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OFFICE OF
PREVENTION, PESTICIDES AND
TOXIC SUBSTANCES

MEMORANDUM

May 27, 1999

SUBJECT: Occupational/Residential Handler and Postapplication Residential Risk Assessment for Chlorpyrifos. DP Barcode: D254880. Case No. 818975. PC Code: 059101.

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EPA MRID No.: 40026001, 40094001, 43013501, 44167101, 44458201, 44444801, 44729401, 44729402, 44589001, 44739301

PHED: Yes, Version 1.1

EXECUTIVE SUMMARY

This document contains the occupational and residential exposure assessment for chlorpyrifos, resulting from the residential uses of chlorpyrifos products. Exposures are evaluated for occupationally-exposed Pest Control Operators (PCOs) at residential sites, residents who apply the chlorpyrifos products, and residential populations that may be exposed following pesticide application. Some products containing chlorpyrifos are intended primarily for homeowner use, while some are intended primarily or solely for PCO use. This memorandum addresses non-agricultural uses, focusing on residential sites. Agricultural, ornamental and animal premise uses are addressed elsewhere (memorandum from T. Leighton to D. Smegal, DP Barcode D253985, May 28, 1999).

Chlorpyrifos is an organophosphate insecticide used extensively in residential settings by both residents and PCOs. It is one of the top five insecticides used in residential settings. There are approximately 850 registered products containing chlorpyrifos on the market. Registered uses include a wide variety of food, turf and ornamental plants, as well as indoor products, structural pest control, and in pet collars. It is used in residential and commercial buildings, schools, daycare centers, hotels, restaurants, hospitals, stores, warehouses, food manufacturing plants and vehicles. In addition, it is used as a mosquitocide. In 1998, the Dow AgroSciences estimated that 70% of the urban chlorpryifos use involved termite control.

In June 1997, the registrants of chlorpyrifos voluntarily agreed to measures designed to reduce household exposure to chlorpyrifos, as part of a Risk Reduction Plan. This voluntary plan involved deletion of: indoor broadcast use, use as an additive to paint, direct application to pets (sprays, shampoos and dips), and indoor total-release foggers. The technical chlorpyrifos products have been amended to reflect the negotiated plan. The technical label limits end use product labeling to only those sites which are specified on its label. In addition, as part of this agreement, the registrants agreed to work with EPA to develop policies for a number of areas including:

- limiting household consumer use to only products packaged as ready-to-use;
- prohibiting use in inappropriate areas (e.g., toys, drapes, furniture);
- requiring PCOs to clean up spills and misapplications;
- requiring more training of PCOs and more supervision during application;
- reducing exposure by eliminating concentrates which require mixing;
- establishing specific protection measures for humans and pets during and immediately after application;
- revising labels to include appropriate intervals between treatment (e.g., to replace "use as necessary", currently on some labels);
- revising labels for safer termiticide and pet care products per PR notice 96-7 on all termiticide labeling and 96-6 on all pet care product labeling and support the Agency efforts to expedite these changes for other products; and
- accelerate education and training for PCOs on these measures to reduce risk and

exposure, label improvements, and implementation of recent PR Notices 96-7 (for termiticides) and 96-6 (for pet care products), and support the Agency efforts to expedite these changes for other products.

Chlorpyrifos, O,O-diethyl O-(3,5,6-trichloro-2-pyridyl) phosphorothioate, is an insecticide formulated as a wettable powder (containing 50% a.i.), emulsifiable concentrates (41.5-42.8%), dust (containing 0.1-7% a.i.), granular (containing 0.075%-15% a.i.), bait (containing 0.5% a.i.), flowables (containing 30% a.i.), impregnated material (containing 0.5-10% a.i.), pelleted/tableted (containing 0.5-1.0% a.i.), pressurized liquids (0.9-3.8% a.i.), and microencapsulated (0.5-2.5% a.i.). Dow AgroSciences states that formulations with concentrations greater than one pound a.i. per gallon (approximately 13% a.i.) are sold only to pest control or turf and ornamental professionals. Lower concentrations are available to homeowners from other suppliers for over-the-counter purchase. Except aerosols, granules and dusts, all formulated end-use products for application are diluted in water to a concentration of 1 percent a.i. or less (Dow AgroSciences 1998).

