl to apple orchards in San Joaquin County, based on numbers of acres treated each month for a recent five-year interval (2006 – 2010). All carbaryl use occurred in March through May, and more than 5% of annual use occurred during each of these months. Annual exposure was estimated to occur during these 3 months, as summarized in Table 31.

Table 31. Long-Term Exposures to Carbaryl Estimated for Reentry Workers

Exposure scenario [a]	Long-term DFR [b] (µg/cm²)	Months in Year [c]	SADD [d], mg/kg/day	AADD [e], mg/kg/day	LADD [f], mg/kg/day
Apple hand thinning	8.62	3	2.07	0.517	0.276
Citrus pruning	19.0	7	4.56	2.66	1.42
Corn detasseling	2.01	1	2.73	0.228	0.121
Cucumber scouting	0.002	5	0.00024	0.00010	0.000053
Grape leaf pulling	0.399	2	0.319	0.0532	0.0284
Lettuce scouting	5.75	2	0.690	0.115	0.0613
Olive pruning	1.02	1	0.0694	0.00578	0.00308
Ornamental plant harvesting	2.67	3	0.0854	0.0427	0.0228
Potato scouting	1.11	5	0.133	0.0555	0.0296
Strawberry scouting	1.11	6	0.0355	0.0178	0.00947
Tomato staking/tying	1.11	3	0.0888	0.0222	0.0118

[a] No seasonal, annual, or lifetime exposure estimates were prepared for workers reentering treated asparagus, beans, blackberry, cabbage, carrot, tobacco or turf. Infrequent carbaryl use is reported on these sites.
[b] Dislodgeable foliar residue (DFR) values from Table 16. NA: Not Applicable.
[c] Number of months in year in which application exceeded 5% of average annual application (2006-2010) in county of highest crop-specific use of carbaryl.
[d] Seasonal Absorbed Daily Dosage (SADD) calculated as described in text. Transfer coefficients from Table 30 were used in calculations. Exposure estimates are for dermal route, as inhalation route is assumed to be insignificant. Calculation assumptions include: dermal absorption = 70% (Beauvais, 2006a); body weight = 70 kg (Thongsinthusak et al., 1993); and exposure duration of 8 hours.
[e] Annual Average Daily Dosage (AADD) = SADD x (months of application in year)/(12 months)
[f] Lifetime Average Daily Dosage (LADD) = AADD x (40 years labor)/(75 years lifespan)

Figure 12. Carbaryl Applications to Apples in San Joaquin County, 2006 – 2010 [a]



[a] Percent calculations based on acres treated (DPR, 2012a; queried April 26, 2012). Note scale: each line on y-axis represents 10%.

Although carbaryl is used for chemical thinning of apples in addition to pest control uses, University of California recommendations for chemical thinning state that follow-up hand thinning is usually needed for some common California apple varieties such as Gala and Fuji

(Grant *et al*., 2006). Thus, chemical thinning does not always preclude hand thinning and it is reasonable to assume that exposure to carbaryl can occur when hand thinning apples.

Asparagus Hand Harvesting

Hand harvesting of asparagus is the representative activity for all reentry activities in asparagus. The PHI following carbaryl applications to asparagus is 1 day. For exposure estimates, the estimated DFR on apple foliage 1 day post-application was used, as well as a TC of 1,000 cm^2/hour (Arthur, 2005).

Examination of applications reported over a recent 10-year interval (2001 - 2010) suggests that carbaryl is not frequently used on asparagus in California (DPR, 2012a; data not shown). Seasonal, annual, and lifetime exposures are not anticipated for reentry activities in asparagus.

Bean Scouting

Scouting in beans is the representative activity for all reentry activities in beans and peas. Reentry for these activities is allowed at expiration of the REI of 12 hours, and predicted Day 0 DFR for strawberry foliage was used to estimate short-term exposure.

Examination of applications reported over a recent 10-year interval (2001 - 2010) suggests that carbaryl is not frequently used on beans and peas in California (DPR, 2012a; data not shown). Seasonal, annual, and lifetime exposures are not anticipated for scouting in beans and other reentry activities in beans and peas.

Blackberry Pruning

Pruning blackberries is the representative activity for all reentry activities in all berries other than strawberries. Reentry for these activities is allowed at expiration of the REI of 12 hours, and predicted Day 0 DFR for strawberry foliage was used to estimate short-term exposure.

Examination of applications reported over a recent 10-year interval (2001 - 2010) suggests that carbaryl is not frequently used on blackberries, or on any berries other than strawberries, in California (DPR, 2012a; data not shown). Seasonal, annual, and lifetime exposures are not anticipated for pruning or other reentry activities in berries (other than strawberries).

Cabbage Scouting

Scouting in cabbage is the representative activity for all reentry activities in all crucifers (e.g., broccoli, cauliflower). Reentry for these activities is allowed at expiration of the REI of 12 hours, and predicted Day 0 DFR for cabbage foliage was used to estimate short-term exposure.

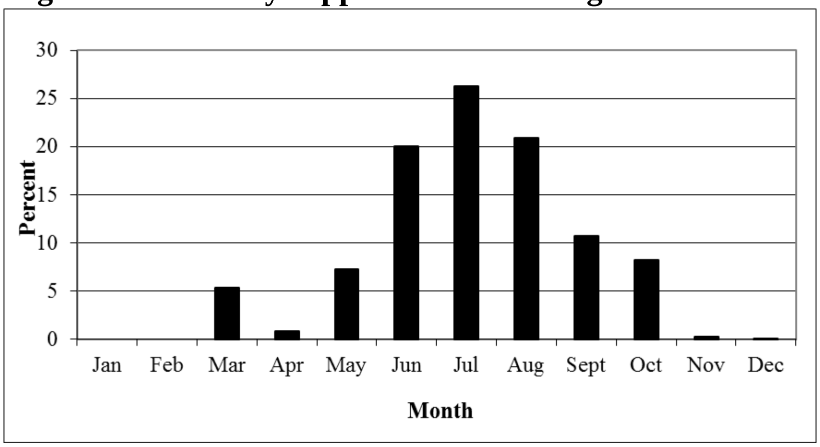
Examination of applications reported over a recent 10-year interval (2001 - 2010) suggests that carbaryl is not frequently used on cabbage and other crucifers in California (DPR, 2012a; data not shown). Seasonal, annual, and lifetime exposures are not anticipated for cabbage scouting or other reentry activities in crucifers.

Citrus Pruning

Pruning citrus is the representative activity for all reentry activities in citrus. Carbaryl product labels require an extended REI of 3 days following applications to citrus, and predicted Day 3 DFR for orange foliage was used to estimate short-term exposure.

Pruning of oranges in the southern San Joaquin Valley ordinarily occurs in spring and summer, and ends in August (O'Connell *et al.*, 2009). Figure 13 summarizes all applications of carbaryl to orange groves in Tulare County, based on numbers of acres treated each month for a recent five-year interval (DPR, 2012a). The estimated high-use interval for carbaryl is March and May through October; more than 5% of annual use occurred during each of these months. The typical interval for pruning overlaps 6 of these 7 months (March and May – August). Annual exposure was assumed to occur during the 6 overlapping months.

Figure 13. Carbaryl Applications to Oranges in Tulare County, 2006 – 2010 [a]



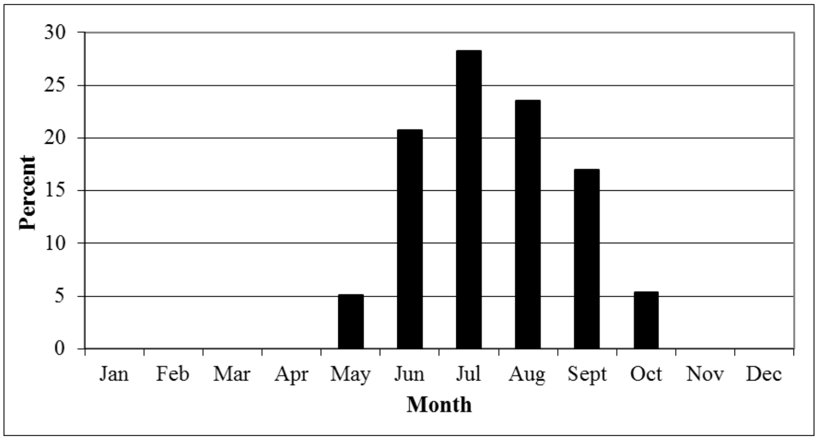
[a] Percent calculations based on acres treated (DPR, 2012a; queried April 26, 2012).

Corn Detasseling

Detasseling is the highest-contact activity allowed in carbaryl-treated corn; hand harvesting is prohibited by carbaryl product labels. Although detasseling is predominantly done in the Midwest, and is certainly not common in California, it is sometimes done on research plots; additionally, pollen harvesting from research plots is a common activity that could be anticipated to involve similar contact (Stanford, 1988). Reentry for detasseling in corn is allowed at expiration of the REI of 21 days, and predicted Day 21 DFR for apple foliage was used to estimate short-term exposure.

Figure 14 summarizes all applications of carbaryl to corn in Sacramento County. The majority of carbaryl use occurred in May through October, and more than 5% of annual use occurred during each of these months. These months span the time from when corn typically has sprouted to when it is harvested in the Sacramento Valley (Brittan *et al.*, 2008). However, detasseling and pollination only occur over about two weeks during the growing season (Stanford, 1988), suggesting that 6 months of exposure is unlikely for these activities. Because of the short interval when detasseling and pollination are conducted, exposure associated with these high-contact activities was assumed to occur during 1 month.

Figure 14. Carbaryl Applications to Corn in Sacramento County, 2006 – 2010 [a]



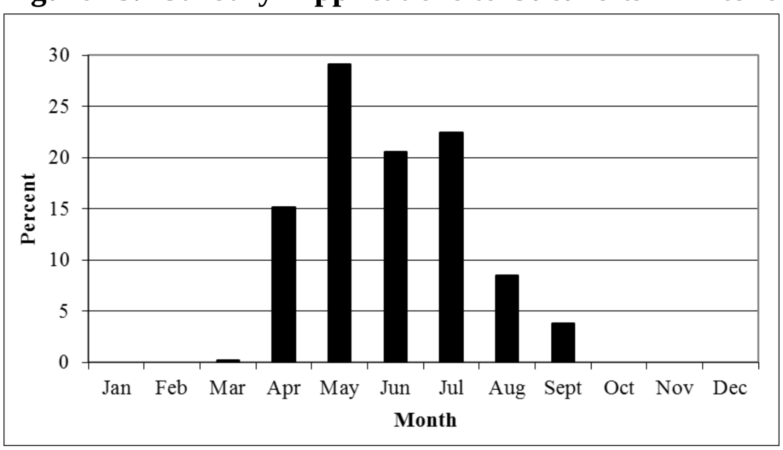
[a] Percent calculations based on acres treated (DPR, 2012a; queried April 26, 2012).

Cucumber Scouting

Scouting in cucumbers is the representative activity for all reentry activities in all cucurbits (e.g., melons, pumpkin, squash). Reentry for these activities is allowed at expiration of the REI of 12 hours, and predicted Day 0 DFR for cucumber foliage was used to estimate short-term exposure.

Scouting is assumed to occur at any time during the growing season. Figure 15 summarizes applications of carbaryl to melons in Fresno County. The majority of carbaryl use occurred in April through August, with more than 5% of annual use occurred during each of these months. Exposure was assumed to occur during these 5 months.

Figure 15. Carbaryl Applications to Cucurbits in Fresno County, 2006 – 2010 [a]



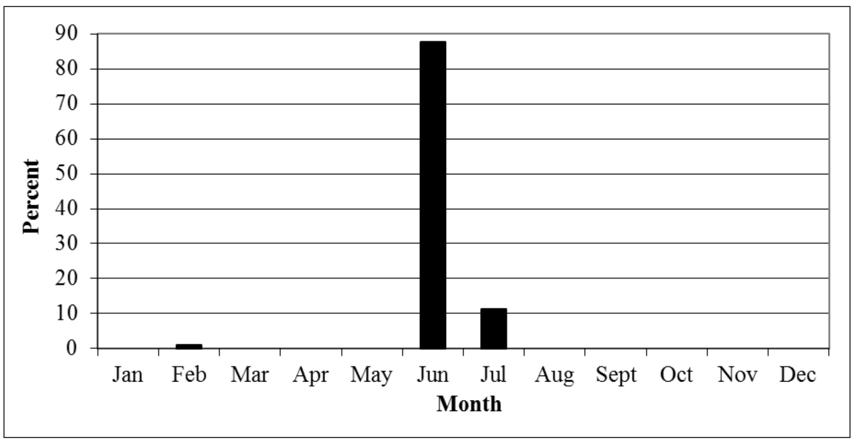
[a] Percent calculations based on acres treated (DPR, 2012a; queried April 27, 2012).

Grape Leaf Pulling

Grape leaf pulling which increases exposure of the grapes to sunlight, represents all activities in grapes. The REI following carbaryl applications to grapes is 12 hours, and predicted Day 0 DFR for strawberry foliage was used to estimate short-term exposure.

Based on information in CFWAP (Edmiston *et al.*, 1999), leaf pulling in table grapes and wine grapes in the San Joaquin Valley occurs from April – July. Figure 16 summarizes all applications of carbaryl to grapes in Fresno County. Most use occurred in June and July, which completely overlaps the typical activity period for leaf pulling. Annual exposure was estimated to occur during these 2 months.

Figure 16. Carbaryl Applications to Grapes in Fresno County, 2006 – 2010 [a]



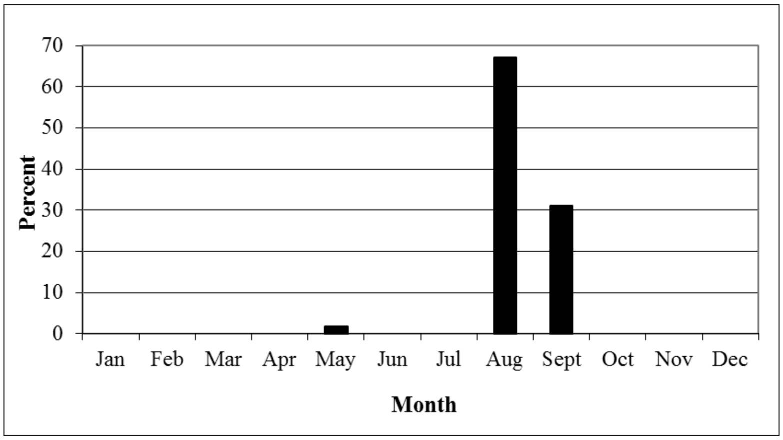
[a] Percent calculations based on acres treated (DPR, 2012a; queried April 27, 2012). Note scale: each line on y-axis represents 10%.

Lettuce Scouting

Scouting in lettuce is the representative activity for all reentry activities in leafy green vegetables (e.g., celery, collards). Reentry for these activities is allowed at expiration of the REI of 12 hours, and predicted Day 0 DFR for apple foliage was used to estimate short-term exposure.

Scouting is assumed to occur at any time during the growing season. Figure 17 summarizes applications of carbaryl to lettuce in Fresno County. The majority of carbaryl use occurred in August and September, and exposure was assumed to occur during these 2 months.

Figure 17. Carbaryl Applications to Lettuce in Fresno County, 2006 – 2010 [a]



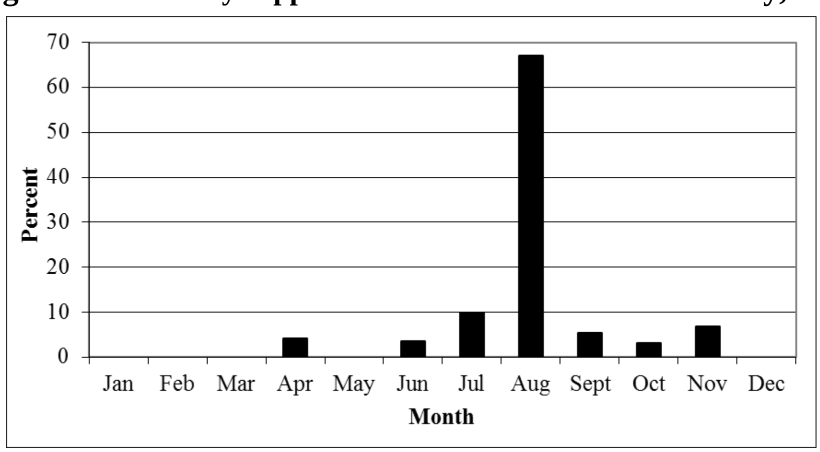
[a] Percent calculations based on acres treated (DPR, 2012a; queried April 27, 2012). Note scale: each line on y-axis represents 10%.

<u>Olive Pruning</u>

Pruning olive trees is the representative activity for cultivation activities of tree nuts and tree plantations. Reentry in olives is allowed at expiration of the extended REI of 3 days, and predicted Day 3 DFR for olive foliage was used to estimate short-term exposure.

Figure 18 summarizes applications of carbaryl to olive orchards in Tulare County. The majority of carbaryl use occurred in July through September. Use during each of these 3 months was greater than 5% of annual use. However, pruning of olives in both the Sacramento and San Joaquin valleys occurs in the spring, typically in April (O'Connell *et al.*, 2005; Krueger *et al.*, 2011). Figure 18 shows that about 4% of annual carbaryl use in Tulare County occurred in April, suggesting that workers pruning olive trees could potentially be exposed to carbaryl. For seasonal, annual, and lifetime estimates, exposure was assumed to occur during the month of April.

Figure 18. Carbaryl Applications to Olives in Tulare County, 2006 – 2010 [a]



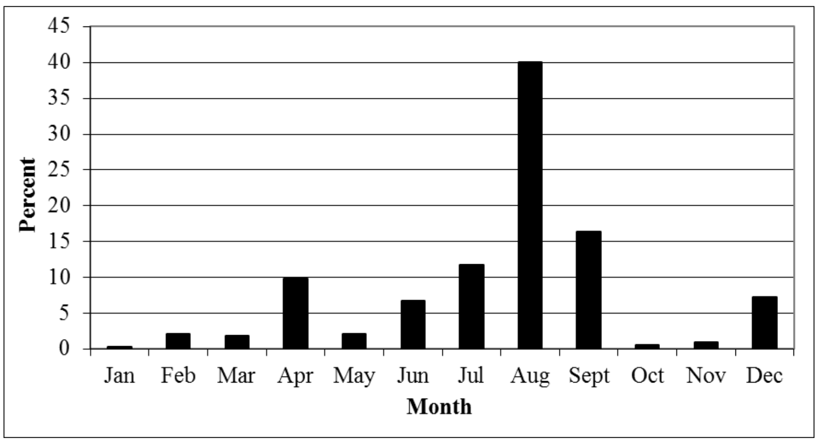
[a] Percent calculations based on acres treated (DPR, 2012a; queried April 27, 2012). Note scale: each line on y-axis represents 10%.

Ornamental Hand Harvesting

Hand harvesting of ornamentals represents harvesting of all nursery and greenhouse plants, and re-entry into quarantined treated commodities. No PHI is specified on carbaryl product labels following applications to ornamentals; that is, harvest can occur the same day as the application. Predicted Day 0 DFR for orange foliage was used to estimate short-term exposure.

Figure 19 summarizes applications in San Diego County to ornamentals (greenhouse and outdoor nursery-grown cut flowers and container-grown plants). Applications were ≥ 5% of the annual total in 6 months, including January, May, July through September, and December. Exposure estimates of ornamental hand harvesters assume exposure during these 6 months.

Figure 19. Applications of Carbaryl to Ornamentals in San Diego County, 2006 – 2010 [a]



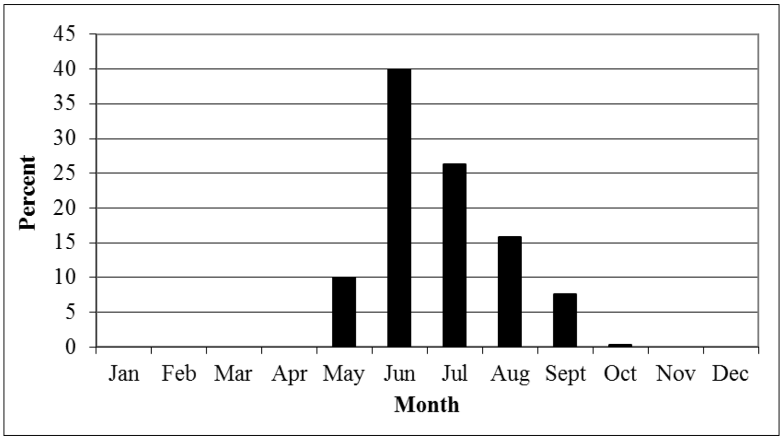
[a] Percent calculations based on acres treated (DPR, 2012a; queried on April 27, 2012).

Potato Scouting

Scouting in potatoes is the representative activity for all reentry activities in root vegetables. Reentry for these activities is allowed at expiration of the REI of 12 hours, and predicted Day 0 DFR for strawberry foliage was used to estimate short-term exposure.

Scouting is assumed to occur at any time during the growing season. Figure 20 summarizes applications of carbaryl to potatoes in San Joaquin County. The majority of carbaryl use occurred in May – September, and exposure was assumed to occur during these 5 months.