The toxicity endpoints used in this document to assess hazards include short-, intermediate- and long-term dermal and inhalation endpoints, and the acute oral endpoint. A route-specific short-term dermal no-observed adverse effect level (NOAEL) of 5 mg/kg/day from a 21-day dermal rat study has been identified based on plasma and red blood cell (RBC) cholinesterase (ChE) inhibition of 45% and 16%, respectively at 10 mg/kg/day (the lowest observed adverse effect level, LOAEL). Therefore, a dermal absorption adjustment is not necessary. The intermediate- and long-term dermal NOAEL is converted from an oral NOAEL of 0.03 mg/kg/day from a 2-year oral dog study using a 3 percent dermal absorption factor. Plasma and RBC ChE inhibition occurred in this study at a dose level of 0.1 mg/kg/day. Dermal absorption was estimated to be 3 percent based on the ratio of the oral lowest-observed-adverse effect level (LOAEL) of 0.3 mg/kg/day from the rat developmental neurotoxicity study (MRID Nos. 44556901, 44661001) to the dermal LOAEL of 10 mg/kg/day from the 21-day dermal study (MRID No. 40972801) for plasma and red blood cell cholinesterase inhibition. This absorption factor is comparable to the dermal absorption estimated from human data of 1-3% (MRID No. 00249203).

The short- and intermediate-term inhalation NOAEL is 0.1 mg/kg/day from two separate 90-day rat inhalation studies that did not observe effects at the highest dose tested. At higher oral doses of 0.3 mg/kg/day(LOAEL), 43% plasma and 41% RBC ChE were observed in animals. The lung absorption is assumed to be 100 percent or oral absorption. The long-term inhalation NOAEL is converted from an oral NOAEL of 0.03 mg/kg/day from the 2-year dog study, assuming that inhalation and oral absorption are equivalent. The acute oral NOAEL is 0.5 mg/kg/day from an acute oral rat study that observed 28-40% plasma cholinesterase inhibition 3-6 hours after dosing male rats with a single dose of 1 mg/kg/day (HIARC memorandum from D. Smegal to S. Knizner, March 4, 1999, Document number 013249). The acute oral NOAEL was used to assess short-term exposures resulting from incidental ingestion (i.e., hand to mouth exposures) of less than one week for children. This is considered appropriate because exposures and risks are calculated for the day of application, when residential exposures are expected to be greatest. Oral exposure was not evaluated for workers. The exposure duration for short-term

assessments is 1 to 7 days. Intermediate-term durations are 1 week to several months, and long-term exposures are durations greater than several months.

For dermal and inhalation risk assessment, risk estimates are expressed in terms of the Margin of Exposure (MOE), which is the ratio of the NOAEL selected for the risk assessment to the exposure. For occupationally exposed workers, MOEs > 100 (i.e., 10x uncertainty factor for interspecies extrapolation and 10x uncertainty factor for intraspecies variability) do not exceed HED's level of concern. For residential populations, MOEs > 300, which includes an additional 3x Food Quality Protection Act (FQPA) safety factor do not exceed HED's level of concern. The acute population adjusted dose (aPAD) used to assess short-term oral exposures is 0.0017 mg/kg/day, which is the acute oral NOAEL divided by an uncertainty factor of 300.

Multiple exposure studies were conducted by the registrant and submitted to the Agency that evaluate exposures to PCOs/residential handlers and residents following postapplication of chlorpyrifos products. These data include biological monitoring, passive dosimetry and environmental measurements. These data, along with the Pesticide Handlers Exposure Database (PHED) Version 1.1, were used to assess potential PCO exposures resulting from handling and applying chlorpyrifos in residential settings. Postapplication residential exposures were assessed using primarily the registrant-submitted data. In the absence of data, the Draft Standard Operating Procedures (SOPs) for Residential Exposure Assessments (December 18, 1997) were used to estimate exposures. Obviously, exposures associated with all uses of chlorpyrifos products have not been monitored. Therefore, the available data were used to evaluate similar uses (i.e., lawn studies used to evaluate yard and ornamental sprays, residential crack and crevice exposure data used to evaluate similar treatments in other buildings).

HED is in the process of revising the residential exposure assessment SOPs and plans to present some of the major issues to the Science Advisory Panel (SAP) in July 1999. This process may identify specific areas of further concern with respect to chlorpyrifos and exposure to the general population. For example, some of the secondary exposure pathways that EPA is currently addressing and that will be presented to the SAP include exposures resulting from residue tracked into homes from outdoor use, indoor dust, and spray drift. In a recent study, polycyclic aromatic hydrocarbons (PAHs) that are abundant in house dust were shown to increase the toxicity of chlorpyrifos in vitro, particularly at low levels (i.e., 2-50 μM PAHs with 1-180 nM chlorpyrifos-oxon, a metabolite of chlorpyrifos that inhibits acetyl cholinesterase) (Jett et al. 1999). Currently, there are no SOPs available to evaluate these potential exposure pathways. These scenarios however, may be evaluated in the future pending revisions to the residential SOPs.

There is insufficient use information and exposure data to assess exposure resulting from use in vehicles (i.e., planes, trains, automobiles, buses, boats) and other current label uses such as treatment of indoor exposed wood surfaces, supermarkets, restaurants, theaters, furniture, and draperies. However, HED has concern for these uses based on the scenarios assessed within this document.

Risk and Uncertainty Characterization

Occupational/Residential Handler Risks

The following scenarios result in MOEs that exceed HED's level of concern (i.e., MOE less than 100 and 300 for occupational and residential pesticide handlers, respectively):

- Indoor Crack and Crevice Treatment by a PCO and residential applicator;
- Broadcast Turf Treatment by a PCO (intermediate and long-term applicator, mixer/loader) and short-term residential mixer/loader/applicator;
- Spot Treatment of Turf by a residential mixer/loader/applicator;
- Application of Insecticidal Dust Products by a worker and residential applicator;
- Application of Granular Baits by a PCO and residential applicator (by hand, belly grinder or push-type spreader);
- Termiticide Treatments for Pre-Construction by a PCO;
- Termiticide Treatments for Post-Construction by a PCO;
- Paintbrush Applications by a residential applicator; and
- Ornamental Application by a residential mixer/loader/applicator.

The following scenarios result in MOEs greater than 100 and 300 that do not exceed HED's level of concern for occupational or residential pesticide handlers, respectively:

- Ready-to-Use Formulated product (Ant Stop) containing 0.5% ai chlorpyrifos, and
- Mixer/loader of lawn care products wearing PPE, and working less than several months a year (i.e., intermediate-term duration).

The results of the PCO handler assessment in residential settings for intermediate and/or long-term exposure scenarios indicate that most of the MOEs are less than 100, and therefore exceed HED's level of concern. The only intermediate-term scenarios that result in a MOE consistently above 100 is the use of a 0.5% ready-to-use formulated product (MOE = 140), and lawn care professionals that wear PPE and mix and load lawn products for intermediate durations (i.e., less than several months a year) (total MOEs 140-160). The majority of risks were estimated based on chemical-specific biomonitoring studies submitted by Dow AgroSciences (i.e., indoor crack and crevice treatment, broadcast turf application, ready-to-use formulated product, and pre- and post-construction termiticide treatment) in which the PCOs wore label-specified personal protective equipment (PPE). Several of these studies did not apply the product at the maximum label rate, or only evaluated exposures for a few hours (i.e. 1-3 hours) of the work day, and consequently could underestimate exposures and risks to PCOs. Overall, the exposures and risks for PCOs based on the chemical-specific biomonitoring studies are considered to be central tendency estimates because they evaluated less than a full day's exposure at the maximum label rate or they exclude accidental exposure (e.g., exposure resulting from a broken hose). In the absence of chemical-specific data, PCO exposures were estimated using data from PHED or the