Figure 20. Applications of Carbaryl to Potatoes in San Joaquin County, 2006 – 2010 [a]



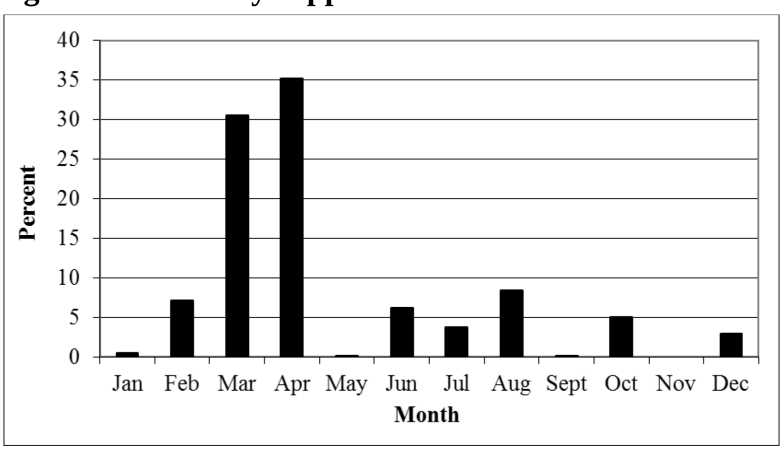
[a] Percent calculations based on acres treated (DPR, 2012a; queried on April 27, 2012).

Strawberry Scouting

Strawberry scouting represents all activities in strawberries. Reentry following carbaryl application is allowed at expiration of the REI of 12 hours, and predicted Day 0 DFR for strawberry foliage was used to estimate short-term exposure.

Scouting is assumed to occur at any time during the growing season. Figure 21 summarizes all applications of carbaryl to strawberries in Monterey County. Most use occurred in February – April and in June, August, and October. Annual exposure was estimated to occur during these 6 months.

Figure 21. Carbaryl Applications to Strawberries in Monterey County, 2006 – 2010 [a]



[a] Percent calculations based on acres treated (DPR, 2012a; queried April 27, 2012).

Tobacco Hand Harvesting

Tobacco harvesting represents all activities in tobacco. Although tobacco is not grown commercially in California, it is grown on university and small farm plots. Both the PHI and REI following carbaryl applications to tobacco is 2 days, and predicted Day 2 DFR for tobacco foliage was used to estimate short-term exposure.

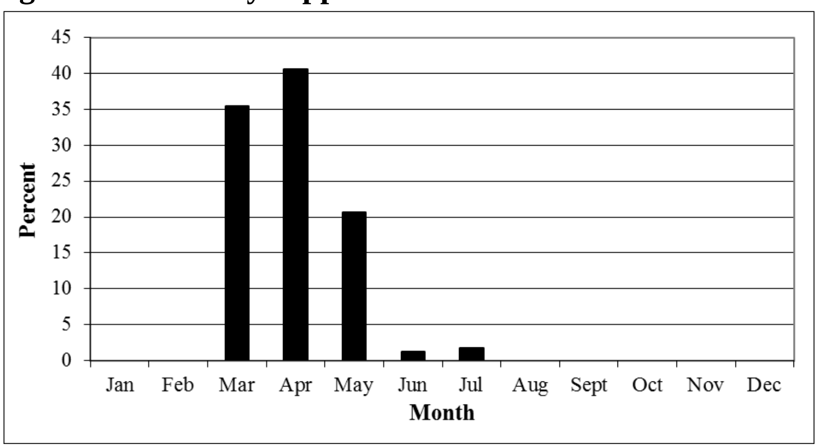
Only one 7-acre carbaryl application was reported on tobacco over a recent 10-year interval (2001 - 2010) which suggests that carbaryl is not frequently used on tobacco in California (DPR, 2012a; data not shown). Seasonal, annual, and lifetime exposures to carbaryl are not anticipated for tobacco harvesters.

Tomato Staking/Tying

Staking and tying represent all activities in tomatoes. The REI following carbaryl applications to tomatoes is 12 hours, and predicted Day 0 DFR for strawberry foliage was used to estimate short-term exposure.

Based on information in CFWAP (Edmiston *et al.*, 1999), staking and tying of tomato vines in the San Joaquin Valley occurs from March – May (Tulare County was the only county that provided dates for this activity). Figure 22 summarizes all applications of carbaryl to tomatoes in Fresno County. Most use occurred in March – May, which completely overlaps the typical activity period for staking and tying. Annual exposure was estimated to occur during these 3 months.

Figure 22. Carbaryl Applications to Tomatoes in Fresno County, 2006 – 2010 [a]



[a] Percent calculations based on acres treated (DPR, 2012a; queried April 27, 2012).

Turf Maintenance

Turf maintenance represents all activities related to sod growing, landscape maintenance, and golf course maintenance. Although carbaryl product labels specify a 24-hour PHI following application to sod, no PHI is specified following applications to golf courses, lawns, and other turf. For this reason, reentry was assumed to occur the same day as the application. The maximum application rate allowed for carbaryl on turf is 8.28 lbs AI/acre (0.19 lbs AI/1,000 ft^2 x 43,560 ft^2/acre = 8.28 lbs AI/acre).

Exposure estimates for this scenario do not rely on transfer coefficients and DFR. Instead, exposures were estimated using data from a surrogate study in which exposure was monitored during choreographed activities on turf following an application of oxadiazon (Rosenheck and Sanchez, 1995). This study was reviewed by Beauvais (2012). A surrogate study that monitored exposure of workers harvesting sod treated with chlorothalonil did not conduct monitoring until 2 – 4 days post-application (Merricks, 2000), and was not used.

Briefly, Rosenheck and Sanchez (1995) monitored exposure of 10 volunteers performing a 16-minute Jazzercise® routine on turf treated with a liquid oxadiazon product at a rate of 3.0 lbs AI/acre. Dermal exposure was monitored with outer whole-body dosimeters, cotton gloves, hand washes, and face/neck wipes. Dermal exposures for occupational scenarios assume that reentry workers wear long-sleeved shirt, long pants, and shoes; exposures were calculated by assuming a 90% protection factor for covered body regions (Beauvais, 2012). The mean exposure rate, adjusted to the maximum application rate of 8.28 lbs AI/acre for carbaryl (i.e., after multiplying by 8.28/3.0), is 345 µg/kg/hour. The 95th percentile exposure rate is 489 µg/kg/hour (Beauvais, 2012).

The short-term exposure (STADD) was calculated from the 95th percentile exposure rate as follows, assuming 70% dermal absorption and an 8-hour workday:

(489 µg/kg/hour) x (8 hours/day) x 0.70 = 2,738 µg/kg/day = **2.74 mg/kg/day**.

Seasonal, annual, and lifetime exposures are not anticipated for turf maintenance, because landscape maintenance workers are not anticipated to encounter carbaryl-treated lawns on more than occasionally and because carbaryl applications on sod, on turfgrass, and for landscape maintenance are infrequently reported (DPR, 2012a; data not shown). For this reason, only short-term exposures are needed for this scenario.

Residential Handler Exposure

Exposure estimates for residential handlers were based on data from a chemical-specific exposure monitoring study (Merricks, 1997); a surrogate exposure monitoring study (Klonne and Honeycutt, 1999); or on data from PHED. In addition to the study by Merricks (1997), a chemical-specific biomonitoring study was available that reported on monitoring of handler exposure estimates during residential applications of liquid carbaryl products to turf by hose-end sprayer (Rice and Grant, 2003). Exposure estimates could not be based on this study, however, as no information was provided on PPE and clothing worn by handlers, confounding interpretation of the results.

Table 32 summarizes residential handler exposure estimates. Handlers were assumed to wear protective clothing and chemical-resistant gloves as required on product labels. With one exception, all product labels with residential use directions require handlers to wear waterproof, latex, rubber, or other specific type of chemical-resistant gloves. The label for Ortho Bug-Geta Plus Snail, Slug & Insect Killer (239-2514-ZC) is exceptional in that it specifies use of “protective gloves,” which is not necessarily equivalent to chemical-resistant gloves (e.g., a user might consider a leather or cotton glove to be protective, yet these types of gloves are not chemical-resistant). Additionally, residential users of pesticides do not face the same level of enforcement that occupational users do, and some users may not wear label-required clothing and gloves. Exposures for such cases are discussed below in the Exposure Appraisal.

Table 32. Residential Handler Estimates of Exposure to Carbaryl

Residential Handler Scenario [a]	Exposure Rate (µg/lb AI handled)		STADD (mg/kg/day) [b]		
	Dermal	Inhalation	Dermal	Inhalation	Total
Backpack M/L/A [c]	85,637	67.1	0.163	0.000182	0.163
LPHW M/L/A [d]	4,170	19.7	0.00792	0.0000535	0.00794
Trigger Spray Applicator [d]	35,700	202	0.000939	0.00000759	0.000946
Hose-End M/L/A [d]	3,720	3.83	0.00707	0.0000104	0.00708
Dust L/A [d]	136,000	7,100	0.136	0.0101	0.146
Push-Type Spreader L/A [e]	627	3.18	0.0259	0.000188	0.026

[a] L/A = Loader/Applicator. LPHW = Low-pressure Handwand. M/L/A = Mixer/Loader/Applicator. Handlers are assumed to wear long-sleeved shirts, long pants, and chemical-resistant gloves. Only short-term uses are anticipated for residential handlers of carbaryl products.

[b] STADD = Short-term Average Daily Dose. Assumes application of 0.19 lb AI/1000 ft^2 of lawn (LPHW, backpack, and hose-end sprayers); one 32-ounce bottle per day (0.946 liters/day), containing 0.00263 lb AI (0.00119 kg AI) on 1000 ft^2 of ornamentals (trigger spray); 0.1 lb AI/day (dust; equivalent to one can); or 8.28 lbs AI/acre on a 0.5 acre lawn (push-type spreader). Calculation assumptions include: dermal absorption = 70% (Beauvais, 2006a); body weight = 70 kg (Thongsinthusak *et al*., 1993); inhalation rate 16.7 liters/min (Andrews and Patterson, 2000); and inhalation absorption = 100% (Frank, 2008).

[c] Exposure rates from the Pesticide Handlers Exposure Database. See Table 26 and Appendix 3.

[d] Exposure estimates based on data from Merricks (1997), as summarized in Table 20.

[e] Estimates were based on data from Klonne and Honeycutt (1999), as summarized in Table 20.

Backpack Sprayer Applications

Table 32 summarizes short-term exposure estimates for residential handlers applying carbaryl with backpack sprayers. Estimates are based on PHED data in Table 26. Residential handlers were assumed to use backpack sprayers to apply carbaryl to 1,000 ft^2 of lawn at the maximum allowed rate of 0.19 lb AI/1,000 ft^2. Carbaryl liquid applications are restricted to spot treatments of 1,000 ft^2 (0.023 acres), and allow up to 2 – 4 applications per year, at least 7 days apart. For this reason, multiple exposures are each considered to be short-term, and no seasonal, annual, or lifetime exposures are anticipated.

Low Pressure Handwand Applications

Exposure estimates for handlers using low-pressure handwand sprayers to apply carbaryl are based on exposure monitoring conducted by Merricks (1997), as summarized in Table 20. Exposure estimates are given in Table 32. Residential handlers were assumed to use low-pressure handwand sprayers to apply carbaryl to 1,000 ft^2 of lawn at the maximum allowed rate of 0.19 lb AI/1,000 ft^2. Carbaryl liquid applications are restricted to spot treatments of 1,000 ft^2 (0.023 acres), and allow up to 2 – 4 applications per year, at least 7 days apart. For this reason, multiple exposures are each considered to be short-term, and no seasonal, annual, or lifetime exposures are anticipated.

Trigger Sprayer Applications

Exposure estimates for handlers using trigger sprayers to apply carbaryl are based on exposure monitoring conducted by Merricks (1997), as summarized in Table 20. Exposure estimates are given in Table 32. Residential handlers were assumed to apply a 32-ounce bottle in a day (0.946 liters/day), containing 0.00263 lb AI (0.00119 kg AI) to apply carbaryl to 1,000 ft^2 of ornamentals. Carbaryl liquid applications are restricted to spot treatments of 1,000 ft^2 (0.023 acres), and allow up to 2 – 4 applications per year, at least 7 days apart. For this reason, multiple exposures are each considered to be short-term, and no seasonal, annual, or lifetime exposures are anticipated.

Hose-End Sprayer Applications

Exposure estimates in Table 32 for handlers using hose-end sprayers to apply carbaryl are based on exposure monitoring conducted by Merricks (1997), as summarized in Table 20. Exposure estimates are given in Table 32. Residential handlers were assumed to use hose-end sprayers to apply carbaryl to 1,000 ft^2 of lawn at the maximum allowed rate of 0.19 lb AI/1,000 ft^2. Carbaryl liquid applications are restricted to spot treatments of 1,000 ft^2 (0.023 acres), and allow up to 2 – 4 applications per year, at least 7 days apart. For this reason, no seasonal, annual, or lifetime exposures are anticipated.

Dust Applications

Exposure estimates in Table 32 for handlers applying carbaryl dust products are based on exposure monitoring conducted by Merricks (1997), as summarized in Table 20. Of the 24 dust applications monitored by Merricks (1997), 22 were made using a pump-type mechanical duster, and two were made with the shaker can that the dust was packaged in. The 22 handlers using the mechanical duster were monitored during loading and applying; no loading was needed for the shaker can. Exposures were reported as group statistics, without differentiating between the two types of applicators used in the study. Monitoring results from Merricks (1997) are expected to provide health-protective exposure estimates for shaker can use. Residential handlers were assumed to apply 0.1 lb AI/day, which is equivalent to one container. Carbaryl dust applications are restricted to at least 2 – 3 weeks apart. For this reason, multiple exposures are each considered to be short-term, and no seasonal, annual, or lifetime exposures are anticipated.

Granular Push-Type Spreader Applications

Exposure estimates in Table 32 for handlers using a push-type spreader to apply granular carbaryl products are based on exposure monitoring conducted by Klonne and Honeycutt (1999). Exposure rates are summarized in Table 20. The maximum residential application rate for carbaryl granular/bait products is 0.19 lb AI per 1000 ft^2, which is equivalent to 8.28 lbs AI/acre (0.19 lbs AI/1,000 ft^2 x 43,560 ft^2/acre = 8.28 lbs AI/acre). Lawn size is assumed to be 0.5 acre (21,780 ft^2; Vinlove and Torla, 1995). Residential handlers were assumed to use push-type spreaders to apply carbaryl to 0.5 acres of lawn at the maximum allowed rate of 8.28 lbs AI/acre. Carbaryl granular product labels with turf use directions do not have a minimum reapplication interval, and state only that applications may be repeated as needed. However, seasonal, annual, and lifetime residential uses are not anticipated.

Residential Post-Application Exposure

The representative reentry scenario in residential settings is dermal exposure from reentry onto treated lawns. Other possible residential post-application exposures are anticipated to be lower than turf reentry.

Dermal Exposure from Reentry onto Treated Lawns

Table 33 summarizes reentry dermal exposures of adults and toddlers on carbaryl-treated lawns. Exposures are estimated using data from a surrogate study in which exposure was monitored during choreographed activities on turf following an application of oxadiazon (Rosenheck and Sanchez, 1995). This study was reviewed by Beauvais (2012).

Table 33. Residential Reentry Dermal Exposure to Carbaryl on Treated Turf

	Body Weight (kg) [a]	Body Surface Area (cm^2) [b]	Exposure Rate (µg/kg/hour) [c]	STADD (mg/kg/day) [d]
Adult	69.4	18,150	1,840	2.58
Toddler	15.0	6,565	3,090	4.33

[a] Adult body weight is mean of body weights in exposure monitoring study (Rosenheck and Sanchez, 1995), and toddler body weight is the mean of the median values for male and female 3 year-old children (U.S. EPA, 1997a). The ratio of body weights = 69.4/15 = 4.63.

[b] The body surface area assumed for adults is the mean of the male and female median values for adults aged 18 and above, and the body surface area assumed for toddlers is the mean of the male and female median values for 3 year-old children (U.S. EPA, 1997a). The ratio of body surface areas = 18,150/6,565 = 2.76.

[c] Exposure rate from study monitoring exposure of adults performing a Jazzercise® routine on treated turf (Rosenheck and Sanchez, 1995). Beauvais (2012) reviewed this study and calculated the exposure rate for adults. The toddler exposure rate was calculated by multiplying the exposure rate by the adult/toddler ratio of body weights and dividing by the adult/toddler body surface area ratio.
(1,840 µg/kg/hour) x 4.63/2.76 = 3,087, which rounds to 3,090 µg/kg/hour.

[d] Short-term Absorbed Daily Dosage (STADD) calculated as described in text. Exposure estimates are for dermal route, as inhalation route assumed to be insignificant. Calculation assumptions include a dermal absorption of 70% (Beauvais, 2006a), and that adults and toddlers spend 2 hours/day on treated turf (U.S. EPA, 1997b).

Briefly, Rosenheck and Sanchez (1995) monitored exposure of 10 volunteers performing a 16-minute Jazzercise® routine on turf treated with a liquid oxadiazon product at a rate of 3.0 lbs AI/acre. Dermal exposure was monitored with outer whole-body dosimeters, cotton gloves, hand washes, and face/neck wipes. The mean exposure rate, adjusted to the maximum application rate of 8.28 lbs AI/acre for carbaryl (i.e., after multiplying by 8.28/3.0), is 1,390 µg/kg/hour. The 95th percentile exposure rate is 1,840 µg/kg/hour (Beauvais, 2012).

The short-term exposure (STADD) for adults is calculated from the 95th percentile exposure rate as follows, assuming 70% dermal absorption and that adults are on treated turf for up to 2 hours/day (U.S. EPA, 1997b):

(1,840 µg/kg/hour) x (2 hours/day) x 0.7 = 2,576 µg/kg/day = **2.58 mg/kg/day**.

Toddlers are assumed to weigh 15 kg, which is the mean of the median values for male and female 3 year-old children (U.S. EPA, 1997a). Dermal exposure of toddlers playing on carbaryl-treated lawns is estimated by multiplying estimated adult exposure rate from Rosenheck and Sanchez (1995) by the ratio of the mean body weight of 69.4 kg of adults in the exposure monitoring study of Rosenheck and Sanchez (1995) – that is, the body weight used to estimate adult exposures – to the default toddler body weight, and dividing by the adult/toddler ratio of assumed body surface areas as summarized in Table 33. The calculation of exposure from the adjusted exposure rate is shown below:

(3,090 μg/kg/hour) x (2 hours/day) x 0.7 = 4,326 μg/kg/day = **4.33 mg/kg/day**

Seasonal, annual, and lifetime exposures are not anticipated for residential scenarios involving carbaryl, and only short-term exposures are needed for this scenario.

Incidental Non-dietary Ingestion of Pesticides Applied to Turf

In addition to dermal exposure, toddlers potentially absorb turf-applied pesticides through ingestion of residues transferred when hands contact turf then are placed in the mouth (hand-to-mouth transfer), ingestion of residues transferred when objects (e.g., toys or grass itself) contact turf then are placed in the mouth (object-to-mouth transfer), and soil ingestion (U.S. EPA, 1997b). No acceptable exposure monitoring studies have been conducted for these activities on carbaryl-treated turf, and exposures were estimated from environmental residues and assumptions described below. Total non-dietary ingestion exposure from hand-to-mouth transfers, object-to-mouth transfers, and soil ingestion was estimated to be 0.00125 + 0.00162 + 0.000229 = 0.00310 mg/kg/day. As dermal exposure to toddlers was estimated to be 4.33 mg/kg/day, non-dietary ingestion exposure of carbaryl is expected to be insignificant (i.e., aggregate dermal + non-dietary ingestion exposure, and exposure by the dermal route alone, would both round to 4.33 mg/kg/day).

Hand-to-Mouth Transfer

Hand-to-mouth transfer is estimated based on transferable residues on turf (TTR). Data from Mester (1999) show that following a liquid carbaryl product application at the rate of 8.17 lb carbaryl/acre, the Day 0 TTR was 0.927 μg/cm². Adjusted to the maximum rate of 8.28 lbs AI/acre allowed for turf use gives a Day 0 TTR of 0.939 μg/cm^2.

Other factors used in estimating hand-to-mouth transfer include the surface area of a toddler's hands expected to contact the mouth, the number of times the hands contact both turf and mouth in an hour, the percentage of residues transferred from the hands to the mouth with each contact, and the number of hours toddlers play on turf. The median surface area of both hands contacting the mouth was assumed to be 20 cm² (Smegal *et al.*, 2001). The rate of hand-to-mouth contact for estimating a short-term exposure was assumed to be 20 events/hour, based on the 90th percentile contact rate from a study reviewed by U.S. EPA (Smegal *et al.*, 2001). With each hand-to-mouth contact, 50% of residues were assumed to be transferred to the mouth; 5% transfer from turf to hands was assumed as well (Smegal *et al.*, 2001). Finally, toddlers were assumed to spend 2 hours/day on turf (U.S. EPA, 1997b). The exposure calculation is shown below:

STADD = [(0.939 μg/cm²) x (20 cm²) x (20 events/hour) x (0.5) x (0.05) x (2 hour/day)]/(15 kg)
= 1.25 μg/kg/day = **0.00125 mg/kg/day**.

Object to Mouth Transfer

Like hand-to-mouth transfer, object-to-mouth transfer is also estimated based on Day 0 TTR, which for carbaryl was assumed to be 0.939 μg/cm^2. Object-to-mouth transfer assumes that small objects (including grass) are swallowed, and that 100% of residues on the swallowed grass or similar objects are available for absorption. For this reason, the only other factor used in estimating object-to-mouth transfer is the surface area of the object (including grass) expected to be ingested during play. For this scenario U.S. EPA (1997b) assumes that children may ingest 25 cm^2/day (i.e., 2 x 2 inches or 4 in^2), based on "the approximate area from which a child may grasp a handful of grass." The exposure calculation is shown below:

STADD = [(0.939 µg/cm²) x (25 cm²)]/(15 kg) = 1.62 µg/kg/day = **0.00162 mg/kg/day**.

Soil Ingestion

U.S. EPA (1997b) describes the soil ingestion scenario as follows: "This scenario assumes that pesticide residues in soil are ingested by toddlers who play on treated areas (i.e., yards, gardens, playgrounds) as a result of normal mouthing activities (i.e., these estimates do not represent exposure among toddlers who exhibit pica, an abnormal ingestion behavior)." The following assumptions were made in estimating exposure: that 100% of the applied AI to the turf was "located within the soil's uppermost 1 cm" (U.S. EPA, 1997b); that 0.1 g of soil was ingested per day (U.S. EPA, 1997a); and that bulk soil density was 0.67 cm^3/g soil. The exposure calculation (including units conversion factors) is shown below:

STADD = [(8.28 lbs AI/acre) x (0.1 g/day) x (1.0/cm) x (0.67 cm^3/g) x (4.54 x 10^8 µg/lb) x (2.47 x 10^{-8} acre/cm²)] / (15 kg) = 0.229 µg/kg/day = **0.000229 mg/kg/day**.

Swimmer Exposure

Carbaryl residues have been detected in surface waters in California. Exposures of adults and children swimming in surface waters are summarized in Table 34, and were estimated based on equations listed in U.S. EPA (1997b). The carbaryl dose absorbed dermally was estimated from the concentration in the water and the duration of swimming, as well as the skin permeability and the surface area of exposed skin, which is assumed to be 18,150 cm² for an adult and 8,545 cm² for a 6 year-old child (U.S. EPA, 1997b).

K_p is the skin permeability coefficient, calculated with the following equation from U.S. EPA (2004): $\log K_p = -2.80 + 0.66 \log K_{ow} - 0.0056$ MW. Carbaryl has a molecular weight of 201.2 and $\log K_{ow}$ of 1.85; its calculated K_p is 0.002 cm/hour.

For short-term exposures, exposure time was assumed to be 5 hours/day (U.S. EPA, 2003, and carbaryl concentration was taken to be the highest post-application swimmable water sample concentration, 6.94 µg/liter (Walters *et al.*, 2003), from a Sacramento fish pond in 2000. For long-term exposures, the exposure time was assumed to average 2.3 hours/day for children and 1.3 hours/day for adults (U.S. EPA, 2003); carbaryl concentration was assumed to be the median concentration of 0.0001 µg/liter in surface water samples collected in California through July 2000 (Guo, 2000). Weather was assumed to be suitable for outdoor swimming for 100 days each year. The short-term exposure dermal calculation for adults in shown below.

Dermal exposure = [(6.94 μg/liter) x (18,150 cm^2) x (5 hours/day) x (0.002 cm/hour) x (L/1,000 cm^3)] / (70 kg) = 0.018 μg/kg/day = **0.000018 mg/kg/day**.

Non-dietary ingestion is calculated by assuming an ingestion rate of 0.05 liters/hour. The short-term oral exposure for adults is shown below.

Oral exposure = [(6.94 μg/liter) x (0.05 liters/hour) x (5 hours/day)] / (70 kg) = 0.025 μg/kg/day = **0.000025 mg/kg/day**.

Dermal and oral exposures are aggregated to estimate STADD:

STADD = 0.000018 mg/kg/day + 0.000025 mg/kg/day = **0.000043 mg/kg/day**

The calculated aggregate adult and child swimmer exposures to carbaryl are shown in Table 34. Aggregate exposures include only dermal and oral routes, as exposures by the inhalation route are considered negligible in an outdoor setting (U.S. EPA, 2003).

Table 34. Exposures of Swimmers to Carbaryl in Surface Water

	STADD [a] (mg/kg/day)	SADD [b] (mg/kg/day)	AADD [c] (mg/kg/day)
Adult	0.000043	0.00000016	0.000000000044
Child (6 year-old)	0.00011	0.00000070	0.00000000019

[a] STADD = Short-term Average Daily Dose. Aggregate dermal and non-dietary ingestion estimated using equations from U.S. EPA (1997b) as described in text. The carbaryl concentration was assumed to be 6.94 μg/liter (Walters *et al.*, 2003), and exposure duration was assumed to be 5 hours (U.S. EPA, 2003).
[b] SADD = Seasonal Average Daily Dose. Aggregate dermal and non-dietary ingestion estimated using equations from U.S. EPA (1997b) as described in text. The carbaryl concentration was assumed to be 0.0001 μg/liter (Guo, 2000), and exposure duration was assumed to be 2.3 hours/day for children and 1.3 hours/day for adults (U.S. EPA, 2003).
[c] AADD = Annual Average Daily Dose. Assumes swimming up to 100 days per year.

Airborne Exposures Associated with Applications

Agricultural Applications

Bystanders might be exposed to carbaryl if they are adjacent to fields or orchards that are being treated or have recently been treated. In the absence of acceptable monitoring data for carbaryl, data from a surrogate study with methyl parathion were used to estimate exposure (Wofford and Ando, 2003; Barry, 2006). The study and selected data from it, including data used to calculate exposure estimates, are summarized in Table 17. The peak total concentration was 7.32 μg/m^3, and occurred at a downwind sampler (Sampler 17) during the application (Barry, 2006).

The application monitored by Wofford and Ando (2003) had a methyl parathion application rate of 2 lbs AI/acre. As concentrations in air are assumed to be proportional to application rate, bystanders near a citrus orchard receiving a carbaryl application at the maximum allowed rate of 12 lbs AI/acre would be anticipated to be exposed to higher concentrations than predicted by Wofford and Ando (2003). The concentrations used to estimate 1-hour and 24-hour short-term exposures were therefore adjusted for the maximum application rate (multiplied by 12/2 = 6). Table 35 summarizes the bystander exposure estimates.

Table 35. Estimated Exposure to Carbaryl for Bystanders to Agricultural Applications

	Assumed Carbaryl Concentration ($\mu g/m^3$) [a]	Inhalation Rate [b]	Absorbed Dose [c]
1-Hour Absorbed Dose (during heavy activity for 1 hour) [d]			
Infant	43.9	0.25 m^3/kg/hour	0.0110 mg/kg/hour
Adult	43.9	0.045 m^3/kg/hour	0.00198 mg/kg/hour
Short-Term Absorbed Daily Dosage (STADD) [e]			
Infant	32.5	0.59 m^3/kg/day	0.0192 mg/kg/day
Adult	32.5	0.28 m^3/kg/day	0.00910 mg/kg/day
Seasonal Absorbed Daily Dosage (Seasonal ADD) [f]			
Infant	1.59	0.59 m^3/kg/day	0.00469 mg/kg/day
Adult	1.59	0.28 m^3/kg/day	0.00223 mg/kg/day
Annual Absorbed Daily Dosage (AADD) [g]			
Infant	1.59	0.59 m^3/kg/day	0.000391 mg/kg/day
Adult	1.59	0.28 m^3/kg/day	0.000186 mg/kg/day
Lifetime Absorbed Daily Dosage (LADD) [h]			
Adult	1.59	0.28 m^3/kg/day	0.000186 mg/kg/day

[a] Based on air monitoring done in 2003 during and following an airblast application of a surrogate chemical, methyl parathion, to a walnut orchard in San Joaquin County (Wofford and Ando, 2003; Barry, 2006). Concentrations were time-weighted averages (TWA) multiplied by the ratio of maximum allowed application rate on citrus of 12 lbs AI/acre (for short-term exposures), or the typical application rate on citrus of 10 lbs AI/acre (seasonal exposure) to the 2 lbs AI/acre rate used in the study monitored by Wofford and Ando (2003).

[b] Different inhalation rates were used for the 1-hour and daily absorbed doses. The inhalation rates for 1-hour absorbed dose estimates were calculated from values reported in Andrews and Patterson (2000), assuming heavy activity and dividing by the mean body weight for males and females (71.8 kg). Hourly inhalation rates for heavy activity are 1.9 m^3/hour for infants (Layton, 1993; U.S. EPA, 1997a) and 3.2 m^3/hour for adults (Wiley *et al*., 1991; U.S. EPA, 1997a; OEHHA, 2000). Daily inhalation rates are default values from Andrews and Patterson (2000).

[c] 1-hour absorbed doses assume 1-hour exposure during heavy activity, and are based on the highest concentration measured by Wofford and Ando (2003). Absorbed daily doses assume a typical mixture of activity levels throughout the day and are based on the highest 21-hour and 5-day TWA air concentrations from Wofford and Ando (2003).

[d] 1-hour absorbed dose (mg/kg/hour) = (highest 1-hour air concentration) x (inhalation rate).

[e] STADD (mg/kg/day) = (TWA air concentration) x (inhalation rate).

[f] Seasonal ADD (mg/kg/day) = (TWA air concentration) x (inhalation rate). High-use season estimated at 1 month.

[g] Annual ADD = (Seasonal ADD) x (annual use months per year)/12. Annual use estimated at 1 month.

[h] Lifetime concentrations assume average annual exposures occur each year over a lifetime for residential bystanders residing at the same location. Infants are a relatively small part of the assumed lifetime, and no separate lifetime estimates are calculated for them.

As available information suggests that exposures of less than 24 hours can result in toxicity, 1-hour exposure estimates were calculated based on the highest measured concentration in the surrogate study, which was from an 11-hour sample begun at the start of the 9.25-hour application. This concentration was adjusted to account for the maximum application rate for carbaryl (6 x 7.32 μg/m^3 = 43.9 μg/m^3). The adjusted 21-hour TWA from Table 17 was used to estimate short-term 24-hour exposure to carbaryl (6 x 5.41 μg/m^3 = 32.5 μg/m^3).

Multiple applications are allowed each year on several crops, suggesting that seasonal and annual bystander exposures can occur. For example, labels for liquid products allow up to eight applications per year on sweet corn and citrus, with minimum intervals of 3 days and 14 days, respectively, between applications. Up to seven applications are allowed each year on fruiting vegetables such as tomatoes, and up to six on root vegetables and cucurbits. Multiple applications are allowed on other crops as well. Individuals in areas where these crops are grown could experience seasonal and annual exposures from repeated applications in nearby fields or orchards.

Urban and Suburban Applications for Public Pest Control

Individuals in residential areas could be exposed to airborne carbaryl during government pest control programs, such as spraying for the glassy wing sharpshooter. Unlike agricultural applications, which legally exclude non-handlers from application sites, when urban and suburban areas are sprayed, individuals can be in the spray zone. Air concentrations associated with these applications are summarized in Table 18. Table 36 summarizes exposure estimates.

Table 36. Exposure Estimates Associated with Public Pest Control Programs

	Carbaryl Concentration (μg/m^3) [a]	Inhalation Rate [b]	Absorbed Dose [c]
1-Hour Absorbed Dose (during heavy activity for 1 hour) [d]			
Infant	12.0	0.25 m^3/kg/hour	0.0030 mg/kg/hour
Adult	12.0	0.045 m^3/kg/hour	0.00054 mg/kg/hour
Short-Term Absorbed Daily Dosage (STADD) [e]			
Infant	0.60	0.59 m^3/kg/day	0.00015 mg/kg/day
Adult	0.60	0.28 m^3/kg/day	0.000027 mg/kg/day

[a] Concentration used to calculate 1-hour absorbed doses is the highest carbaryl concentration measured at a single sampler during an 80-minute sampling interval that spanned an application (Neher *et al*., 1982). Concentration used to calculate STADD was the highest 24-hour time-weighted average (TWA) air concentration and is the mean of three samplers in the first 24 hours following an application (Walters *et al*., 2003). See Table 18 for study details.

[b] Different inhalation rates were used for the 1-hour and STADD absorbed doses. The inhalation rates for 1-hour absorbed dose estimates were calculated from values reported in Andrews and Patterson (2000), assuming heavy activity and dividing by the mean body weight for males and females (71.8 kg). Hourly inhalation rates for heavy activity are 1.9 m^3/hour for infants (Layton, 1993; U.S. EPA, 1997) and 3.2 m^3/hour for adults (Wiley *et al*., 1991; U.S. EPA, 1997; OEHHA, 2000). Daily inhalation rates are default values from Andrews and Patterson (2000).

[c] 1-hour absorbed doses assume 1-hour exposure during heavy activity, and STADD absorbed doses assume a typical mixture of activity levels throughout the day.

[d] 1-hour absorbed dose (mg/kg/hour) = (highest 1-hour air concentration) x (inhalation rate).

[e] STADD (mg/kg/day) = (TWA air concentration) x (inhalation rate).

Ambient Inhalation Exposure

Air monitoring conducted by the U.S. Geological Survey (Majewski, 2002) suggests that airborne carbaryl exposures not associated with particular applications can occur. Conversely, ambient air monitoring conducted in Fresno, Tulare and Kings counties by ARB (2008) did not detect carbaryl. Exposures to carbaryl in ambient air are anticipated to be equal to or less than bystander exposures to carbaryl, as the highest pesticide concentrations in air occur adjacent to an application (Siebers *et al.*, 2003; Garron *et al.*, 2009). Bystander exposure estimates are thus health-protective estimates for airborne carbaryl exposures both adjacent to and away from applications.

EXPOSURE APPRAISAL

This exposure assessment contains exposure estimates covering labeled uses of carbaryl. Some exposure scenarios were highlighted in the Abstract as having the highest level of concern with respect to exposure. No specific exposure value was used to select these scenarios. Selection followed preliminary consideration of the toxicity profile of carbaryl. Toxicity endpoints for risk assessment are addressed by Rubin (2012).

Some of the exposure scenarios utilized surrogate data (e.g., PHED data, time-zero residues for field worker exposure). The default exposure interval for occupational scenarios is 8 hours/day without time for breaks, etc., and the daily exposure estimates may overestimate actual exposures. Conversely, during a growing season some periods can have intensive activity that results in work days exceeding 8 hours, in which case exposures may be underestimated to some extent. In the absence of scenario-specific data, exposure estimates incorporate defaults; relationships between defaults and actual values are often unknown.

Estimated Dermal Absorption

Dermal absorption was estimated at 70%, based on a study using rats (Shah and Guthrie, 1983). The use of acetone as a vehicle in this study could result in an overestimate of dermal absorption. Organic solvents can damage the skin barrier properties, artificially increasing dermal penetration (Scheuplein and Ross, 1970; Fartasch, 1997). U.S. EPA (1998a) recommends that the vehicle used in dermal penetration studies should be the same as that “under which field exposure occurs,” and states that organic solvents “must not be used.” However, comparison of two studies using similar doses but different vehicles suggests that for carbaryl use of an organic solvent vehicle has little effect on absorption. The low dose of 34.5 $\mu g/cm^2$ applied in a carboxymethyl cellulose vehicle by Cheng (1995) was about the same as the low dose of 31 $\mu g/cm^2$ applied to adult rats in an acetone vehicle by Shah *et al.* (1987a). The absorption reported for both was similar: 34.0% absorption reported by Cheng (1995) following a 24-hour exposure and 30.1% absorption reported by Shah *et al.* (1987a) after 72 hours. These data suggest that use of acetone as a vehicle by Shah *et al.* (1987a) did not increase dermal absorption of carbaryl.

Although data from a well-conducted study using human volunteers would be ideal, the low recoveries of the IV and dermal doses decrease confidence in the estimate from Feldman and Maibach (1974). The location of the radiolabel on the carbaryl molecule was unspecified, and the majority of its excretion was apparently not urinary. Use of a minor metabolite excreted in urine to estimate absorbed dose is undesirable because it results in exaggeration of measurement and extrapolation errors (Woollen, 1993).

Thus, data from Shah and Guthrie (1983) are considered to be the best available for the anticipated range of occupational and residential exposures. Application of higher doses than those anticipated in the field can result in underestimating dermal absorption (Thongsinthusak *et al.*, 1999). Estimates of dermal exposure to handlers, assuming a default body weight of 70 kg and a body surface area of 18,150 cm², suggest that anticipated dermal exposures to carbaryl range from approximately 0.00362 µg/cm² to 234 µg/cm². Reentry exposures would be anticipated to be in the range of 0.498 µg/cm² to 26.4 µg/cm². Of 46 occupational scenarios (29 handler and 17 reentry) with short-term exposure estimates, a total of 18 exceed 4 µg/cm² and only four exceed 31 µg/cm². These expected field exposures suggest that a dose of 4 µg/cm² would cover most carbaryl exposures. Available data suggest that absorption of carbaryl is dose-dependent (for within-study dose-absorption comparisons, see in Figures 1 and 2 in Beauvais, 2006a). It is possible that a dermal absorption study using doses below 4µg/cm² might yield higher dermal absorption.

A well-conducted study with appropriate dose levels can potentially be used to refine the estimated dermal absorption. As explained by Frank (2009c) in discussing dermal absorption studies, "*in vitro* animal and/or human data alone were insufficient for determining the dermal absorption pattern of a given pesticide. This position was based primarily on the lack of a detailed, standardized methodology for *in vitro* dermal absorption studies." However, "*in vitro* data may prove to be useful if combined with other information, in a weight-of-evidence approach, for predicting a Dermal Absorption Factor (DAF)…when laboratory studies demonstrate that the ratio of the animal *in vitro* to *in vivo* DAF is close to 1, a human in vitro study conducted under the same laboratory conditions as the animal test is potentially a good predictor of human dermal absorption." As discussed below, this evaluation of *in vitro* dermal absorption data for carbaryl differs from that used by U.S. EPA (Shah, 2007; U.S. EPA, 2008).

Handler Exposure Estimates

Exposure estimates for which chemical-specific or appropriate surrogate data were unavailable were derived using data from PHED (1995), which may reflect older handler equipment and practices. Among studies in PHED used to estimate handler exposure to carbaryl, the most recent was conducted in 1994.

Chemical-specific data (i.e., from studies using carbaryl) and appropriate surrogate studies were available for some scenarios included in PHED. When such data were available, they were used to estimate exposure rather than PHED. Table 37 summarizes exposure rates from PHED for these scenarios (Beauvais *et al*., 2007). For each of the scenarios, exposure estimates calculated from PHED would be higher than estimates based on chemical-specific or surrogate studies. For M/L/A using low-pressure handwand, the short-term dermal exposure rate from PHED is 5,270 µg/lb AI handled. The short-term exposure rate from Merricks (1997), used to estimate exposure for this scenario, is slightly lower at 4,170 µg/lb AI handled. For M/L/A using a hose-end sprayer, the short-term dermal exposure rate from PHED is more than six times the rate estimated from Merricks (1997). For L/A using a push-type spreader, the short-term dermal exposure rate from PHED is 14-fold higher than the rate estimated from Klonne and Honeycutt (1999).

Table 37. Unit Exposure Data from the Pesticide Handlers Exposure Database (PHED)

Task [a]	Formulation	PHED Scenario [b]	Short-Term Exposure [c] (µg/lb AI handled)			Long-Term Exposure [d] (µg/lb AI handled)		
			Dermal	Inhalation	Total [e]	Dermal	Inhalation	Total [e]
Low-Pressure Handwand								
M/L/A	Liquid	22	5,270	88.9	5,360	1,895	31.9	1,930
Push-Type Spreader								
L/A	Granular	25	8,910	21.4	8,930	3,200	7.68	3,210
Hose-End Sprayer								
M/L/A	Liquid	26	25,520	54.3	25,600	9,190	19.5	9,210

[a] L/A is loader/applicator. M/L/A is mixer/loader/applicator.
[b] See Appendix 3 for scenario details and calculations. PHED scenario numbers are from Beauvais *et al.* (2007).
[c] Upper confidence limit (UCL) for 95th percentile exposure = 1/SQRT(2)*MEAN*EXP[Z(0.95)*0.8326 + Z(0.90)*0.8326/SQRT(n)]; see Equation 5 in Powell (2007).
[d] UCL for arithmetic mean exposure = MEAN*EXP[Z(0.90)*0.8326/SQRT(n)]; Equation 6 in Powell (2007).
[e] Total exposure = (Dermal absorption)*(Dermal exposure) + (Inhalation exposure).

In order to account for some of the uncertainty inherent in using PHED and to increase our confidence that exposures are not underestimated, DPR policy is to use the 90% upper confidence limit (UCL) on an exposure statistic, instead of the statistic itself, when using PHED (Frank, 2007). UCLs are used not because DPR believes that exposures are consistently greater than the population mean, but because available data are so sparse that it is likely that the sample mean is not close to the true population mean. In exposure monitoring, ranges of sample results can be quite broad, and can include values that are substantially higher than sample means (Grover *et al*., 1986; Vercruysse *et al*., 1999). Some exposure monitoring studies have reported sample ranges that span as much as three orders of magnitude (e.g., Hines *et al*., 2001). Thus, it is apparent that handlers could have exposures well above sample means; such estimates are not unreasonable. The approximation used to estimate the UCL can result in a several-fold increase in estimated exposure (Beauvais *et al*., 2010a).