Draft Residential SOPs. The PHED data used for the mixer/loader for lawn treatment, and granular bait application (hand, belly grinder and push-type spreader) scenarios are representative of the chlorpyrifos uses as the surrogate data were monitored for the same uses. In the absence of PHED data, (e.g., dust application) the Draft Residential SOP assumptions were used.

The results of the residential handler assessment for short- term exposure scenarios indicate that eight of the nine scenarios evaluated have total MOEs that exceed HED's level of concern defined by a target MOE of 300. The only short-term scenario that results in a MOE above 300 is the use of a 0.5% ready-to-use formulated product. MOEs exceeding HED's level of concern for the residential handler ranged from 1 to 897 for dermal risk, from 2.5 to 56,700 for inhalation risk, and from 0.8 to 880 for total risk. For a number of scenarios, multiple evaluations were conducted using application rates less than the maximum label rate, or application using different equipment or methods (i.e., ornamental treatment via low pressure hand wand and hose-end sprayer, and granular application via hand, belly grinder and push-type spreader) to assist in risk mitigation and management decisions. In some of these instances, the MOE was greater than 300. Due to an absence of chemical-specific homeowner applicator studies, the majority of residential applicator risks were estimated based on the data from the Draft Residential SOPs (i.e., indoor crack and crevice treatment, broadcast turf application, insecticidal dust product use, granular bait application, paintbrush application, and treatment of ornamentals). In all cases, it was assumed that residents wore short pants, short sleeves, and no gloves, in accordance with current Agency policy. Only one of the residential handler scenarios was evaluated using chemical-specific data submitted by Dow AgroSciences.

Postapplication Residential Risks

The following scenarios result in MOEs less than 300 that exceed HED's level of concern:

- Broadcast Turf Treatment Using a Liquid or Granular Formulation;
- Yard Sprays;
- Indoor Crack and Crevice Treatment;
- Pet Collar Products; and
- Termiticide Treatments for Basement, Plenum and Slab Construction Homes (some of the MOEs for children exceed HED's level of concern).

While the following scenarios result in MOEs predominantly greater than 300 that do not exceed HED's level of concern for postapplication residential exposures:

- Aerial and ground-based fogger mosquitocide application; and
- Termiticide treatment (crawl space homes).

The results of the residential postapplication exposure scenarios indicate that seven of the eight scenarios evaluated have MOE that are less than 300, and therefore exceed HED's level of concern. Many of the MOEs exceeded HED's level of concern for residential postapplication exposure. MOEs ranged from 7.5 to 3700 for total risk. The only scenario that resulted in a

MOE consistently above 300 was from the aerial and ground-based fogger mosquitocide applications. The MOEs following termiticide treatment of crawlspace homes were above 300, however, treatment of other construction type homes for termites resulted in MOEs below 300 for children. The majority of residential postapplication risks were estimated based on chemical-specific studies submitted by Dow AgroSciences (i.e., crack and crevice treatment of the kitchen and bathroom, broadcast treatment of turf with chlorpyrifos spray and granules, and termiticide treatment). The exposure and risk estimates based on the chemical-specific studies are considered to be reasonable estimates (i.e., arithmetic average exposure was used to calculate risk). Because these studies were conducted in adults, conservative assumptions were used to estimate child exposures. However, because adult activity patterns differ from children, i.e., hand-to-mouth activity, some of the registrant-submitted chemical-specific studies could under-estimate a child's exposure (e.g., lawn studies are not designed to reflect any potential for incidental ingestion of residues from treated turf, soil and/or granules). In the absence of chemical-specific data, exposures were estimated based on data from the Draft Residential SOPs (i.e., indoor crack and crevice treatment, and pet collar uses), which are considered to result in high-end risk estimates. Scientific literature studies, the AgDrift Model and the Draft Residential SOPs were used to evaluate mosquitocide uses.