Carbaryl product labels limit the use of human flaggers to those supporting ultra-low volume aerial applications for Rangeland Grasshopper and Mormon Cricket Suppression through the APHIS Program or an affiliated state program. Flaggers are required to be in an enclosed cab. In the absence of exposure monitoring data for flaggers in enclosed cabs, the enclosed cab was assumed to provide 90% protection to flaggers. Thongsinthusak *et al.* (1991) examined available data on reduction of exposure for applicators within a variety of enclosed cabs (e.g., with and without air filtration), and reported a range of 31% – 100% reduction of airborne concentrations inside versus outside the cab and a range of 84% – 99.7% reduction of residues measured on dermal patches. After reviewing the data, Thongsinthusak *et al.* (1991) recommended a protection factor of 98% for an enclosed cab with positive pressure and air filtration. More recently, Heitbrink *et al*. (2003) reported 11% penetration of aerosol particles into enclosed cabs of 3- to 4-year old with air filtration during field evaluations. It is reasonable to assume that flaggers inside an enclosed cab have substantially less exposure than flaggers standing outside with no engineering control. However, Kline *et al.* (2003) suggest that contamination inside cabs can itself be a source of exposure. As carbaryl product labels require use of enclosed cabs for flaggers, and do not specify positive pressure or air filtration, the 90% protection factor might result in an underestimate of flagger exposures.

Occupational Post-Application Exposure Estimates

In the absence of chemical-specific exposure monitoring data, field worker re-entry exposure estimates were appropriately based on chemical-specific DFR values; however, crop-specific DFR values were unavailable for most crops on which carbaryl may be used. The use of data from one crop to represent residues on another introduces uncertainties in exposure estimates. Residues may dissipate at different rates on different crops, due to factors such as leaf topography and physical and chemical properties of leaf surfaces.

DFR studies typically sample on several days post-application, but not necessarily on all days needed for exposure assessment. To interpolate DFR on days not sampled, predicted DFR estimates are based on log-linear regressions of daily mean DFR, in which natural logarithms of daily mean DFR are regressed on the post-application days when sampling occurred (Edmiston *et al*., 2002). Predicted DFR values were calculated by taking the exponent of the daily log values from the regression. As noted by Finney (1941), "The result of transforming back the mean of the logarithms is to obtain the geometric mean of the original sample, which will tend to underestimate the arithmetic mean of the population." That is, simply taking the exponential of ln DFR results in an underestimate of the predicted DFR; this was demonstrated by Beauvais *et al.* (2010b) for two endosulfan DFR data sets. Powell (1991) described an approach for an unbiased backtransformation that has often been used by DPR. Comparison of daily arithmetic and geometric means for carbaryl DFR data, however, show that arithmetic means are within 25% of geometric means, suggesting that the impact of taking the exponential of ln DFR for these data sets was minimal.

The rate of contact with treated foliage, unlike DFR, is not chemical specific (U.S. EPA, 2000). Transfer coefficient values for various crop activities are readily available, based on studies using other chemicals. Where activity- and crop-specific TCs were not available, defaults based on studies with similar activities and crops were used. These defaults were likely to be health-protective (U.S. EPA, 2000).

Although multiple studies support a correspondence between DFR residues on crops and fieldworker exposures (e.g., Zweig *et al*., 1985; Bruce *et al*., 2006b), available data do not appear to support a consistent relationship between TTR and exposure (Baugher *et al*., 2004). This suggests that the model which works well for fieldworker exposures might not apply to post-application exposures on turf. For this reason, post-application exposures were based on a surrogate exposure monitoring study instead, adjusted for differences in application rates (Rosenheck and Sanchez, 1995). Rather than any occupational activity, such as turf maintenance or sod harvesting, this study used a choreographed Jazzercise® routine. For occupational reentry involving treated turf or sod, U.S. EPA relied on a study conducted by the Agricultural Reentry Exposure Task Force (ARTF) which monitored exposure of workers harvesting chlorothalonil-treated sod (Merricks, 2000). However, the ARTF monitored sod harvester exposure 2 – 4 days post-application, whereas carbaryl has a 1-day REI for sod harvesting, and no REI for reentry onto turf. Some tasks, such as installation of sod and some landscape and golf course maintenance activities, involve crawling around on turf. For such tasks, the sod harvester exposure study could potentially underestimate exposure. The ARTF conducted a study of golf course maintenance workers intended to address exposures during typical golf course maintenance activities (Klonne and Bruce, 2005); however, exposures were highly variable and may have been affected by changing levels of moisture on the grass, making the study results difficult to interpret. Rosenheck and Sanchez (1995) gives good representative data for Day 0 reentry for high-contact activities in landscape maintenance.

Residential Handler Exposure

Users of pesticides are legally required to follow use directions given on pesticide product labels; primary enforcement of these requirements is the responsibility of County Agricultural Commissioners (CACs) with DPR support. In California the CACs inspect agricultural and structural sites where pesticides are used, ensuring compliance during occupational use; between 1997 and 2001, an estimated 13,000 such inspections were conducted annually of private property operators and licensed pest control businesses (DPR, 2001). However, non-occupational pesticide handlers are not inspected for safety. In recognition of this enforcement gap, exposure estimates were calculated for users not complying with product label requirements for PPE. These estimates are summarized in Table 38.

Table 38. Estimates of Carbaryl Exposure for Residential Handlers Not Wearing Label-Required Clothing and Gloves

Residential Handler Scenario [a]	Exposure Rate (µg/lb AI handled)		STADD (mg/kg/day) [b]		
	Dermal	Inhalation	Dermal	Inhalation	Total
Backpack M/L/A [c]	242,000	67.1	0.460	0.000182	0.460
LPHW M/L/A [d]	334,000	19.7	0.635	0.0000535	0.635
Trigger Spray Applicator [d]	287,000	202	0.00861	0.00000866	0.00862
Hose-End M/L/A [d]	700,000	3.83	1.33	0.0000104	1.33
Dust L/A [d]	1,390,000	7,100	0.276	0.000188	0.276
Push-Type Spreader L/A [e]	6,680	3.18	1.39	0.0101	1.40

[a] L/A = Loader/Applicator. LPHW = Low-pressure Handwand. M/L/A = Mixer/Loader/Applicator. Handlers are assumed to wear loose-fitting shorts and no gloves. Only short-term uses are anticipated for residential handlers of carbaryl products.
[b] STADD = Short-term Average Daily Dose. Assumes application of 0.19 lb AI/1000 ft^2 of lawn (LPHW, backpack, and hose-end sprayers); one 32-ounce bottle per day (0.946 liters/day), containing 0.00263 lb AI (0.00119 kg AI) on 1000 ft^2 of ornamentals (trigger spray); 0.1 lb AI/day (dust; equivalent to one can); or 8.28 lbs AI/acre on a 0.5 acre lawn (push-type spreader). Calculation assumptions include: dermal absorption = 70% (Beauvais, 2006a); body weight = 70 kg (Thongsinthusak *et al*., 1993); inhalation rate 16.7 liters/min (Andrews and Patterson, 2000); and inhalation absorption = 100% (Frank, 2008).
[c] Exposure rates from the Pesticide Handlers Exposure Database. See Table 26 and Appendix 3.
[d] Exposure estimates based on data from Merricks (1997), as summarized in Table 20.
[e] Estimates were based on data from Klonne and Honeycutt (1999), as summarized in Table 20.

Comparison of total exposure estimates in Table 38 with those in Table 32 show that without required clothing and chemical-resistant gloves, exposure estimates are increased between

2.8-fold (for backpack M/L/A) and 80-fold (for LPHW M/L/A). For backpack sprayer M/L/A with or without required clothing and chemical-resistant gloves, the highest exposures are to the upper arms and back. For a shirtless backpack M/L/A, upper arms and back each account for about one-third of total dermal exposure. For residential handlers using hose-end sprayers a low pressure handwand, or a push-type spreader, lower leg exposure dominates total exposure. Conversely, for residential handlers loading and applying carbaryl dust or using a trigger sprayer, hand exposure dominates and wearing of chemical-resistant gloves is critical for reducing exposure.

Residential Post-Application Exposure

Residential reentry exposures on carbaryl-treated turf were estimated from a study using a choreographed Jazzercise® routine (Rosenheck and Sanchez, 1995). Exposure estimates for residential turf reentry cover a range of activities, such as lawn mowing, crawling and playing, and golfing on treated turf. Putnam *et al.* (2008) monitored dermal exposure of eight golfers at the University of Massachusetts Turfgrass Research Center following an application of Sevin SL at a rate of 6.99 lbs AI/acre (7.85 kg AI/ha), which was watered in with 1.3 cm water. Rosenheck and Sanchez (1995) reported lower exposures on irrigated than on non-irrigated turf, and the post-application watering in done by Putnam *et al.* (2008) would be anticipated to yield lower exposures than if no irrigation had been done. Two groups of four golfers each were monitored with whole-body dosimeters and two pairs of cotton gloves; each group was monitored after a different carbaryl application. Beginning at 1 hour post-irrigation, golfers simulated playing 18 holes by walking 6,500 yards, hitting a ball 85 times, and then taking 85 practice swings over a 4-hour monitoring interval. Volunteers also teed up balls, replaced divots, and wiped clubs with a golf bag towel as needed. On average a total of 122 $\pm$ 17.0 µg carbaryl was recovered from dosimeters, corresponding to a 4-hour exposure of 0.145 µg/kg, or 0.0362 µg/kg/hour. In comparison, mean dermal exposure on irrigated turf estimated by Beauvais (2012) for an application rate of 6.99 lbs AI/acre, based on data from Rosenheck and Sanchez (1995), would be 365 µg/kg/hour, or about four orders of magnitude greater. The post-application watering in by Putnam *et al.* (2008) used more water than did Rosenheck and Sanchez (1995), 1.3 cm and 0.254 cm, respectively. It is likely that irrigation with a greater amount of water decreased available residues in the study by Putnam *et al.* (2008). Also, it is likely that the simulated golfer activity monitored by Putnam *et al.* (2008) would be associated with lower transfer of available pesticide residues than the Jazzercise® routine monitored by Rosenheck and Sanchez (1995), as the Jazzercise® routine involves lying on the ground and moving around. The exposure estimates based on exposure monitoring conducted by Rosenheck and Sanchez (1995) on non-irrigated turf are anticipated to be health protective, and could overestimate exposures for reentry activities like golfing that involve less contact with treated turf.

Tree fruit can be harvested from trees in residential yards, or in pick-your-own settings. Vegetables and fruit can be harvested from gardens following carbaryl use, resulting in post-application exposure. These scenarios differ from the corresponding occupational reentry scenarios in two ways: individuals may wear shorts and a t-shirt rather than a long-sleeved shirt and pants, and picking of fruit or vegetables for personal use is anticipated to involve much less time. Review of several studies suggests that an appropriate transfer coefficient (TC) for individuals harvesting or thinning fruit while wearing shorts and a t-shirt can be as high as 15,000 cm^2/hour. While this is higher than the occupational TC, the time spent picking fruit and vegetables in a residential setting is much less than the 8 hours/day assumed for occupational reentry scenarios. The best estimate is 0.25 hours per day for youth (age 10-12 years) and 0.67 hours per day for adults (age 18-64 years), based on the 95^{th} percentile values for time spent working in a garden or other circumstances working with soil (U.S. EPA, 1997a). Because the time spent doing these activities is anticipated to be substantially lower in residential than in the occupational scenarios, mitigation of any elevated risks associated with the occupational scenarios is expected to address residential exposures as well.

Swimmer Exposure

Swimmer exposures to carbaryl in surface waters were estimated based on concentrations of carbaryl reported from surface water sampling and assumptions about uptake of carbaryl from water. No biomonitoring or other exposure monitoring data were available. Exposure estimates were provided for adults for consistency with other scenarios, and for children, as likely worst-case because children have relatively greater surface area exposed to the water, per body weight, than adults.

The carbaryl concentration used to calculate seasonal and annual swimmer exposure estimates was derived from DPR's Surface Water Database. This database contains data reported from a variety of environmental monitoring studies targeting pesticides. These studies were conducted by several agencies, had different detection limits, and different study designs. Sampling frequency and sample collection site varied, and it is possible that the highest carbaryl concentrations were not reflected in the samples collected. Some studies monitored irrigation drains, which would be anticipated to have higher concentrations than rivers, for example (although the highest reported concentrations occurred in samples collected from rivers). The collection sites chosen for environmental monitoring might also be biased toward those where pesticides are most likely to occur; if so, the median concentrations used to calculate long-term exposures may be overestimated. However, these data were considered to be more appropriate for calculating swimmer exposure estimates than newer studies, which emphasized collection during rain events (Ensminger and Kelly, 2011a and 2011b). Most swimming is anticipated to occur during hot, dry weather, but in several studies carbaryl was detected most frequently in runoff from rain events.

Swimmer exposures were estimated based on equations and defaults for swimmers in treated swimming pools (U.S. EPA, 2003). The relevance of the assumptions underlying these calculations for swimmers in surface waters, rather than swimming pools, is unknown. No information is available for frequency or duration of swimming in surface waters (as opposed to community or residential swimming pools).

Airborne Exposures

Public exposures to airborne carbaryl were estimated based on concentrations in air and assumptions about uptake from the air. Inhalation exposure might be overestimated by the default absorption of 100% assumed in exposure calculations. However, as no biomonitoring or other exposure monitoring data were available, no prediction is possible about the extent to which inhalation exposure might be overestimated.

No monitoring has been conducted of carbaryl concentrations in air associated with agricultural applications, and surrogate data were used to estimate bystander exposure. Although evidence suggests that the specific AI has less effect on drift than do application method and physical factors such as droplet size (SDTF, 1997), there are a number of uncertainties associated with using data from an application of methyl parathion to estimate bystander exposures to carbaryl. Barry (2006) and Beauvais (2007) discussed uncertainties in relating data from Wofford and Ando (2003) to off-site concentrations of a different pesticide being applied to a different orchard crop. Briefly, differences in crop height and foliar density, as well as vapor pressure of the active ingredient, size of the application, and weather conditions including wind speed and direction all affect off-site chemical movement (Barry, 2006; Beauvais, 2007).

Concentrations used to estimate acute exposures were based on an application sample interval of 11 hours. Over the course of that time, the concentration could potentially fluctuate. In addition to factors previously mentioned, the concentration of pesticide in air at any single location can change as the applicator moves through orchard and the location of applicator with respect to the sampler changes. No data are available to estimate the extent of this fluctuation.

Comparison with U.S. EPA Exposure Assessment

An estimated 70% dermal absorption is used in this exposure assessment for carbaryl (Beauvais, 2006a), based on studies in rats following 12 hours exposure to carbaryl (Shah and Guthrie, 1983). Following submission of an *in vitro* comparative dermal penetration study using rat skin and human skin (a study which was not submitted to DPR), U.S. EPA estimated that rat skin was approximately 2.8 times more permeable than human skin (Shah, 2007). Rather than calculate a separate dermal absorption value, U.S. EPA (2008) adjusted the dermal toxicity estimate, which was based on a study in rats, upward by 2.8-fold for the assumed difference in dermal absorption between rats and humans. The effect on the risk calculation is equivalent to applying a dermal absorption of 36% (100% x 1/2.8), about half the dermal absorption assumed in this exposure assessment.

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

For occupational exposures this assessment assumed a 40-year career over a 75-year lifespan for calculating lifetime average daily dose (LADD). U.S. EPA assumed exposure for 35 work-years over a 70-year lifespan (Britton, 2007a). These approaches set the LADDs to 53% and 50%, respectively, of the annual average daily dose (AADD).

REFERENCES

Andrews, C.M. 2000. Worker Health and Safety Branch Policy on the Statistical Analysis for Dislodgeable Foliar Residue Data. Memo No. HSM-00011, dated February 4. Sacramento, CA: California Department of Pesticide Regulation, Worker Health and Safety Branch. http://www.cdpr.ca.gov/docs/whs/memo/hsm00011.pdf

Andrews, C. and Patterson, G. 2000. Interim Guidance for Selecting Default Inhalation Rates for Children and Adults. HSM-00010. Sacramento, CA: Worker Health and Safety Branch, Medical Toxicology Branch, California Department of Pesticide Regulation, Cal-EPA. December 1, 2000. http://www.cdpr.ca.gov/docs/whs/memo/hsm00010.pdf

Aprea, C., Sciarra, G., Sartorelli, P., Desideri, E., Amati, R. and Sartorelli, E. 1994. Biological monitoring of exposure to organophosphorus insecticides by assay of urinary alkylphosphates: Influence of protective measures during manual operations with treated plants. International Archives of Occupational and Environmental Health 66:333-338.

ARB. 2008. Report on Ambient Air Monitoring For Methomyl and Carbaryl in Fresno, Tulare and Kings Counties During July and August 2007. Unpublished study conducted by California Air Resources Board, report dated December 9. Sacramento, CA: Air Resources Board, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/emon/pubs/tac/studies/methomyl_application_report_12-09.pdf

Arthur, J. 2005. Malathion: Occupational Exposure and Risk Assessment for the Interim Reregistration Eligibility Decision (IRED) Document. DP Barcode: D315898; Chemical Number: 057701; EPA MRID Nos.: 45005910, 45491901, 45138202, 45491902, 45138201, 45469501. Washington, DC: Health Effects Division, Office of Pesticide Programs, U.S. Environmental Protection Agency.

Barry, T. 2006. Alternate Methidathion Application Air Concentration Estimates. Memorandum to Randy Segawa, Agriculture Program Supervisor IV, Environmental Monitoring Branch, from Terrell Barry, Ph.D., Senior Environmental Research Scientist, Environmental Monitoring Branch, Department of Pesticide Regulation, dated August 18. Sacramento, CA: Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/emon/pubs/ehapreps/analysis_memos/methairblast.pdf

Baugher, D.G., Klonne, D.R., Mihlan, G.J. and Ross, J.H. 2004. The ORETF Algorithm for Defining the Relationship of Transferable Turf Residues to Post-Application Dermal Exposure. Unpublished study submitted by the Outdoor Residential Exposure Task Force. DPR Data Volume 51643-073, Record No. 209674.

Baynes, R.E. and Riviere, J.E. 1998. Influence of inert ingredients in pesticide formulations on dermal absorption of carbaryl. American Journal of Veterinary Research 59:168-175.

Beauvais, S. 2002. Evaluation of Data Package 195138, Submitted by Aventis Cropscience, Residential Use of Carbaryl. Memo No. HSM-02022, dated July 19. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/whs/memo/hsm02022.pdf

Beauvais, S. 2006a. Dermal Absorption of Carbaryl. Memo No. HSM-06006, dated May 8. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/whs/memo/hsm06006.pdf

Beauvais, S. 2006b. Review of Carbaryl Airblast Exposure Monitoring and Sock Dosimetry Analytical Method Validation Studies, Data Packages 210452 and 213826. Memo No. HSM-06002, dated February 24. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/whs/memo/hsm06002.pdf

Beauvais, S. 2007. Estimation of Exposure of Persons in California to Pesticide Products that Contain Methidathion . Report No. HS-1805. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/whs/pdf/hs1805.pdf

Beauvais, S. 2008. Health-Protective Estimates of Seasonal and Annual Reentry Exposure to Endosulfan: Substantiating the Assumed Typical Reentry Day. Memo No. HSM-08001, dated January 14. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/whs/memo/hsm08001.pdf

Beauvais, S. 2011a. Chemical-Specific Exposure Monitoring Studies for Handlers of Carbaryl Products. Memo No. HSM-11002, dated June 2. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/whs/memo/hsm11002.pdf

Beauvais, S. 2011b. Exposure Monitoring Study for Residential Handlers Applying Granular Pesticides Via Push Spreader. Memo No. HSM-11003, dated May 31. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/whs/memo/hsm11003.pdf

Beauvais, S. 2011c. Respirator Assigned Protection Factors and Information on Compliance with Legal Requirements for Respirators. Memo No. HSM-11004, dated May 31. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/whs/memo/hsm11004.pdf

Beauvais, S. 2012. Primary Review of Turf Reentry Exposure Monitoring and Residue Dissipation Study with Oxadiazon. Memo No. HSM-12005, dated May 4. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/whs/memo/hsm12005.pdf

Beauvais, S., Powell, S. and Zhao, W. 2007. Surrogate Handler Exposure Estimates for Use in Assessments by the California Department of Pesticide Regulation. Report No. HS-1826. Sacramento, CA: Worker Health and Safety Branch, California Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/whs/pdf/hs1826.pdf

Beauvais, S.L., Silva, M.H. and Powell, S. 2010a. Human health risk assessment of endosulfan. Part III: Occupational handler exposure and risk. Regulatory Toxicology and Pharmacology 56:28-37.

Beauvais, S.L., Silva, M.H. and Powell, S. 2010b. Human health risk assessment of endosulfan. Part IV: Occupational reentry and public non-dietary exposure and risk. Regulatory Toxicology and Pharmacology 56:38-50.

Beech, JA. 1980. Estimated worst case trihalomethane body burden of a child using a swimming pool. Medical Hypotheses 6:303-307.

Borzelleca, J.F. and Skalsky, H.L. 1980. The excretion of pesticides in saliva and its value in assessing exposure. Journal of Environmental Science and Health B15:843-866.

Bouchard, M., Carrier, G. and Brunet, R.C. 2008. Assessment of absorbed doses of carbaryl and associated health risks in a group of horticultural greenhouse workers. International Archives of Occupational and Environmental Health 81:355-370.

Brittan, K.L., Schmierer, J.L., Munier, D.J., Klonsky, K.M. and Livingston, P. 2008. Sample Costs to Product Field Corn on Mineral Soils in the Sacramento Valley. UC ANR Publication CO-SV-08. Oakland, CA: UC Cooperative Extension, Agriculture and Natural Resources, University of California. http://coststudies.ucdavis.edu/files/CornSV2008.pdf

Britton, W. 2007a. Carbaryl: Revisions to Occupational Exposure and Risk Assessment. DP Barcode: 334881, PC Code: 056801. July 9, 2007. Washington, DC: Health Effects Division, Office of Prevention, Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

Britton, W. 2007b. Carbaryl: Revisions to Residential Exposure and Risk Assessment. DP Barcode: 334862, PC Code: 056801. June 29, 2007. Washington, DC: Health Effects Division, Office of Prevention, Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

Bruce, E., Korpalski, S., Johnson, D., Klonne, D., Nagel, W., Holden, L. and Lange, B. 2006a. Effect of dislodging techniques on foliar residue determination for agricultural crops. Archives of Environmental Contamination and Toxicology 50:138-143.