No data are available to evaluate the postapplication residential exposures and risks associated with the use of insecticidal dust products indoors. In addition, there are no recommended procedures for evaluating these products in the Residential SOPs. Nevertheless, HED has concerns about the use of these products based on the very low MOEs (i.e., < 10) calculated using the Residential SOPs for residents or workers that could apply these products. HED recommends that the registrant provide additional information on the potential postapplication residential exposures associated with these products.

Furthermore, to put the exposure estimates in perspective, based on the short-term dermal NOAEL of 5 mg/kg/day for chlorpyrifos, to reach a MOE of 300 a person could only receive 1/8th of a water size drop of Dursban 1-12 (12.6% active ingredient, EPA Reg No. 62719-56) per day for a short-term duration (1-7 days). However, it is possible that an individual could be exposed to higher doses of chlorpyrifos than 5 mg/kg/day without experiencing adverse health effects because of the large uncertainty factor of 300 applied to protect the most sensitive members of the human population, and the sensitive toxicological endpoint of cholinesterase inhibition used to select the NOAEL for chlorpyrifos. In both animals and humans, significant cholinesterase inhibition usually precedes the onset of clinical signs, which typically occur at higher doses.

1.0 INTRODUCTION

This document is organized as follows:

2.0 Background
3.0 Occupational and Residential Exposure
3.1 Handler Exposures and Assumptions
3.2 Residential Postapplication Exposures and Assumptions
3.2.1 Indoor Postapplications Exposures)
3.2.2 Outdoor Postapplications Exposures)
4.0 Occupational and Residential Risk Characterization
4.1 Risk and Uncertainty Characterization of Handler Exposures
4.2 Risk and Uncertainty Characterization of Postapplication Residential Exposures

2.0 BACKGROUND

Purpose

This document evaluates the potential health effects of occupational and residential exposure to chlorpyrifos, resulting from the residential uses of chlorpyrifos products. Exposures are evaluated for occupationally-exposed Pest Control Operators (PCOs), residents who apply the chlorpyrifos products, and residential populations that may be exposed following pesticide application. This information will be incorporated into the Chlorpyrifos Reregistration Eligibility Decision Document (RED).

Criteria for Conducting Exposure Assessments

An occupational and residential exposure assessment is required for an active ingredient if (1) certain toxicological criteria are triggered and (2) there is potential exposure during use or to persons entering treated sites after application is complete. Both criteria are met for chlorpyrifos.

Summary of Toxicological Endpoints

The Hazard Identification Committee memo, dated March 4, 1999, indicates that there are toxicological endpoints of concern for chlorpyrifos. The endpoints, and associated uncertainty factors used in assessing the risks for chlorpyrifos are presented in Table 1.

Table 1 Chlorpyrifos Hazard Endpoints, Uncertainty Factors and MOEs					
EXPOSURE SCENARIO	**DOSE (mg/kg/day)**	**ENDPOINT**	**STUDY**	**MOE for Workers**	**MOE for Residents**
Acute Dietary (oral)	NOAEL=0.5 UF = 100 FQPA = 3	plasma cholinesterase inhibition at peak time of inhibition (3-6 hours post exposure) at 1 mg/kg.	Blood Time Course Study	NR	300
Short-Term (Dermal)	Dermal NOAEL =5	Plasma and RBC cholinesterase inhibition of 45 and 16%, respectively at 10 mg/kg/day. (Dermal absorption factor not necessary)	21-day dermal rat study	100	300
Intermediate-and Long-Term (Dermal)	Oral NOAEL =0.03	Plasma and RBC cholinesterase inhibition at 0.1 mg/kg/day. (Use 3% dermal absorption)	2 year dog study	100	300
Short-,and Intermediate-Term (Inhalation)	Inhalation NOAEL= 0.1	Lack of effects in 2 rat inhalation studies at the highest dose tested. >40% plasma and >40% RBC cholinesterase inhibition following oral doses of 0.3 mg/kg/day (100% lung absorption assumed)	Two 90 day rat inhalation studies	100	300
Long-Term (Inhalation)	Oral NOAEL= 0.03	Plasma and RBC cholinesterase inhibition at 0.1 mg/kg/day (Assume inhalation and oral absorption equivalent)	2 year dog study	100	300