Bruce, E.D., Holden, L.R. and Korpalski, S.J. 2006b. Agricultural Reentry Task Force Transfer Coefficient Database: A Summary of its Development and Use. Unpublished study conducted by the Agricultural Reentry Task Force, LLC. Revised report dated January 13. MRID 46734002.

Cal/OSHA. 2007. Assigned Protection Factors for Respirators. Sacramento, CA: Occupational Safety & Health Standards Board, Division of Occupational Safety and Health, California Department of Industrial Relations. Website accessed May 19, 2011. http://www.dir.ca.gov/oshsb/respiratorprotectionfactors0.html

Carman, G.E., Westlake, W.E. and Gunther, F.A. 1972. Potential residue problem associated with low volume sprays on citrus in California. Bulletin of Environmental Contamination and Toxicology 8:38-45.

Chaisson, C.F., Sielken, R.L. and Waylett, D.K. 1999. Overestimation bias and other pitfalls associated with the estimated 99.9th percentile in acute dietary exposure assessments. Regulatory Toxicology and Pharmacology 29:102-127.

Chang, S.K., Williams, P.L., Dauterman, W.C. and Riviere, J.E. 1994. Percutaneous absorption, dermatopharmacokinetics and related bio-transformation studies of carbaryl, lindane, malathion, and parathion in isolated perfused porcine skin. Toxicology 91:269-280.

Chapman, R.A. and Cole, C.M. 1982. Observations on the influence of water and soil pH on the persistence of insecticides. Journal of Environmental Science and Health B17:487-504.

Cheng, T. 1995. Dermal Absorption of ^{14}C-Carbaryl (XLR Plus) in Male Rats (Preliminary and Definitive Phases). Laboratory Project Identification HWI-6224-206. Unpublished study submitted by the Rhone-Poulenc, Research Triangle Park, NC. DPR Data Volume 169-386, Record No. 167057.

Chuzel, F. 1999. Carbaryl: 6-Month Carcinogenicity Study in p53 Knockout Mice by Dietary Administration: Lab Project Number: 604134. Unpublished study prepared by Rhone-Poulenc Agro. DPR Data Volume 169-398, Record No. 177755.

Clayton, M. 2005. 2005 Status Report Pesticide Contamination Prevention Act. Report No. EH05-07. Sacramento, CA: Environmental Monitoring Branch, Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/emon/pubs/ehapreps/eh0507.pdf

Comer, S.W., Staiff, D.C., Armstrong, J.F. and Wolfe, H.R. 1975. Exposure of workers to carbaryl. Bulletin of Environmental Contamination and Toxicology 13:385-391.

Creely, K.S. and Cherrie, J.W. 2001. A novel method of assessing the effectiveness of protective gloves—results from a pilot study. The Annals of Occupational Hygiene 45:137-143.

Currier, W.W., MacCollom, G.B. and Baumann, G.L. 1982. Drift residues of air-applied carbaryl in an orchard environment. Journal of Economic Entomology 75:1062-1068.

Dawson, B.J. 2001. Ground-Water Quality in the Southeastern Sacramento Valley Aquifer, California, 1996. U.S. Geological Survey Water Investigations Report 01-4125. Sacramento, CA: National Water Quality Assessment Program, U.S. Geological Survey. http://water.usgs.gov/pubs/wri/wri014125/

Dawson, J.L. 2003. Carbaryl: Revised HED Risk Assessment - Phase 5- Public Comment Period, Error Correction Comments Incorporated. March 14, 2003. DP Barcode D287532, PC Code 056801. Washington, DC: Health Effects Division, Office of Pesticide Programs, U.S. Environmental Protection Agency.

Dobozy, V.A. 2002. Carbaryl: Updated Toxicology Disciplinary Chapter for the Reregistration Eligibility Decision Document. May 24, 2002. PC Code 056801, DP Barcode D282980, Submission S615586, Case 818954. Washington, DC: Health Effects Division, Office of Pesticide Programs, U.S. Environmental Protection Agency.

Domagalski, J.L., Knifong, D.L., Dileanis, P.D., Brown, L.R., May, J.T., Connor, V. and Alpers, C.N. 2000. Water Quality in the Sacramento River Basin, California,1994–98. U.S. Geological Survey Circular 1215. Sacramento, CA: National Water Quality Assessment Program, U.S. Geological Survey. http://pubs.usgs.gov/circ/circ1215

Dong, M.H., Krieger, R.I., and Ross, J.H. 1992. Calculated reentry interval for table grape harvesters working in California vineyards treated with methomyl. Bulletin of Environmental Contamination and Toxicology 49:708-714.

DPR. 2001. Compliance Assessment Report Pesticide Handler and Field Worker Safety Survey. Sacramento, CA: Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/enforce/cmpasses.pdf

DPR. 2007. Summary of Pesticide Use Report Data 2006: Indexed by Chemical. Report dated November 2007. Sacramento, CA: Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/pur/pur06rep/chmrpt06.pdf

DPR. 2008. Summary of Pesticide Use Report Data 2007: Indexed by Chemical. Report dated December 2008. Sacramento, CA: Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/pur/pur07rep/chmrpt07.pdf

DPR. 2009. Summary of Pesticide Use Report Data 2008: Indexed by Chemical. Report dated November 2009. Sacramento, CA: Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/pur/pur08rep/chmrpt08.pdf

DPR. 2010. Summary of Pesticide Use Report Data 2009: Indexed by Chemical. Report dated December 2010. Sacramento, CA: Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/pur/pur09rep/chmrpt09.pdf

DPR. 2011a. Summary of Pesticide Use Report Data 2010: Indexed by Chemical. Report dated December 2011. Sacramento, CA: Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/pur/pur10rep/chmrpt10.pdf

DPR. 2011b. Report of Pesticides Sold in California: 2009. Sacramento, CA: Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/mlassess/nopdsold.htm

DPR. 20011c. Prioritization and Status of Active Ingredients for Risk Characterization: Report 52. Report dated July 15, 2011. Sacramento, CA: Department of Pesticide

Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/dept/prec/2011/prec_letter_report_52_20110916.pdf

DPR. 2012a. California Pesticide Information Portal (CalPIP), Pesticide Use Report database. Website accessed for database queries on several dates. Sacramento, CA: Department of Pesticide Regulation, California Environmental Protection Agency. http://calpip.cdpr.ca.gov/cfdocs/calpip/prod/main.cfm

DPR. 2012b. California Pesticide Illness Query (CalPIQ), Pesticide Illness Surveillance Program (PISP) database. Website accessed for database queries on multiple dates. Sacramento, CA: Department of Pesticide Regulation, California Environmental Protection Agency. http://apps.cdpr.ca.gov/calpiq

Durham W.F. and Wolfe, H.R. 1962. Measurement of the exposure of workers to pesticides. Bulletin of the WHO 26:75-91.

Edmiston, S., Cowan, C. and Welsh, A. 1999. California Farm Worker Activity Profile: A Database of Farm Worker Activity Demographics. Report No. HS-1751. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/whs/pdf/hs1751.pdf.

Edmiston, S., Powell, S., Spencer, J. and Curtis, C. 2002. Guidance for Determination of Dislodgeable Foliar Residue. Report No. HS-1600, Revision No. 1. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/whs/pdf/hs1600.pdf.

Ensminger M., Kelley, K. 2011a. Monitoring Urban Pesticide Runoff in California 2008 – 2009. Report 249. Sacramento, CA: Environmental Monitoring Branch, Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/emon/pubs/ehapreps/study_249_ensminger.pdf

Ensminger M., Kelley, K. 2011b. Monitoring Urban Pesticide Runoff in Northern California, 2009 – 2010. Report 264. Sacramento, CA: Environmental Monitoring Branch, Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/emon/pubs/ehapreps/report_264.pdf

Estesen, B.J., Buck, N.A. and Ware, G.W. 1982. Dislodgeable insecticide residues on cotton foliage: carbaryl, cypermethrin, and methamidophos. Bulletin of Environmental and Contamination Toxicology 28:490-493.

Fartasch, M. 1997. Ultrastructure of the epidermal barrier after irritation. Microscopy Research and Technique 37:193-199.

Feldmann, R.J. and Maibach, H.I. 1974. Percutaneous penetration of some pesticides and herbicides in man. Toxicology and Applied Pharmacology 28:126-132.

Finney, D.J. 1941. On the distribution of a variate whose logarithm is normally distributed. Supplement to the Journal of the Royal Statistical Society 7:155-161.

Frank, J.P. 2007. Method for Approximating Confidence Limits for Upper Bound and Mean Exposure Estimates from the Pesticide Handlers Exposure Database (PHED). Memo No. HSM-07005, dated September 20. Sacramento, CA: California Department of Pesticide Regulation, Worker Health and Safety Branch. http://www.cdpr.ca.gov/docs/whs/memo/hsm07005.pdf

Frank, J.P. 2008. Default Inhalation Retention/Absorption Values To Be Used For Estimating Exposure To Airborne Pesticides. Memo No. HSM-08011, dated December 31. Sacramento, CA: California Department of Pesticide Regulation, Worker Health and Safety Branch. http://www.cdpr.ca.gov/docs/whs/memo/hsm08011.pdf

Frank, J.P. 2009a. Method For Calculating Short-Term Exposure Estimates. Memo No. HSM-09004, dated February 13. Sacramento, CA: California Department of Pesticide Regulation, Worker Health and Safety Branch. http://www.cdpr.ca.gov/docs/whs/memo/hsm09004.pdf

Frank, J.P. 2009b. Exposure Assessment Policy and Procedure - Default Transfer Coefficients. Memo No. HSM-09005, dated February 17. Sacramento, CA: California Department of Pesticide Regulation, Worker Health and Safety Branch. http://www.cdpr.ca.gov/docs/whs/memo/hsm09005.pdf

Frank, J.P. 2009c. Letter to Jessica P. Ryman-Rasmussen, Ph.D., Toxicologist, Risk Assessment Branch IV, Health Effects Division, U.S. EPA Office of Pesticide Programs, from Joseph P. Frank, D.Sc., Senior Toxicologist, Worker Health and Safety Branch, California Department of Pesticide Regulation, dated August 18, 2009. Sacramento, CA: Department of Pesticide Regulation, California Environmental Protection Agency.

Froines, J.R. 2007. Findings of the Scientific Review Panel on the Proposed Identification of Methidathion as a Toxic Air Contaminant as Adopted at the Panel's January 11, 2007 Meeting. http://www.arb.ca.gov/srp/findings/1-11-07.pdf

Gee, J. 2002. Summary of Toxicology Data: Carbaryl. Sacramento, CA: Medical Toxicology Branch, Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/toxsums/pdfs/105.pdf

Gilliom, R.J., Barbash, J.E., Crawford, C.G., Hamilton, P.A., Martin, J.D., Nakagaki, N., Nowell, L.H., Scott, J.C., Stackelberg, P.E., Thelin, G.P. and Wolock, D.M. 2007. The Quality of Our Nation's Waters—Pesticides in the Nation's Streams and Ground Water, 1992–2001. U.S. Geological Survey Circular 1291. Reston, VA: U.S. Geological Survey. http://pubs.usgs.gov/circ/2005/1291

Grant, J.A., Johnson, R.S. and Vossen, P.M. 2006. UC IPM Pest Management Guidelines: Apple. Apple Thinning Sprays. UC ANR Publication 3432. Davis, CA: UC Cooperative Extension, Agriculture and Natural Resources, University of California – Davis. http://www.ipm.ucdavis.edu/PMG/r4900111.html

Ground Water Protection Unit. 2009. Sampling for Pesticide Residues in California Well Water: 2008 Update of the Well Inventory Database. Report No. WIR2008. Sacramento, CA: Environmental Monitoring Branch, Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/emon/pubs/ehapreps/eh2008.pdf

Ground Water Protection Unit. 2010. Sampling for Pesticide Residues in California Well Water: 2009 Update of the Well Inventory Database. Report No. WIR2009. Sacramento, CA: Environmental Monitoring Branch, Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/emon/pubs/ehapreps/eh2009.pdf

Ground Water Protection Unit. 2011. Sampling for Pesticide Residues in California Well Water: 2010 Update of the Well Inventory Database. Report No. WIR2010. Sacramento, CA: Environmental Monitoring Branch, Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/emon/pubs/ehapreps/eh2010.pdf

Grover, R., Cessna, A.J., Muir, N.I., Riedel, D., Franklin, C.A. and Yoshida, K. 1986. Factors affecting the exposure of ground-rig applicators to 2,4-D dimethylamine salt. Archives of Environmental Contamination and Toxicology 15:677-686.

Gunasekara, A.S. 2007. Environmental Fate of Carbaryl. Sacramento, CA: Environmental Monitoring Branch, Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/emon/pubs/fatememo/carbaryl2007.pdf

Gunasekara, A.S., Rubin, A.L., Goh, K.S., Spurlock, F.C. and Tjeerdema, R.S. 2008. Environmental fate and toxicology of carbaryl. Reviews of Environmental and Contamination Toxicology 196:95-121.

Guo, L. 2000. Recommendation for Priority Surface Water Monitoring Studies on Selected Pesticides. Memorandum dated August 2. Sacramento, CA: Environmental Monitoring Branch, Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/emon/pubs/ehapreps/m080200.pdf

Hahn, G.J. and Meeker, W.Q. 1991. Statistical Intervals: A Guide for Practitioners. New York, John Wiley & Sons, Inc.

Harkness, J.E. and Wagner, J.E. 1989. The Biology and Medicine of Rabbits and Rodents, 3rd Edition. Lea and Febiger, Philadelphia (cited in: “Biomethodology of the Mouse,” online training by the University of Iowa Institutional Animal Care and Use Committee at http://research.uiowa.edu/animal/?get=mouse. Website accessed December 23, 2010).

Haskell, D.E. 1998. Canada-United States Trade Agreement (CUSTA) Working Group, Final Draft of Position Paper for Issue Eight: Typical Workdays for Various Crops. Memo No. HSM-980001. Sacramento, CA: California Department of Pesticide Regulation, Worker Health and Safety Branch. http://www.cdpr.ca.gov/docs/whs/memo/hsm98001.pdf

Hecht, S.S. 2002. Human urinary carcinogen metabolites: biomarkers for investigating tobacco and cancer. Carcinogenesis 23:907-922.

Heitbrink, W.A., Moyer, E.S., Jensen, P.A., Watkins, D.S. and Martin, S.B. Jr. 2003. Environmental agricultural tractor cab filter efficiency and field evaluation. American Industrial Hygiene Association Journal 64:394-400.

Hernandez, B.Z., Spencer, J., Schneider, F., Welsh, A and Fredrickson, S. 1998. A Survey of Dislodgeable Pesticide Residues on Crop Foliage at Field Reentry, 1994-1995. Report No. HS-1728. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/whs/pdf/hs1728.pdf.

Hernandez, B.Z., Spencer, J., Schneider, F., Welsh, A and Fredrickson, S. 2002. A Summary of Dislodgeable Foliar Pesticide Residues at Expiration of the Restricted Entry Interval. Report No. HS-1784. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/whs/pdf/hs1784.pdf

Hines, C.J., Deddens, J.A., Tucker, S.P. and Hornung, R.W. 2001. Distributions and determinants of pre-emergent herbicide exposures among custom applicators. Annals of Occupational Hygiene 45:227-239.

Hwang, S.W. and Schanker, L.S. 1974. Absorption of carbaryl from the lung and small intestine of the rat. Environmental Research 7:206-211.

Iwata, Y., Knaak, J.B., Spear, R.B. and Foster, R.J. 1977. Worker reentry into pesticide treated crops. I. Procedure for the determination of dislodgeable pesticide residues on foliage. Bulletin of Environmental and Contamination Toxicology 18:649.

Iwata, Y., Dusch, M.E., Carman, G.E. and Gunther, F.A. 1979. Worker environment research: Residues from carbaryl, chlorbenzilate, dimethoate, trichlorfon applied to citrus. Journal of Agricultural and Food Chemistry 27:1127-1141.

Kline, A.A., Landers, A.J., Hedge, A., Lemley, A.T., Obendorf, S.K. and Dokuchayeva, T. 2003. Pesticide exposure levels on surfaces within sprayer cabs. Applied Engineering in Agriculture 19:397-403.

Klonne, D. and Honeycutt, R. 1999. A Generic Evaluation of Homeowner Exposure Associated with Granular Turf Pesticide Handling and Application to Residential Lawns. Unpublished study submitted by the Outdoor Residential Exposure Task Force. ORETF Study No. OMA003. DPR Data Volume 142-0207, Record No. 183473.

Klonne, D.R., Artz, S.C., Prochaska, C. and Rotondaro, A. 1999a. Determination of Dermal and Inhalation Exposure to Reentry Workers During Harvesting in Tobacco. Unpublished study submitted by the Agricultural Reentry Task Force. ARTF Study No. ARF024. DPR Data Volume 52062-313, Record No. 175982.

Klonne, D.R., Bruce, E.D., Artz, S.C. and Howell, C. 1999b. Determination of Dermal and Inhalation Exposure to Reentry Workers During scouting in Sunflower. Unpublished study submitted by the Agricultural Reentry Task Force. ARTF Study No. ARF022. DPR Data Volume 52062-311, Record No. 175980.

Klonne, D.R. and Merricks, D.L. 2000. Determination of Dermal and Inhalation Exposure to Reentry Workers During Harvest in Juice Oranges. Unpublished study submitted by the Agricultural Reentry Task Force. ARTF Study No. ARF041. DPR Data Volume 50366-173, Record No. 181583.

Klonne, D., Fuller, R. and Honeycutt, R. 2000a. Determination of Dermal and Inhalation Exposure to Reentry Workers During Pruning of Olive Trees. Unpublished study submitted by the Agricultural Reentry Task Force. ARTF Study No. ARF033. DPR Data Volume 50317-256, Record No. 176446.

Klonne, D., Fuller, R. and Merricks, D. 2000b. Determination of Dermal and Inhalation Exposure to Reentry Workers During Harvesting in Juice Grapefruit. Unpublished study submitted by the Agricultural Reentry Task Force. ARTF Study No. ARF042. DPR Data Volume 50366-174, Record No. 181584.

Klonne, D.R., Fuller, R. and Belcher, T. 2000c. Determination of Dermal and Inhalation Exposure to Reentry Workers During Weeding in Cabbage. Unpublished study submitted by the Agricultural Reentry Task Force. ARTF Study No. ARF037. DPR Data Volume 169-394, Record No. 176828.

Klonne, D.R., Fuller, R. and Howell, C. 2000d. Determination of Dermal and Inhalation Exposure to Reentry Workers During Harvesting in Nursery Stock. Unpublished study submitted by the Agricultural Reentry Task Force. ARTF Study No. ARF044. DPR Data Volume 50366-176, Record No. 181586.

Klonne, D.R., Fuller, R. and Lange, B. 2001a. Determination of Dermal and Inhalation Exposure to Reentry Workers During Harvesting in Cabbage. Unpublished study submitted by the Agricultural Reentry Task Force. ARTF Study No. ARF050. DPR Data Volume 275-374, Record No. 184096.

Klonne, D.R., Fuller, R. and Rotondaro, A. 2001b. Determination of Dermal and Inhalation Exposure to Reentry Workers During Harvesting in Cucumbers. Unpublished study submitted by the Agricultural Reentry Task Force. ARTF Study No. ARF045. DPR Data Volume 50723-014, Record No. 182763.

Klonne, D.R., Fuller, R. and Willard, T. 2001c. Determination of Dermal and Inhalation Exposure to Reentry Workers During Hand Pruning in Apples. Unpublished study submitted by the Agricultural Reentry Task Force. ARTF Study No. ARF047. DPR Data Volume 50723-015, Record No. 182764.

Klonne, D.R. and Bruce, E.D. 2005. Determination of Dermal and Inhalation Exposure to Reentry Workers During Maintenance Activities in Golf Courses. Unpublished study submitted by the Agricultural Reentry Task Force. ARTF Study No. ARF057. DPR Data Volume 275-443, Record No. 222217.

Knaak, J.B., Tallant, M.J., Kobzelt, S.J. and Sullivan, L.J. 1968. The metabolism of carbaryl in man, monkey, pig and sheep. Journal of Agricultural and Food Chemistry 16:465-470.

Knaak, J.B., Yee, K., Ackerman, C.R., Zweig, G., Fry, D.M. and Wilson, B.W. 1984. Percutaneous absorption and dermal dose-cholinesterase response studies with parathion and carbaryl in the rat. Toxicology and Applied Pharmacology 76:252-263.

Krolski, M.E. 2005. Sevin 2G – Determination of Transferable Residues from Turf. Unpublished study submitted by Bayer CropScience LP, conducted by Bayer CropScience, Grayson Research LLC, and ABC Laboratories, Inc. Bayer Study No. CA25TF01, Bayer PSI/Report No. RACAX015. DPR Data Volume 169-0471, Record No. 220612.

Krueger, W.H., Klonsky, K.M. and De Moura, R.L. 2011. Sample Costs to Establish a High Density Olive Orchard and Produce Table Olives: Sacramento Valley. UC ANR Publication OL-SV-11. Davis, CA: UC Cooperative Extension, Agriculture and Natural Resources, University of California. http://coststudies.ucdavis.edu/files/OliveTableSV2011.pdf

Kurtz, D.A. and Bode, W.M. 1985. Application exposure to the home gardener. In: Dermal Exposure Related to Pesticide Use, edited by R.C. Honeycutt, G. Zweig and N.N. Ragsdale. ACS Symposium Series 273. Washington, DC: American Chemical Society, pages 139-161.

Lavy, T.L., Mattice, J.D., Massey, J.H. and Skulman, B.W. 1993. Measurements of year-long exposure to tree nursery workers using multiple pesticides. Archives of Environmental and Contamination Toxicology 24:123-144.

Layton, D.W. 1993. Metabolically consistent breathing rates for use in dose assessments. Health Physics 64:23-36.

Leavitt, J.R.C., Gold, R.E., Holcslaw, T. and Tupy, D. 1982. Exposure of professional applicators to carbaryl. Archives of Environmental and Contamination Toxicology 11:57-62.

Leonard, J.A. and Yeary, R.A. 1990. Exposure of workers using hand-held equipment during urban application of pesticides to trees and ornamental shrubs. American Industrial Hygiene Association Journal 51:605-609.

Lunchick, C. 2002. Assessment of Carbaryl Residential Use Patterns Using the Residential Exposure Joint Ventures Database. Unpublished report submitted by Aventis CropScience, dated May 30, 2002. DPR Data Volume 169-417, Record No. 187710.

MacCollom, G.B., Currier, W.W. and Baumann, G.L. 1985. Pesticide drift and quantification from air and ground applications to a single orchard site. In: Dermal Exposure Related to Pesticide Use - Discussion of Risk Assessment, edited by R.C. Honeycutt, G. Zweig and N.N. Ragsdale. Washington, DC: American Chemical Society, pages 189-199.

MacCollom, G.B., Currier, W.W. and Baumann, G.L. 1986. Drift comparisons between aerial and ground orchard application. Journal of Economic Entomology 79:459-464.

MacPherson, S.E., Scott, R.C. and Williams, F.M. 1991. Fate of carbaryl in rat skin. Archives of Toxicology 65:594-598.

Majewski, M.S. and Baston, D.S. 2002. Atmospheric Transport of Pesticides in the Sacramento, California, Metropolitan Area, 1996 – 1997. Water Resources Investigations Report 02-4100. Sacramento, CA: National Water Quality Assessment Program, U.S. Geological Survey. http://pubs.usgs.gov/wri/wri024100/wri02-4100.pdf

Mehler, L. 2011. Case Reports Received by the California Pesticide Illness Surveillance Program, 1992 – 2008 in Which Health Effects Were Evaluated as Definitely, Probably, or Possibly Related to Exposure to Carbaryl, Alone or in Combination. Pesticide Illness Surveillance Program custom database query on January 6, 2011, Worker Health and Safety Branch, Department of Pesticide Regulation, California Environmental Protection Agency.

Merricks, D.L. 1997. Carbaryl Mixer/Loader/Applicator Exposure Study during Application of RP-2 Liquid (21%) Sevin Ready to Use Insect Spray or Sevin 10 Dust to Home Garden Vegetables. Unpublished study conducted by Agrisearch Incorporated, Rhone Poulenc Agricultural Company and Morse Laboratories Incorporated. DPR Document Number 169-481, Record No. 228571.

Merricks, D.L. 2000. Determination of Dermal and Inhalation Exposure to Reentry Workers During Harvesting in Sod. Unpublished study submitted by the Agricultural Reentry Task Force. ARTF Study No. ARF035. DPR Data Volume 50366-177, Record No. 181587.

Mester, T.C. 1999. Carbaryl: Determination of Transferable Residues from Turf Treated with Dragon(R) Sevin(R) Liquid. Study No. 98S15602. Unpublished study submitted by the Rhone-Poulenc Ag Company. DPR Volume Number 169-392, Record No. 174883.

Moody, R.P. and Nadeau, B. 1994. Nitrile butyl rubber glove permeation of pesticide formulations containing 2,4-D-amine, DDT, DEET, and Diazinon. Bulletin of Environmental Contamination and Toxicology 52:125-130.

NLM. 2011. Hazardous Substances Data Bank (HSDB). Bethesda, MD: U.S. National Library of Medicine, National Institutes of Health, Health & Human Services. Database accessed December 24, 2010. http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB.htm

Neher, L.A., Segawa, R.T. and Oshima, R.J. 1982. Monitoring of the 1982 Gypsy Moth Eradication Ground Spray Program in Santa Barbara County. Report No. 82-02. Sacramento, California: Environmental Monitoring and Pest Management Branch, Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/emon/pubs/ehapreps/eh8202.pdf

Nigg, H.N., Stamper, J.H. and Knaak, J.B. 1984a. Leaf, fruit and soil surface residues of carbosulfan and its metabolites in Florida citrus groves. Journal of Agricultural And Food Chemistry 32:80-84.

Nigg, H.N., Stamper, J.H. and Queen, R.M. 1984. The development and use of a universal model to predict tree crop harvester pesticide exposure. American Industrial Hygiene Association Journal 45:182-186.

Nordmark, C., Dias, J., Clayton, M., Troiano, J. and Pepple, M. 2006. Sampling for Pesticide Residues in California Well Water: 2006 Update of the Well Inventory Database. Report No. EH06-05. Sacramento, CA: Environmental Monitoring Branch, Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/emon/pubs/ehapreps/eh0605.pdf

Nordmark, C., Dias, J., Clayton, M., Troiano, J. and Pepple, M. 2008. Sampling for Pesticide Residues in California Well Water: 2007 Update of the Well Inventory Database. Report No. EH08-01. Sacramento, CA: Environmental Monitoring Branch, Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/emon/pubs/ehapreps/eh0801.pdf

O'Brien, R.D. and Dannelley, C.E. 1965. Penetration of insecticides through rat skin. Journal of Agricultural and Food Chemistry 13:245-247.

O'Connell, L., Margetich, S. and Edmiston, S. 1993. Worker Exposure to Captan Residues While Performing Cultural Activities on Table Grapes. Report no. HS-1522. Sacramento, California: Worker Health and Safety Branch, Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/whs/pdf/hs1522.pdf

O'Connell, N.V., Ferguson, L., Freeman, M.W., Klonsky, K.M. and Livingston, P. 2005. Sample Costs to Establish and Produce Table Olives, Manzanillo Variety: San Joaquin Valley – Micro-Sprinkler Irrigation. UC ANR Publication OL-SJ-05. Davis, CA: UC Cooperative Extension, Agriculture and Natural Resources, University of California. http://coststudies.ucdavis.edu/files/olivetblsjv2005.pdf

O'Connell, N.V., Kallsen, C.E., Klonsky, K.M. and De Moura, R.L. 2009. Samples Costs to Establish an Orange Orchard and Produce Oranges: Navel & Valencias, San Joaquin Valley – South, Low Volume Irrigation. Publication OR-VS-09. Davis, CA: UC Cooperative Extension, Agriculture and Natural Resources, University of California – Davis. http://coststudies.ucdavis.edu/files/orangevs2009.pdf

OEHHA. 2000. Air Toxics Hot Spots Program Part IV: Technical support document. Exposure assessment and stochastic analysis. Scientific Review Panel Draft. Sacramento, CA:. Office of Environmental Health Hazard Assessment, California Environmental Protection Agency. http://www.oehha.ca.gov/air/hot_spots/finalStoc.html#download

Petropoulou, S.S., Gikas, E., Tsarbopoulos, A. and Siskos, P.A. 2006. Gas chromatographic-tandem mass spectrometric method for the quantitation of carbofuran, carbaryl and their main metabolites in applicators' urine. Journal of Chromatography A 1108:99-110.

PHED. 1995. The Pesticide Handlers Exposure Database, Version 1.1. Prepared for the PHED Task Force representing Health and Welfare Canada, U.S. Environmental Protection Agency, and the National Agricultural Chemicals Association; prepared by Versar, Inc., 6850 Versar Center, Springfield, VA 22151.

PMRA. 2009. Proposed Re-evaluation Decision: Carbaryl. PRVD2009-14. Ottawa, Ontario: Health Canada Pest Management Regulatory Agency. http://publications.gc.ca/collections/collection_2010/arla-pmra/H113-27-2009-14-eng.pdf

Powell, S. 1991. Implementation in the SAS System of the Bradu and Mundlak minimum variance unbiased estimator of the mean of a lognormal distribution. In: Proceedings of the 16th Annual SAS Users Group International Conference. Cary, NC: SAS Institute, Inc., pages 1467-1471. http://www.sascommunity.org/sugi/SUGI91/Sugi-91-264%20Powell.pdf

Powell, S. 2003. Why Worker Health And Safety Branch Uses Arithmetic Means in Exposure Assessment. HSM-03022, dated September 22. Sacramento, CA: California Department of Pesticide Regulation, Worker Health and Safety Branch. http://www.cdpr.ca.gov/docs/whs/memo/hsm03022.pdf

Powell, S. 2007. Recommended Method for Approximating Confidence Limits for Upper Bound and Mean Exposure Estimates from the Pesticide Handlers Exposure Database (PHED) to Replace the Method of HSM-02037. Memo No. HSM-07004. Sacramento, CA: Worker Health and Safety Branch, California Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/whs/memo/hsm07004.pdf

Putnam, R.A., Doherty, J.J. and Clark, J.M. 2008. Golfer exposure to chlorpyrifos and carbaryl following application to turfgrass. Journal of Agricultural and Food Chemistry 56:6616-6622.

Rech, C., Bissell, S. and Margetich. S. 1989. Worker Exposure to Chlorothalonil Residues During the Harvest of Fresh Market Pole Tomatoes. Report no. HS-1456. Sacramento, California: Worker Health and Safety Branch, Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/whs/pdf/hs1456.pdf

Rice, F. and Grant, J. 2003. Measurement of Pesticide Exposure of Suburban Residents Associated with the Residential Use of Carbaryl. Unpublished study submitted by Bayer CropScience, Research Triangle Park, NC. Bayer CropScience Report Number B004255. MRID 45897401. DPR Data Volume 169-478, Record 228568.

Rosenheck, L. and Sanchez, S.E. 1995. Evaluation of Turf Re-entry Exposure to a Broadcast Application of Ronstar® 50WP. Unpublished study submitted by Rhone-Poulenc Ag Company and conducted by Pan-Agricultural Labs, Inc. Pan-Ag Study No. 93293. DPR Data Volume 169-382, Record No. 166124.

Ross, L.J., Stein, R., Hsu, J., White, J. and Hefner, K. 1996. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Winter 1991-92 and 1992-93. Report No. EH 96-02. Sacramento, CA: Environmental Monitoring and Pest Management Branch, California Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/emon/pubs/ehapreps/eh9602.pdf

Rubin, A. 2012. Carbaryl (1-Naphthyl Methylcarbamate) Risk Characterization Document. Sacramento, CA: Medical Toxicology Branch, Department of Pesticide Regulation, California Environmental Protection Agency.

Rutz, R. 1997. A History of the Listing of Pesticides as Restricted Materials in California. Report No. HS-1669. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/whs/pdf/hs1669.pdf

Scheuplein, R.J. and Ross, L.W. 1970. Effects of surfactants and solvents on the permeability of epidermis. Journal of Society of Cosmetic Chemists 21:853–873.

Schuette, J., Weaver, D., Troiano, J., Pepple, M. and Dias, J. 2003. Sampling for Pesticide Residues in California Well Water: 2003 Well Inventory Database, Cumulative Report 1986-2003. Report No. EH03-08. Sacramento, CA: Environmental Monitoring Branch, Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/emon/pubs/ehapreps/eh0308.pdf

Schuette, J., Troiano, J. and Pepple, M. 2005. 2005 Update of the Well Inventory Database. Report No. EH05-06. Sacramento, CA: Environmental Monitoring Branch, Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/emon/pubs/ehapreps/eh0506.pdf

Segawa, R.T. 1988. Monitoring the Pesticide Treatments of the Japanese Beetle Eradication Project, Sacramento County, California, 1983 – 1986. Volume I: Carbaryl. Memo dated December 23. Sacramento, California: Environmental Monitoring and Pest Management Branch, Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/emon/pubs/ehapreps/eh8813.pdf.

Segawa, R.T., Weaver, D., Sava, R., Marade, J. and Oshima, R. 1982. Helicopter Spray Trial with Sevin XLR (Carbaryl), Tulare County, 1982. Report No. 82-04. Sacramento, California: Environmental Monitoring and Pest Management Branch, Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/emon/pubs/ehapreps/eh8204.pdf.

Shah, P.V. 2007. Carbaryl: Review of in vitro Dermal Absorption Study (MRID 47151902). PC Code 056801, DP Bar Code # D340148. Washington, DC: Health Effects Division, Office of Prevention, Pesticides, and Toxic Substances, U.S. Environmental Protection Agency.

Shah, P.V., Monroe, R.J. and Guthrie, F.E. 1981. Comparative rates of dermal penetration of insecticides in mice. Toxicology and Applied Pharmacology 59:414-423.

Shah, P.V. and Guthrie, F.E. 1983. Percutaneous penetration of three insecticides in rats: a comparison of two methods for *in vivo* determination. The Journal of Investigative Dermatology 80:291-293.

Shah, P.V., Fisher, H.L., Sumler, M.R., Monroe, R.J., Chernoff, N. and Hall, L.L. 1987. Comparison of the penetration of 14 pesticides through the skin of young and adult rats. Journal of Toxicology and Environmental Health 21:353-366.

Shealey, D.B., Barr, J.R., Ashley, D.G., Patterson, D.G., Jr., Camann, D.E. and Bond, A.E. 1997. Correlation of environmental carbaryl measurements with serum and urinary 1-naphthol measurements in a farmer applicator and his family. Environmental Health Perspectives 105:510-513.

Siepmann, S. and Jones, M.R. 1998. Hazard Assessment of the Insecticide Carbaryl to Aquatic Organisms in the Sacramento-San Joaquin River System. Administrative Report No. 98-1. Rancho Cordova, CA: California Department of Fish and Game, Office of Spill Prevention and Response. http://www.cdpr.ca.gov/docs/sw/hazasm/hazasm98_1.pdf.

Simpson, G.R. 1965. Exposure to orchard pesticides. Archives of Environmental Health 10:884-885.

Smegal, D., Dawson, J. and Evans, J. 2001. Recommended Revisions to the Standard Operating Procedures (SOPs) for Residential Exposure Assessments. Policy 12. Science Advisory Council for Exposure. Revised February 22, 2001.

Smith, L.D. 2005. Determination of Dermal and Inhalation Exposure to Workers During Application of a Liquid Pesticide Product by Open Cab Airblast Application to Orchard Crops. Study Number AHE07, report dated August 23. Unpublished study submitted by Agricultural Handlers Exposure Task Force. DPR Data Volume 108-340, Record No. 219609.

Spencer, W.F., Shoup, T.D., Cliath, M.M., Farmer, W.J. and Haque, R. 1979. Vapor pressures and relative volatility of ethyl and methyl parathion. Journal of Agricultural and Food Chemistry 27:273-278.

Stanley, J.G. and Trial, J.G. 1980. Disappearance constants of carbaryl from streams contaminated by forest spraying. Bulletin of Environmental Contamination and Toxicology 25:771-776.

Starner, K. 2007. Assessment of Acute Aquatic Toxicity of Current-Use Pesticides in California, with Monitoring Recommendations. Memorandum to Kean S. Goh, Ph.D., Environmental Program Manager (Supervisor) I, Environmental Monitoring Branch, from Keith Starner, Environmental Scientist, Environmental Monitoring Branch, Department of Pesticide Regulation, dated October 26. Sacramento, CA: Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/emon/surfwtr/policies/starner_sw01.pdf

Starner, K., Kuivila, K.M., Jennings, B. and Moon, G.E. 1999. Degradation rates of six pesticides in water from the Sacramento River, California. Proceedings of the Technical Meeting Charleston South Carolina March 8-12, 1999. Volume 2 of 3. Contamination of Hydrologic Systems and Related Ecosystems, Water-Resources Investigations Report 99-4018B. U.S. Geological Survey Toxic Substances Hydrology Program. http://wwwrcamnl.wr.usgs.gov/tracel/references/pdf/CA-0216.pdf

SDTF. 1997. A Summary of Airblast Application Studies. Spray Drift Task Force. Stewart Agricultural Research Services, Inc. Macon, MO. http://www.agdrift.com/PDF_FILES/airblast.pdf

Stanford. 1988. Illustrated Guide on How to Work with Corn. June 1988. Stanford University. http://www.stanford.edu/~walbot/methods/corn_guide.pdf

Stewart, P.A., Fears, T., Kross, B., Ogilvie, L. and Blair, A. 1999. Exposure of farmers to phosmet, a swine insecticide. Scandinavian Journal of Work, Environment & Health 25:33-38.

Thompson, R. 1998. Agricultural Worker Contact from Reentry Activities Performed in the United States and Canada: Grower Results. Unpublished study submitted by the Agricultural Reentry Task Force. Performed by Doane Marketing Research, Inc., St. Louis, MO. DPR Volume Number 52062-314, Record No. 175983.

Thongsinthusak, T., Brodberg, R. K., Ross, J. H., Gibbons, D. and Krieger, R. I. 1991. Reduction of Pesticide Exposure by Using Protective Clothing and Enclosed Cabs. HS-1616. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/whs/pdf/hs1616.pdf

Thongsinthusak, T., Ross, J. and Meinders, D. 1993. Guidance for the Preparation of Human Pesticide Exposure Assessments. Report no. HS-1612. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/whs/pdf/hs1612.pdf

Thongsinthusak, T., Ross, J.H. and Dong, M.H. 1999. Significance of dermal dose levels in dermal absorption studies of pesticides. Report No. HS-1801. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/whs/pdf/hs1801.pdf

Tos-Luty, S., Przebirowska, D., Latuszynska, J. and Tokarska-Rodak, M. 2001. Histological and ultrastructural studies of rats exposed to carbaryl. Annals of Agricultural and Environmental Medicine 8:137-144.

Troiano, J., Weaver, D., Marade, J., Spurlock, F., Pepple, M., Nordmark, C. and Bartkowiak, D. 2001. Summary of well water sampling in California to detect pesticide residues resulting from nonpoint-source applications. Journal of Environmental Quality 30:448-459.

UCCE. 2012. Available Cost and Return Studies. Davis, CA: Department of Agricultural and Resource Economics, University of California Cooperative Extension. Website accessed for crop-specific information on several dates. http://www.agecon.ucdavis.edu/outreach/crop/cost.htm

USDA. 1999. Crop Profile for Apples in California. National Institute of Food and Agriculture, U.S. Department of Agriculture. http://www.ipmcenters.org/cropprofiles/docs/caapples.pdf

USDA. 2002. Rangeland Grasshopper and Mormon Cricket Suppression Program. Final Environmental Impact Statement - 2002. Animal and Plant Health Inspection Service, U.S. Department of Agriculture. http://www.sidney.ars.usda.gov/grasshopper/Research/fgheis2.pdf

U.S. EPA. 1992. Dermal Exposure Assessment: Principles and Applications. EPA/600/8-91/011B. Washington, DC: Office of Health and Environmental Assessment, U.S. Environmental Protection Agency. http://www.epa.gov/oppt/exposure/presentations/efast/usepa_1992d_dermalea.pdf

U.S. EPA. 1996. Occupational and Residential Exposure Test Guidelines. OPPTS 875.2100: Foliar Dislodgeable Residue. 712-C-96-267. Washington, DC: Office of Prevention, Pesticides and Toxic Substances, U.S. Environmental Protection Agency. http://www.epa.gov/ocspp/pubs/frs/publications/Test_Guidelines/series875.htm

U.S. EPA. 1997a. Exposure Factors Handbook. EPA/600/P-95/002Fa. Washington, DC: Office of Research and Development, U.S. Environmental Protection Agency. http://www.epa.gov/ncea/pdfs/efh/front.pdf

U.S. EPA. 1997b. Standard Operating Procedures (SOPs) for Residential Exposure Assessments (Draft dated 12/17/97). Contract No. 68-W6-0030, Work Assignment No. 338102. Residential Exposure Assessment Work Group, including Office of Pesticide Programs, Health Effects Division and Versar, Inc. Washington, DC: Office of Pesticide Programs, U.S. Environmental Protection Agency and Office of Science Coordination and Policy. http://www.epa.gov/oppfead1/trac/science/trac6a05.pdf

U.S. EPA. 1997c. Annual Spray Drift Review. Report of Peer Review Panel findings. Washington, DC: Office of Pesticide Programs, Environmental Fate and Effects Division, U.S. Environmental Protection Agency. http://www.epa.gov/scipoly/sap/meetings/1997/december/spraydrift.htm

U.S. EPA. 1998a. Health Effects Test Guidelines. OPPTS 870.7600: Dermal Penetration. EPA 712-C-98-350. Washington, DC: Office of Prevention, Pesticides and Toxic Substances, U.S. Environmental Protection Agency. http://www.epa.gov/ocspp/pubs/frs/publications/Test_Guidelines/series870.htm

U.S. EPA. 1998b. PHED Surrogate Exposure Guide. Estimates of Worker Exposure from the Pesticide Handler Exposure Database, Version 1.1. Washington, DC: Office of Prevention, Pesticides and Toxic Substances, U.S. Environmental Protection Agency. http://www.epa.gov/pesticides/science/phedsur-expo-guide.pdf

U.S. EPA. 1999. Use of Values from the PHED Surrogate Table and Chemical-Specific Data, Policy Number 007. Science Advisory Council for Exposure. Dated March 11. Washington, DC: Office of Pesticide Programs, Health Effects Division, U.S. Environmental Protection Agency.