NR = Not Relevant
UF = Uncertainty Factor
MOE = Margin of Exposure
RBC = Red blood cell

As shown on Table 1, the short-term dermal NOAEL is 5 mg/kg/day from a 21-day dermal rat study, based on plasma and red blood cell (RBC) cholinesterase (ChE) inhibition of 45% and 16%, respectively at 10 mg/kg/day. Therefore, no dermal absorption factor adjustment is necessary. The intermediate- and long-term dermal NOAELs and long-term inhalation NOAEL are 0.03 mg/kg/day based on plasma and RBC ChE inhibition in a 2 year dog study. Because an oral NOAEL was selected, a dermal absorption factor of 3%, and a 100% default inhalation absorption factor (i.e., inhalation and oral absorption are equivalent) were used. Dermal absorption was estimated to be 3 percent based on the ratio of the oral lowest-observed-adverse effect level (LOAEL) of 0.3 mg/kg/day from the rat developmental neurotoxicity study (MRID Nos. 44556901, 44661001) to the dermal LOAEL of 10 mg/kg/day from the 21-day dermal study (MRID No. 40972801) for plasma and red blood cell cholinesterase inhibition. This absorption

factor is comparable to the dermal absorption estimated from human data of 1-3% (MRID No. 00249203).

The short- and intermediate-term inhalation NOAEL is 0.1 mg/kg/day based on lack of effects in two rat inhalation studies at the highest dose tested. At higher oral doses of 0.3 mg/kg/day >40% plasma and >40% RBC ChE were observed in animals. The acute oral NOAEL is 0.5 mg/kg/day from an acute oral rat study that observed 28-40% plasma cholinesterase inhibition 3-6 hours after dosing male rats with a single dose of 1 mg/kg/day (HIARC memorandum from D. Smegal to S. Knizner, March 4, 1999, Document number 013249). The acute oral NOAEL was used to assess short-term exposures resulting from incidental ingestion (i.e., hand to mouth exposure) of less than one week. This is considered appropriate because exposures and risks are calculated for the day of application, when residential exposures are expected to be greatest.

Summary of Use Pattern and Formulation

At this time some products containing chlorpyrifos are intended primarily for residential use, while some are intended primarily or solely for PCO use. Both occupational/PCO (non-agricultural) and residential use are evaluated in this document. Agricultural uses are addressed elsewhere.

Types of Pesticide/Targeted Pest/Use Sites

Chlorpyrifos is an organophosphate insecticide used extensively in residential settings by both residents and pest control operators (PCOs). It is one of the top five insecticides used in residential settings. There are approximately 850 registered products containing chlorpyrifos on the market. Registered uses include a wide variety of food, turf and ornamental plants, as well as indoor products, structural pest control, and in pet collars. It is used in residential and commercial buildings, schools, daycare centers, hotels, restaurants, hospitals, stores, warehouses, food manufacturing plants and vehicles. In addition, it is used as a mosquitocide. In 1998, Dow AgroSciences estimated that 70% of the urban chlorpryifos use involved termite control.