U.S. EPA. 2000. Agricultural Transfer Coefficients. Policy Number 003.1. Science Advisory Council for Exposure. Revised August 7. Washington, DC: Office of Pesticide Programs, Health Effects Division, U.S. Environmental Protection Agency

U.S. EPA. 2001. Standard Values for Daily Acres Treated in Agriculture. Policy Number 009.1, Science Advisory Council for Exposure. Revised September 25.

U.S. EPA. 2003. User's Manual: Swimmer Exposure Assessment Model (SWIMODEL) Version 3.0. Washington, DC: Office of Pesticide Programs, Antimicrobials Division, U.S. Environmental Protection Agency. http://www.epa.gov/oppad001/swimodelusersguide.pdf

U.S. EPA. 2004. Risk Assessment Guidance for Superfund (RAGS), Volume 1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment). July 2004. Washington, DC: Office of Superfund Remediation and Technology Innovation, U.S. Environmental Protection Agency. http://www.epa.gov/oswer/riskassessment/ragse/pdf/part_e_final_revision_10-03-07.pdf

U.S. EPA. 2007. Revised N-Methyl Carbamate Cumulative Risk Assessment. Revised September 24, 2007. Washington, DC: Office of Pesticide Programs, U.S. Environmental Protection Agency. http://www.epa.gov/oppsrrd1/REDs/nmc_revised_cra.pdf

U.S. EPA. 2008. Amended Reregistration Eligibility Decision (RED) for Carbaryl. EPA-738-R-08-010. Revised August 2008. Washington, DC: Office of Prevention, Pesticides and Toxic Substances, U.S. Environmental Protection Agency. http://www.epa.gov/oppsrrd1/REDs/carbaryl-red-amended.pdf

U.S. EPA. 2010. Carbaryl Summary Document. Registration Review: Initial Docket. Case #0080. Docket Number EPA-HQ-OPP-2010-0230. Washington, DC: Pesticide Re-evaluation Division, U.S. Environmental Protection Agency. http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2010-0230-0003

Vercruysse, F., Drieghe, S., Steurbaut, W. and Dejonckeere. 1999. Exposure assessment of professional pesticide users during treatment of potato fields. Pesticide Science 55:467-473.

Versar. 1992. PHED: The Pesticide Handlers Exposure Database Reference Manual. Prepared for the PHED Task Force: Health and Welfare Canada, U. S. Environmental

Protection Agency, National Agricultural Chemicals Association. Springfield, VA: Versar, Inc.

Vinlove, F. and Torla, R. 1995. Comprehensive estimation of U.S. home lawn area. Journal of Turfgrass Management 1:83-97.

Vogel, J.R., Majewski, M.S. and Capel, P.D. 2008. Pesticides in rain in four agricultural watersheds in the United States. Journal of Environmental Quality 37:1101-1115.

Waldron, A. 1985. The potential for applicator-worker exposure to pesticides in greenhouse operations. In: Dermal Exposure Related to Pesticide Use, edited by R.C. Honeycutt, G. Zweig and N.N. Ragsdale. ACS Symposium Series 273. American Chemical Society, Washington DC, pages 311-319.

Walters, J., Goh, K.S., Li, L., Feng, H., Hernandez, J. and White, J. 2003. Environmental monitoring of carbaryl applied in urban areas to control the glassy-winged sharpshooter in California. Environmental Monitoring and Assessment 82:265-280.

Ware, G.W., Esteson, B. and Cahill, W.P. 1978. Dislodgeable insecticide residues on cotton (1975). Bulletin of Environmental Contamination and Toxicology 20:17-19.

Weaver, D., Johnson, W.C. and Oshima, R.J. 1982. Helicopter Spray Trial with Carbaryl (XLR). Report No. 82-03. Sacramento, CA: Environmental Monitoring and Pest Management Branch, Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/emon/pubs/ehapreps/eh8203.pdf.

Weaver, D., Zalkin,F., Segawa, R.T., Sava, R., Wilkerson, M.R., Franz, J.R., Duncan, D. and Simpson, S. 1983. Monitoring of the 1983 Gypsy Moth Eradication Ground Spray Program in Six California Counties. Report No. 83-03. Sacramento, CA: Environmental Monitoring and Pest Management Branch, Department of Pesticide Regulation. http://www.cdpr.ca.gov/docs/emon/pubs/ehapreps/eh8303.pdf.

WHS. 2007. Summary of Results from the California Pesticide Illness Surveillance Program, 2005. Report No. HS-1869. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide Regulation, California Environmental Protection Agency. http://www.cdpr.ca.gov/docs/whs/pdf/hs1869.pdf

Wiley, J.A., Robinson, J.P., Piazza, T., Garrett, K., Cirksena, K., Cheng, Y.T. and Martin, G. 1991. Activity Patterns of California Residents. Contract No. A6-177-33. Final Report. Sacramento, CA: Air Resources Board, Research Division, California Environmental Protection Agency. http://arb.ca.gov/research/apr/past/a6-177-33.pdf

Wofford, P. and C. Ando. 2003. Preliminary Methyl Parathion Air Concentrations Measured Adjacent to Two Walnut Orchard Applications. Memorandum dated September 25, 2003 to Randy Segawa, Senior Environmental Research Scientist. Sacramento, CA: Environmental Monitoring Branch, Department of Pesticide Regulation, California

Environmental Protection Agency.
http://www.cdpr.ca.gov/docs/emon/pubs/tac/tacpdfs/methpara03.pdf

Woollen, B.H. 1993. Biological monitoring for pesticide absorption. The Annals of Occupational Hygiene 37:525-540.

Zweig, G., Gao, R.-Y., Witt, J.M., Popendorf, W. and Bogen. K. 1984. Dermal exposure to carbaryl by strawberry harvesters. Journal of Agricultural and Food Chemistry 32:1232-1236.

Zweig, G., Leffingwell, J.T. and Popendorf, W. 1985. The relationship between dermal pesticide exposure by fruit harvesters and dislodgeable foliar residues. Journal of Environmental Science and Health B20:27-59.

APPENDIX 1: OCCUPATIONAL REENTRY SCENARIOS TABLE FOR CARBARYL USES IN CALIFORNIA

This table was prepared by reviewing carbaryl product labels. Maximum application rates and minimum preharvest intervals (PHI) were chosen when they differed between labels; however, application rates and PHI were generally the same on all labels.

Rows are sorted by site category (FC = Field Crops; FN = Fruits and Nuts; V = Vegetables; M = Miscellaneous; OT = Ornamentals, Herbs, Trees, Nursery/Greenhouse), then by use sites.

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

Within Tier I and Tier II, suggested representative activities are shown in bold. These are activities that generally should be addressed specifically in an exposure assessment. Tier III activities are considered to be covered by Tier I and Tier II activities. For several crops, more than one activity is shown in bold; each activity should be considered in light of pesticide-specific information (i.e., one activity doesn't consistently represent the others). For some pesticides, activities not shown in bold should also be considered.

Site Cat [a]	Use Site	Rate [b] (lb AI/A)	PHI [c] (days)	Tier I Activities (High)	Tier II Activities (Medium)	Tier III Activities (Low)
FC	Forage Crops (Alfalfa, Clover, Birdsfoot Trefoil)	1.5	7	None	None	Irrigating [d], Scouting, Mech. Harvesting
FC	Corn, Field and Pop	2	14 REI: 1	**Scouting**	None	Irrigating [d], Mech. Harvesting, Weeding
FC	Corn, Sweet	2	2 REI: 1	**Scouting, Hand Harvesting**	None	Irrigating [d], Weeding, Mech. Harvesting
FC	Rice	1.5	14	**Swimming In Receiving Water**	None	Irrigating [d], Scouting, Harvesting
FC	Grain Sorghum	2	14	None	Irrigating [d], **Scouting**	Weeding/Roguing, Mech. Harvesting
FC	Tobacco	2	2	**Hand Harvesting**	**Scouting**	Irrigating [d], Mech. Harvesting, Pruning, Stripping, Thinning, Topping, Weeding, Reset
FN	Blueberry	2	7	None	**Harvest** (Hand), Pruning/ Thinning/ Hedging, Trellising/ Training, Scouting	Weeding (Mech, Hand), Irrigating, Harvest (Mech), Transplant/Propagate [e]

FN	Caneberries (Blackberry, Boysenberry, Loganberry, Raspberry)	2	7	None	**Harvest** (Hand), Training/Tying/ Trellising, Pruning Canes (Topping/ Thinning), Scouting	Weeding (Mech, Hand), Harvest (Mech), Transplant/Propagate [e]
FN	Citrus	12	5 REI: 3	**Harvesting** (Hand)	**Pruning** (Hand)	Irrigating [d], Weeding (Hand, Mech), Scouting, Transplant/Propagate [e], Pruning (Mech)
FN	Cranberry	2	7	None	**Harvest** (Hand, Dry), Harvest (Hand, Wet) Pruning, Training, Weeding (Hand)	Harvesting (Mechanical, Corraling, Pumping Or Lifting Fruit From Bed), Irrigating [d] (Sprinkler, Flood, Including Frost Control), Weeding (Mechanical), Sanding Beds, Scouting, Ditching, Transplant/Propagate (Spreading And Setting Vines)
FN	Grapes	2	7 REI: 6	**Leaf Pulling**, Cane Turning, Cane Cutting, Thinning	**Harvest** (Hand), Scouting, Pruning (Nondormant)	Weeding (Hand), Girdling, Pruning, Training/Tying/ Trellising, Transplant/Propagate [e]
FN	Olive (Evergreen)	7.5	14 REI: 3	**Pruning** (Hand)	**Harvesting** (Hand, Net)	Weeding (Mech), Irrigating [d], Transplant/Propagate [e]
FN	Pistachio	6	14	None	**Harvest** (Mech, Shake And Sweep [c] Or Net)	Scouting, Harvest (Hand Off Ground), Weeding (Hand, Mech), Irrigating [d], Pruning (Dormant), Transplant/Propagate [e]
FN	Pome Fruits (Apples, Pears, Loquats, Crabapples, Oriental Pears)	3	3	Harvest (Hand), **Thinning**	**Pruning** (Nondormant)	Scouting, Irrigating [d], Weeding (Hand, Mechanical), Propping, Pruning And Tying (Dormant), Animal Control (Field Baits/Traps), Transplant/Propagate [e]
FN	Prickly Pear (Indian Fig) Miscellaneous Fruit	2	3	None	None	Harvesting (Hand), Irrigating [d], Scouting, Fertilizing, Transplant/Propagate [e]
FN	Stone Fruits (Apricots, Cherries, Nectarines, Peaches, Plums, Prunes)	4 (5 dormant)	1	Harvesting (Hand), **Thinning**	**Pruning** (Nondormant)	Scouting, Irrigating [d], Weeding (Mech), Pruning (Dormant), Propping, Transplant/Propagate [e]

FN	Strawberry	2	7	None	**Harvest (Hand)**, Pruning/Pinching	Scouting, Irrigating [d], Weeding/Runner Cut (Mech, Hand), Mulching, Training, Transplant/Propagate [e], Removing Old Plastic/Pipes
FN	Tree Nuts (Almond, Chestnut, Filbert, Pecan, Walnut)	5	14	None	**Harvesting** (Mech Shake And Sweep [f])	Weeding (Mechanical), Irrigating [e], Scouting, Transplant/Propagate [e], Pruning (Dormant)
M	Turfgrass, Sod	8.28	0	None	**Landscape Maintenance, Mechanical Harvesting, Laying Sod**	Irrigation [e], Weeding, Scouting
OT	Forested Areas (Non-Urban Forests, Tree Plantations, Christmas Trees, Parks)	1	0	None	None	Scouting, Harvesting, Chopping Brush, Irrigating [e], Pruning, Thinning, Weeding, Transplanting [d]
OT	Nursery, Greenhouse Cut Flowers Or Greens	1	0	None	**Harvesting (Hand)**	Irrigating [d], Scouting, Thinning, Turning, Tying, Weeding, Bud Pinching (flowers), Transplanting [e]
OT	Ornamental Plants	1	0	None	None	Irrigating [d], Scouting, Thinning, Turning, Tying, Weeding, Transplanting [e]
V	Asparagus (Spears, Ferns, Etc.)	1 (2 post-harvest)	1	None	Irrigating [d], Scouting, **Harvesting (Hand)**	Weeding, Transplanting [e]
V	Beans/Peas Legumes, Fresh	1.5	3	Harvesting (Hand) [g]	Irrigating [d], **Scouting**	Weeding, Transplanting [e], Harvesting (Mech)
V	Beans/Peas, Dried Type	1.5	21	None	Irrigating [d], **Scouting**	Weeding, Transplanting [e], Harvesting (Mech)
V	Beets	2	7	None	Harvesting (Hand) [g]	Irrigating, Scouting, Thinning, Weeding, Transplanting [e], Harvesting (Mech)
V	Broccoli, Broccoli Raab (Rapa, Italian Turnip, Rapini)	2	3	**Harvesting (Hand)**	Irrigating [d], **Scouting**	Weeding, Thinning, Transplanting [e], Harvesting (Mech)
V	Brussels Sprouts	2	3	Irrigating, Topping, **Harvesting (Hand)**	**Scouting**	Weeding, Thinning, Transplanting [e], Harvesting (Mech)
V	Cabbage, Chinese Cabbage (Napa, Won Bok, Celery Cabbage)	2	3	**Harvesting (Hand)**	Irrigating [d], **Scouting**	Weeding, Thinning, Transplanting [e], Harvesting (Mech)

V	Carrots	2	7	None	Harvesting (Hand)	Scouting, Irrigating, Weeding, Harvesting (Mech)
V	Cauliflower	2	3	Tying, Irrigating, Banding, **Harvesting (Hand)**	**Scouting**	Weeding, Transplanting [e], Harvesting (Mech)
V	Celery	2	14	**Harvesting (Hand)**	Irrigating [d], **Scouting**	Weeding, Transplanting [e]
V	Collards	2	14	**Harvesting (Hand)**	Irrigating [d], **Scouting**	Weeding, Thinning, Transplanting [e]
V	Cucumber	1	3	Tying, Staking, **Harvesting (Hand)**	Irrigating [d], **Scouting**	Weeding, Thinning, Transplanting [e], Harvesting (Mech)
V	Dandelion (Chinese Dandelion, Gow Gay)	2	14	**Harvesting (Hand)**	Irrigating [d], **Scouting**	Thinning, Weeding, Transplanting [e], Harvesting (Mech)
V	Eggplant	2	3	Staking, Tying, Pruning (Hand) [g] **Harvesting (Hand)**	Irrigating [d], **Scouting**	Weeding, Transplanting [e]
V	Endive	2	14	**Harvesting (Hand)**	Irrigating [d], **Scouting**	Weeding, Thinning, Transplanting [e], Harvesting (Mech)
V	Horseradish	2	7	None	Harvesting (Hand) [g]	Scouting, Irrigating, Weeding, Harvesting (Mech)
V	Kale	2	14	None	Irrigating [d], Scouting, **Harvesting (Hand)**	Weeding, Thinning, Transplanting [e]
V	Kohlrabi	2	3	Harvesting (Hand) [g]	None	Irrigating, Scouting, Weeding, Thinning, Transplanting [e], Harvesting (Mech)
V	Lettuce	2	14	Head Breaking (For Head), **Harvesting (Hand)**	Irrigating [d], **Scouting**	Thinning, Weeding, Transplanting [e]
V	Melons	1	3	Pruning (Hand) [g], **Harvesting (Hand)**	Irrigating [d], **Scouting**	Weeding, Thinning, Transplanting [e]
V	Mustard Greens	2	14	**Harvesting (Hand)**	Irrigating [d], **Scouting**	Thinning, Weeding, Transplanting [e], Harvesting (Mech)
V	Parsley	2	14	None	Irrigating [d], Scouting, **Harvesting (Hand)**	Weeding, Thinning, Transplanting [e]
V	Parsnip	2	7	None	Harvesting (Hand) [g]	Scouting, Irrigating [d], Weeding, Harvesting (Mech)
V	Peanuts	2	14	None	Irrigating [d], **Scouting**	Weeding, Harvesting (Mech)
V	Peppers	2	3	Staking, Tying, Thinning, **Harvesting (Hand)**	Irrigating [d], **Scouting**	Weeding, Transplanting [e]

V	Potato (White, Irish, Red, Russet)	2	7	None	Irrigating [d], **Scouting,** Harvesting (Hand) [e]	Weeding, Transplanting [e], Harvesting (Mech)
V	Pumpkin	1	3	**Harvesting (Hand)**	Irrigating [d], **Scouting**	Weeding, Thinning, Transplanting [e]
V	Radish	2	7	None	Harvesting (Hand) [g]	Irrigating [d], Scouting, Weeding, Thinning, Transplanting [e], Harvesting (Mech)
V	Salsify	2	7	None	Irrigating [d], **Scouting**	Weeding, Thinning, Transplanting [e], Harvesting (Mech)
V	Spinach	2	14	None	Irrigating [d], Scouting, **Harvesting (Hand)**	Thinning, Weeding, Transplanting [e], Harvesting (Mech)
V	Squash	1	3	Leaf Pulling, **Harvesting (Hand)**	Irrigating [d], **Scouting**, Weeding (Hand)	Weeding (Mech), Thinning, Transplanting [e], Harvesting (Mech)
V	Sugar Beets	1.5	28	Harvesting (Hand) [g]	Irrigating [d], **Scouting**	Weeding, Thinning, Harvesting (Mech)
V	Sweet Potato	2	7	None	Irrigating [d], **Scouting,** Harvesting (Hand) [g]	Weeding, Transplanting [e], Harvesting (Mech)
V	Swiss Chard (Spinach Beet)	2	14	None	Irrigating [d], Scouting, **Harvesting (Hand)**	Thinning, Weeding, Transplanting [e], Harvesting (Mech)
V	Tomato (Fresh Market)	2	3	Tying, Training, Staking, Pruning (Hand), **Harvesting (Hand)**	Irrigating [d], **Scouting**	Weeding, Thinning, Transplanting [e]
V	Tomato (Processing/ Canning)	2	3	Tying, Training, Staking	Irrigating [d], **Scouting,** Pruning (Hand) [a]	Weeding, Transplanting [e], Harvesting (Mech)
V	Turnip	2	7	None	Harvesting (Hand) [g]	Irrigating [d], Scouting, Weeding, Thinning, Transplanting [e], Harvesting (Mech)

[a] Site categories: FC = Field Crops; FN = Fruits and Nuts; M = Miscellaneous; OT = Ornamentals, Herbs, Trees, Nursery/Greenhouse; V = Vegetables.
[b] Rate = Maximum application rate listed for crop in California on any product label.
[c] PHI = Minimum preharvest interval listed for crop in California on any product label. Extended restricted entry intervals (REI) beyond 12 hours are also noted in this column (also with units of days).
[d] Irrigator exposure is dependent upon the method of irrigation used for the crop, where drip irrigation is Tier III (low), flood or furrow irrigation of crops less than 18 inches high is Tier III (low), flood or furrow irrigation of crops 18 inches or taller is Tier II (moderate), sprinkler irrigation of crops less than 18 inches high is Tier II (moderate), and sprinkler irrigation of crops 18 inches or taller is Tier I (high).
[e] Transplant/propagate activity has little potential for exposure in the field, but may present a potential for exposure during the propagation stage in the nursery or greenhouse setting. Refer to greenhouse/nursery scenarios.
[f] Mechanical harvesting by shaking and sweeping to drop and collect fruits/nuts, respectively, may generate dust and debris (falling leaves, branches, produce) sufficient to expose harvester to pesticide residues by dermal contact with or inhalation of debris/dust.
[g] This activity isn't practiced commercially in California at present.

APPENDIX 2: MEASURED AND PREDICTED CARBARYL DISLODGEABLE FOLIAR RESIDUES

Table A2-1. Measured and Predicted DFR for Carbaryl Applied to Cucumber, Cabbage, and Tobacco

Day	Dislodgeable Foliar Residue (μg/cm²)					
	Cucumber		Cabbage		Tobacco	
	Measured [a]	Predicted [b]	Measured [c]	Predicted [b]	Measured [d]	Predicted [b]
0	3.51	1.13	4.03	4.31	4.25	4.86
1	0.245	0.464	3.31	3.46	5.03	3.96
2	0.126	0.191	2.62	2.77	4.73	3.23
3	0.054	0.0782	2.32	2.23	4.53	2.63
4	0.031	0.0321	1.12	1.79	3.00	2.15
5	0.011	0.0132	1.24	1.43	1.45	1.75
6	0.005	0.005	1.03	1.15	2.13	1.43
7	0.004	0.002	1.04	0.923	1.08	1.16
8	ND [e]	NC [e]	ND	0.741	ND	0.949
9	ND	NC	ND	0.594	ND	0.774
10	ND	NC	ND	0.477	ND	0.631
11	ND	NC	ND	0.383	ND	0.515
12	ND	NC	ND	0.307	ND	0.420
13	ND	NC	ND	0.247	ND	0.342
14	ND	NC	0.738	0.198	0.040	0.279
15	ND	NC	ND	0.159	ND	0.228
16	ND	NC	ND	0.128	ND	0.186
17	ND	NC	ND	0.102	ND	0.151
18	ND	NC	ND	0.0821	ND	0.123
19	ND	NC	ND	0.0659	ND	0.101
20	ND	NC	ND	0.0529	ND	0.082
21	ND	NC	0.048	0.0424	0.044	0.067
28	ND	NC	0.005	0.0091	0.015	0.016
35	ND	NC	ND	0.0019	0.010	0.004

[a] Dislodgeable foliar residue (DFR) data from Klonne *et al.* (2001b). Application rate was 1.0 lbs AI/acre. Use measured Day 0 for exposure at 12 hours post-application.
[b] DFR values including Day 0 were calculated using the linear regression generated from study data: $\ln DFR_t = \ln (DFR_0) - kt$ (Andrews, 2000).
[c] DFR data from Klonne *et al.* (2001a). Application rate was 2.0 lbs AI/acre. Use predicted Day 0.
[d] DFR data from Klonne *et al.* (1999a). Application rate was at 2.0 lbs AI/acre. Use predicted Day 0.
[e] ND = Not determined. NC = Not calculated beyond interval sampled.

Table A2-2. Measured and Predicted DFR for Carbaryl Applied to Apple, Orange, and Olive

Day	Dislodgeable Foliar Residue (μg/cm²)					
	Apple		Orange		Olive	
	Measured [a]	Predicted [b]	Measured [c]	Predicted [b]	Measured [d]	Predicted [b]
0	9.07	9.49	28.9	28.5	3.43	3.94
1	9.11	9.03	28.2	27.4	2.90	3.55
2	8.93	8.58	ND [e]	26.3	2.82	3.21
3	7.23	8.17	ND	25.2	3.64	2.90
4	9.01	7.77	25.2	24.2	2.97	2.62
5	6.58	7.39	32.4	23.2	2.28	2.36
6	7.49	7.03	22.6	22.3	2.60	2.13
7	6.22	6.69	16.8	21.4	2.65	1.93
8	ND	6.36	17.9	20.5	ND	1.74
9	ND	6.05	17.6	19.7	ND	1.57
10	ND	5.75	ND	18.9	1.13	1.42
11	ND	5.47	ND	18.2	ND	1.28
12	ND	5.21	ND	17.4	ND	1.16
13	ND	4.95	ND	16.7	ND	1.04
14	4.42	4.71	ND	16.1	0.838	0.944
15	ND	4.48	ND	15.4	ND	NC [e]
16	ND	4.26	ND	14.8	ND	NC
17	ND	4.06	ND	14.2	ND	NC
18	ND	3.86	ND	13.6	ND	NC
19	ND	3.67	ND	13.1	ND	NC
20	ND	3.49	ND	12.6	ND	NC
21	3.25	3.32	10.6	12.0	ND	NC
28	2.39	2.34	9.07	9.04	ND	NC
35	1.42	1.65	7.34	6.79	ND	NC

[a] Dislodgeable foliar residue (DFR) data from Klonne *et al.* (2001c). Application rate was 2.0 lbs AI/acre. Use predicted Day 0 for exposure at 12 hours post-application.
[b] DFR values including Day 0 calculated using the linear regression generated from study data: $\ln DFR_t = \ln (DFR_0) - kt$ (Andrews, 2000).
[c] DFR data from Klonne and Merricks (2000). Application rate was 7.07 lbs AI/acre. Use measured Day 0.
[d] DFR data from Klonne *et al.* (2000a). Application rate was at 7.65 lbs AI/acre. Use predicted Day 0.
[e] ND = Not determined. NC = Not calculated beyond interval sampled.

Table A2-3. Measured and Predicted Residues for Carbaryl Applied to Strawberry

Day	Residue (μg/cm²)	
	Strawberry	
	Measured [a]	Predicted [b]
0	ND [c]	6.05
1	8.08 [d]	5.10
2	ND	4.31
3	2.56	3.63
4	ND	3.06
5	ND	2.59
6	ND	2.18
7	1.32	1.84
8	ND	1.55
9	ND	1.31
10	ND	1.11
11	ND	0.932
12	ND	0.787
13	ND	0.664
14	0.54	0.560
15	0.61	0.472
16	0.55	0.399
17	0.24	0.336

[a] Dislodgeable foliar residue (DFR) data from Zweig *et al.* (1984). Application rate was 2.0 lbs AI/acre.
[b] DFR values including Day 0 calculated using the linear regression generated from study data: $\ln DFR_t = \ln (DFR_0) - kt$ (Andrews, 2000).
[c] ND = Not determined.
[d] Measured Day 1 DFR used to estimate Day 0 and Day 1 exposures.

APPENDIX 3: UNIT EXPOSURE ESTIMATES FROM PHED

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

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

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

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

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

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

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

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

SCENARIO: Long pants, long sleeves, gloves

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

Subset Name: S1DERMAL.MLOD

[a] Subset criteria included actual and estimated head patches. All 24 head observations were actual.

Table A3-2 summarizes exposure results for the dermal, hand, and inhalation subsets, and sums them for the total exposure. All exposure estimates reported in this assessment for PHED were rounded to three significant figures (Beauvais *et al*., 2007). All estimates were rounded to the same extent because the resolution of measurements within each study could not be readily determined; PHED reports results to four decimal places regardless of the resolution in the original data. When hand exposure is added to non-hand dermal exposure to get the total dermal exposure rate, to avoid rounding differences a fourth significant figure is sometimes used.

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

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

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

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

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

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

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

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

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

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

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

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

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

The total exposure calculations are shown below:

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

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

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

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

Table A3-4. Summary of PHED Data Sets for Mixer/Loader and Flagger Scenarios [a]

Scenario No.	Scenario [b]	Data Quality [c]			Numbers of Observations [d]		
		Dermal	Hand	Inhalation	Dermal	Hand	Inhalation
4	Open Pour M/L, G, gl	A	A,B	A,B	12	45	58
5	Open Pour M/L, L, gl	A,B	A	A,B	99	59	85
7	Flagger, L, gl	A	A,B	A,B	21	30	28
8	Flagger, G, gl	E	C	E	20	4	4

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

Table A3-5 summarizes exposure results for subsets in each M/L and flagger scenario.

Table A3-5. Summary of PHED Results for Mixer/Loaders and Flaggers [a]

Scen. No.	Scenario [b]	Short Term [c]			Long Term [d]		
		Dermal	Hand	Inhalation	Dermal	Hand	Inhalation
4	Open Pour M/L, G, gl	32.8	3.19	11.0	11.8	1.15	3.97
5	Open Pour M/L, L, gl	1,340	186	7.34	482	66.9	2.64
7	Flagger, L, gl	131	2.02	0.680	47.2	0.725	0.245
8	Flagger, G, gl	5.51	0.0119	0.588	1.98	0.00426	0.211

[a] Scenario numbers and exposure rates summarized from Appendix I in Beauvais *et al.* (2007). PHED: Pesticide Handlers Exposure Database.
[b] Abbreviations: G: granular; gl: wearing chemical-resistant gloves; L: liquid; M/L: mixer/loader.
[c] Upper confidence limit (UCL) for 95th %ile exposure = 1/SQRT(2)*MEAN*EXP[Z(0.95)*0.8326 + Z(0.90)*0.8326/SQRT(n)]; see Equation 5 in Powell (2007).
[d] UCL for arithmetic mean exposure = MEAN*EXP[Z(0.90)*0.8326/SQRT(n)]; Equation 6 in Powell (2007).

Product labels require engineering controls and personal protective equipment (PPE) for agricultural handlers. Table A3-6 summarizes exposure rates with engineering controls and PPE required on product labels. Required PPE includes respirator, chemical-resistant apron, and chemical-resistant gloves. Required engineering control includes closed cab for flaggers.

Table A3-6. Exposure Rates for Mixer/Loaders and Flaggers Wearing PPE and with Engineering Controls Required by Carbaryl Product Labels [a]

Scen. No.	Scenario [b]	Short Term			Long Term		
		Dermal	Hand	Inhalation	Dermal	Hand	Inhalation
4	Open Pour M/L, G	26.1	3.19	11.0	9.39	1.15	3.97
4	Open Pour M/L, G, aerial	26.1	3.19	1.10	9.39	1.15	0.397
5	Open Pour M/L, L	1,260	186	7.34	454	66.9	2.64
5	Open Pour M/L, L, aerial	1,260	186	0.734	454	66.9	0.264
7	Flagger, L	13.1	0.202	0.0680	4.72	0.0725	0.0245
8	Flagger, G	0.551	0.00119	0.0588	0.198	0.000426	0.0211

[a] Scenario numbers and details summarized from Appendix I in Beauvais *et al.* (2007). Exposure rates assume protective clothing, personal protective equipment (PPE), and engineering controls required on product labels, and are calculated with the following protection factors: respirator, 90% (Cal/OSHA, 2007); chemical-resistant apron, 90% on chest, stomach, and front half of thighs; enclosed cab, 90%.
[b] Abbreviations: aerial: mixing/loading in support of aerial and chemigation applications (required to wear a respirator); G: granular; L: liquid; M/L: mixer/loader.
[c] Upper confidence limit (UCL) for 95th %ile exposure = 1/SQRT(2)*MEAN*EXP[Z(0.95)*0.8326 + Z(0.90)*0.8326/SQRT(n)]; see Equation 5 in Powell (2007).
[d] UCL for arithmetic mean exposure = MEAN*EXP[Z(0.90)*0.8326/SQRT(n)]; Equation 6 in Powell (2007).

Table A3-7 summarizes characteristics of PHED data sets used to estimate applicator exposure.

Table A3-7. Summary of PHED Data Sets for Applicator Scenarios [a]

Scenario No.	Applicator Scenario [b]	Data Quality [c]			Numbers of Observations [d]		
		Dermal	**Hand**	**Inhalation**	**Dermal**	**Hand**	**Inhalation**
9	Airblast, L, OC, gl	A,B	A,B	A,B	42	18	47
10	Airblast, L, CC, gl	A,B	A	A,C	30	20	9
11	Groundboom, L, OC, gl	A,B,C	A,B	A,B	34	29	22
14	Broadcast, CC, G, gl	A	A,B	A,B	28	17	37
16	ROW Sprayer, L, gl	A,C	A, B	A	5	16	16
18	Aerial, L, CC, gl	A,B	A,B	A	17	36	15
19	Aerial, G, CC, gl	C	C	C	12	9	9

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

Table A3-8 summarizes exposure results for subsets in each applicator scenario.

Table A3-8. Summary of PHED Results for Applicators [a]

Scen. No.	Applicator Scenario [b]	Short Term [c]			Long Term [d]		
		Dermal	**Hand**	**Inhalation**	**Dermal**	**Hand**	**Inhalation**
9	Airblast, L, OC, gl	3,310	30.5	17.6	1,190	11.0	6.32
10	Airblast, L, CC, gl	62.1	61.1	1.78	22.3	22.0	0.641
11	Groundboom, L, OC, gl	69.8	15.5	4.12	25.1	5.56	1.48
14	Broadcast, CC, G, gl	7.18	0.616	0.729	2.58	0.222	0.262
16	ROW Sprayer, L, gl	48,400	403	12.3	17,400	145	4.43
18	Aerial, L, CC, gl	9.22	3.18	0.0916	3.32	1.14	0.0329
19	Aerial, G, CC, gl	3.70	0.361	4.52	1.33	0.130	1.63

[a] Scenario numbers and exposure rates summarized from Appendix I in Beauvais *et al.* (2007). PHED: Pesticide Handlers Exposure Database.
[b] Abbreviations: CC: closed cab/cockpit; G: granular; gl: wearing chemical-resistant gloves; L: liquid; OC; open cab/cockpit.
[c] Upper confidence limit (UCL) for 95th %ile exposure = 1/SQRT(2)*MEAN*EXP[Z(0.95)*0.8326 + Z(0.90)*0.8326/SQRT(n)]; see Equation 5 in Powell (2007).
[d] UCL for arithmetic mean exposure = MEAN*EXP[Z(0.90)*0.8326/SQRT(n)]; Equation 6 in Powell (2007).

Table A3-9 summarizes characteristics of PHED data sets used to estimate mixer/loader/applicator exposure.

Table A3-9. Summary of PHED Data Sets for Mixer/Loader/Applicator Scenarios [a]

Scenario No.	Mixer/Loader/Applicator Scenario [b]	Data Quality [c]			Numbers of Observations [d]		
		Dermal	Hand	Inhalation	Dermal	Hand	Inhalation
20	BP Open Pour, L, gl	A,B	C	A,B	11	11	11
20	BP Open Pour, L, ng	A,B	C	A,B	11	11	11
21	HPHW Open Pour, L, gl	A	C	A	11	13	13
21	HPHW Open Pour, L, ng	A	C	A	11	13	13
22	LPHW Open Pour, L, gl	A,B,C	A,B,C	A,B	35	10	10
22	LPHW Open Pour, L, ng	A,B,C	A,B,C	A,B	35	10	10
25	Push-Type Spreader, G, gl	C	C	B	15	15	15
25	Push-Type Spreader, G, ng	C	C	B	15	15	15
26	Garden Hose Sprayer, gl	C	E	C	8	8	8
26	Garden Hose Sprayer, ng	C	E	C	8	8	8

[a] Scenario numbers and details summarized from Appendix I in Beauvais *et al.* (2007). PHED: Pesticide Handlers Exposure Database.

[b] Abbreviations: BP: backpack; CC: closed cab/cockpit; G: granular; gl: wearing chemical-resistant gloves; HPHW: high-pressure handwand; L: liquid; LPHW: low-pressure handwand; ng: no gloves (not wearing chemical-resistant gloves); OC; open cab/cockpit.

[c] Data quality grades are defined in Beauvais *et al.* (2007) and in Versar (1992).

[d] Effective sample size for number of dermal observations was estimated as the harmonic mean, weighted by the squared mean dermal exposure (Powell, 2007).

Table A3-10 summarizes exposure results for each subset in each mixer/loader/applicator scenario. No-glove scenarios are used in comparisons discussed in the Exposure Appraisal.

Table A3-10. Summary of PHED Results for Mixer/Loader/Applicators [a]

Scen. No.	Mixer/Loader/Applicator Scenario [b]	Short Term [c]			Long Term [d]		
		Dermal	Hand	Inhalation	Dermal	Hand	Inhalation
20	BP Open Pour, L, gl	85,600	37.1	67.1	30,800	13.4	24.1
20	BP Open Pour, L, ng	85,600	371	67.1	30,800	134	24.1
21	HPHW Open Pour, L, gl	25,200	1,270	565	9,080	456	203
21	HPHW Open Pour, L, ng	25,200	12,700	565	9,080	4,560	203
22	LPHW Open Pour, L, gl	5,230	40.5	88.9	1,880	14.6	31.9
22	LPHW Open Pour, L, ng	5,230	405	88.9	1,880	146	31.9
25	Push-Type Spreader, G, gl	8,020	890	21.4	2,880	320	7.68
25	Push-Type Spreader, G, ng	8,020	8,900	21.4	2,880	3,200	7.68
26	Garden Hose Sprayer, gl	5,920	19,600	54.3	2,130	7,060	19.5
26	Garden Hose Sprayer, ng	5,920	196,000	54.3	2,130	70,600	19.5

[a] Scenario numbers and exposure rates summarized from Appendix I in Beauvais *et al.* (2007). PHED: Pesticide Handlers Exposure Database. Scenario numbers ending in "A" rely on different hand subsets; otherwise, the same subsets were used to estimate exposures with and without gloves.

[b] Abbreviations: CC: closed cab/cockpit; G: granular; gl: wearing chemical-resistant gloves; L: liquid; M/L: mixer/loader; ng: no gloves (not wearing chemical-resistant gloves); OC; open cab/cockpit.

[c] Upper confidence limit (UCL) for 95th %ile exposure = 1/SQRT(2)*MEAN*EXP[Z(0.95)*0.8326 + Z(0.90)*0.8326/SQRT(n)]; see Equation 5 in Powell (2007).

[d] UCL for arithmetic mean exposure = MEAN*EXP[Z(0.90)*0.8326/SQRT(n)]; Equation 6 in Powell (2007).

APPENDIX 4: APPLICATION SIZES AND RATES FOR CARBARYL USE REPORTED IN CALIFORNIA

Table A4-1 summarizes sizes of carbaryl applications reported in California over a recent 5-year interval. Tables in this appendix were generated by querying the California Pesticide Use Report (PUR; DPR, 2012a), combining applications made each day to fields or orchards under a single grower identification number, assuming that all applications made to a grower's fields could be made by one applicator, be prepared by one mixer/loader, etc.

Table A4-1. Application Rates and Sizes for Selected Crops in California (2006 – 2010)

Application Method [a]	Crop	Application Rate (lbs AI/acre)			Application Size (acres)		
		Maximum [b]	Mean [c]	Assumed [d]	Maximum [e]	Mean [c]	Assumed [d]
Aerial	Tomato	2	1.66	**2**	674	117	120
Airblast – CC	Citrus	12	9.83	10	229	26.3	30
Airblast – OC [f]	Olive	7.5	5.39	6.0	245	47.8	**40**
Airblast – OC [g]	Apple	3	1.81	2	372	32.6	**40**
Groundboom [h]	Tomato	2	0.740	1	462	103 [i]	**80**
Broadcast Spreader [h]	Tomato	2	0.740	1	462	103 [i]	**80**

[a] Abbreviations: CC: closed cab. OC: open cab.
[b] Maximum application rate given on product label, and assumed in estimating short-term exposures.
[c] Highest annual mean value from the Pesticide Use Report (DPR, 2012a).
[d] Value assumed in calculating seasonal, annual, and lifetime exposures. Bold = assumed value same as used in short-term estimates.
[e] Highest single reported acreage treated for one grower in one day (DPR, 2012a). Applications spanning multiple days may be reported on a single day in the PUR.
[f] Additional personal protective equipment is required for airblast applicators applying 5 pounds carbaryl or more per acre. Olive is the representative crop for this scenario.
[g] Apple is the representative crop for airblast applicators applying less than 5 pounds carbaryl per acre.
[h] The highest application rate on any crop receiving groundboom or broadcast spreader (i.e., either liquid or granular carbaryl products) is 2 lbs AI/acre, which is the maximum rate on several crops. Tomato (including processing and fresh market crops) receives more applications than any other crop treated by these methods.
[i] For high-acre groundboom and broadcast spreader, the default assumed for short-term exposures is 200 acres. Seasonal, annual, and lifetime exposures assume 110 acres (102 acres rounded up to the nearest 10 acres).

For some crops, combining all applications reported by each grower resulted in maximum application sizes of hundreds of acres, and mean application sizes in some cases that exceed the default used for short-term estimates, which is the reasonable daily maximum estimated by U.S. EPA (2001). Because uses from several days can be reported in the PUR on a single date, these very large applications are not considered to reflect actual acres treated within one day. In cases where annual mean application sizes are all less than the default, the highest annual mean application size was rounded up to the nearest 10 acres.

Table A4-1 also summarizes application rates. Application rates are not reported in the PUR, and were calculated by dividing pounds of carbaryl applied by acres treated.

Carbaryl applications to nursery and greenhouse stock are reported to the PUR with only the pounds of pesticide used. Table A4-2 summaries pounds of carbaryl reported, summarized by grower (assuming that the employees of a grower can treat multiple greenhouses or nursery blocks in a day). Based on the highest annual mean in Table A4-2, handlers were assumed to typically use 2 pounds of carbaryl per day on ornamentals (rounded up to the nearest lb AI/day from 1.10 lbs AI/day).

Table A4-2. Statistical Summary of Pounds of Carbaryl Applied Daily to Greenhouse and Nursery Stock in California (2006 – 2010) [a]

Year	Number of Applications [b]	Mean (Pounds) [c]	Percentile (Pounds) [c] 10th	50th	90th	100th
2006	258	0.626	0.0738	0.215	1.30	7.91
2007	339	1.10 [d]	0.215	0.430	1.98	30.6
2008	435	1.01	0.134	0.748	1.93	9.89
2009	612	0.719	0.0498	0.215	1.48	24.0
2010	1014	0.506	0.0989	0.247	0.989	6.58
Mean	532	0.792	0.114	0.371	1.54	15.8
SD	300	0.254	0.0644	0.2229	0.421	10.8
CV (%)	56.5	32.0	56.5	61.7	27.4	68.5

[a] Data from the Pesticide Use Report (DPR, 2012a). SD = standard deviation. CV = coefficient of variation.
[b] Applications summed over date and grower identifier if reported in the Pesticide Use Report.
[c] Statistics were rounded to three significant figures.
[d] The assumed typical use rate was 2 lbs carbaryl per day, rounding this mean value up to the nearest whole number.

Most pesticide applications for landscape maintenance are reported to the PUR with only the pounds of pesticide used. Table A4-3 summaries pounds of carbaryl reported, summarized by grower. Handlers were assumed to typically use 16 pounds of carbaryl per day.

Table A4-3. Statistical Summary of Pounds of Carbaryl Applied Daily for Landscape Maintenance in California (2006 – 2010) [a]

Year	Number of Applications [b]	Mean (Pounds) [c]	Percentile (Pounds) [c] 10th	50th	90th	100th
2006	341	15.1 [d]	0.0500	1.93	34.4	421
2007	302	13.0	0.538	3.06	30.8	242
2008	268	9.71	0.0461	0.774	19.9	289
2009	212	9.89	0.0400	1.57	25.4	181
2010	220	10.1	0.0615	1.65	56.7	120
Mean	279	11.3	0.0503	1.77	33.4	251
SD	59.2	2.76	0.00809	0.827	14.1	115
CV (%)	21.2	24.5	16.1	46.0	42.2	45.7

[a] Data from the Pesticide Use Report (DPR, 2012a). SD = standard deviation. CV = coefficient of variation.
[b] Applications summed over date and grower identifier if reported in the Pesticide Use Report.
[c] Statistics were rounded to three significant figures.
[d] The assumed typical use rate was 16 lbs carbaryl per day, rounding this mean value up to the nearest whole number.