Formulation Types and Percent Active Ingredient

Chlorpyrifos, O,O-diethyl O-(3,5,6-trichloro-2-pyridyl) phosphorothioate, is an insecticide formulated as a wettable powder (containing 50% a.i.), emulsifiable concentrates (41.5-42.8%), dust (containing 0.1-7% a.i.), granular (containing 0.075%-15% a.i.), bait (containing 0.5% a.i.), flowables (containing 30% a.i.), impregnated material (containing 0.5-10% a.i.), pelleted/tableted (containing 0.5-1.0% a.i.), pressurized liquids (0.9-3.8% a.i.), and microencapsulated (0.5-2.5% a.i.). Dow AgroSciences states that formulations with concentrations greater than one pound a.i. per gallon (approximately 13% a.i.) are only to pest control or turf and ornamental professionals. Lower concentrations are available to homeowners from other suppliers for over-the-counter

purchase. Except aerosols, granules and dusts, all formulated end-use products for application are diluted in water to a concentration of 1 percent a.i. or less (Dow AgroSciences 1998).

Method and Types of Equipment Used for Mixing/Loading/Applying

- Handgun (PCO): Broadcast turf application
- Backpack/Low Pressure Handwand Equipment : crack and crevice treatment; spot treatment of turf; ornamental application
- Hose End Sprayer: Broadcast turf treatment, ornamental application
- Termite-injection equipment: subterranean termite control
- Belly-grinder equipment or a push type spreader: turfgrass
- Paintbrush: Treatment of infested wood

3.0 OCCUPATIONAL AND RESIDENTIAL EXPOSURE

3.1 Handler Exposures & Assumptions

EPA has determined that there is a potential exposure to mixers, loaders, applicators, or other handlers during usual residential use-patterns associated with chlorpyrifos. Based on the use patterns and potential exposures described above, 11 PCO/residential handler exposure scenarios were identified for chlorpyrifos.

Mixer/loader/applicator (M/L/A) exposure data for chlorpyrifos were required for a reregistration data call in (DCI) issued September 18, 1991 during the reregistration process, since one or more toxicological criteria had been triggered. Requirements for applicator exposure studies are addressed by Subdivision U of the Pesticide Assessment Guideline. Applicator exposure data were required previously by the Agency. The Pesticide Handlers Exposure Database (PHED), Version 1.1 was used for several scenarios. In addition, studies from the scientific literature were used for other situations.

The following studies monitoring PCO/residential application of chlorpyrifos were submitted by the registrant.

- MRID No./Accession No. 40026001. Vaccaro, J.R. (1986) Evaluation of Airborne and Whole Body Exposure of Lawn Care Specialists to Chlorpyrifos During Routine Treatment of Turf.

- MRID No. 44444801. Vaccaro, J.R. et al. (1997). Determination of Exposure and Dose of General Pest Control Operators to Chlorpyrifos during Routine Applications of Dursban Pro® Insecticide to Crack/Crevices and Spots. November 25, 1997. Laboratory Project Study ID: HEH 785.

- MRID No. 44729401. Barnekow, D.E, and Shurdut, B.A. (1998). Evaluation of Workers' Exposure to Chlorpyrifos During the Use of Dursban Pro® Insecticide Concentrate for Broadcast Turf Applications. November 10, 1998. Laboratory Project

Study ID: HEA 97089.

- MRID No. 44739301. Barnekow, D.E, Cook, W.L., Meitl, T.J., and Shurdut, B.A. (1999). Exposure to Chlorpyrifos Whilt Applying a Ready to Use Formulation. January 14, 1999. Laboratory Project Study ID: HEA 97046.

- MRID No. 44729402. Barnekow, D.E, and Shurdut, B.A. (1998). Evaluation of Workers' Exposures to Chlorpyrifos During the Use of Dursban® TC Termiticide Concentrate for Post-Construction Termiticide Applications. October 9, 1998 (original) and December 22, 1998 (amended). Laboratory Project Study ID: HEA 97054.

- MRID No. 44589001. Murphy, P.G., Beard, K.K., Chambers, D.M., Huff, D.W., Marino, T.A., Melichar, M., and Vaccaro, J.R. (1997). Evaluation of Workers' Exposures to Chlorpyrifos During the Use of Dursban® TC Termiticide Concentrate for Pre-Construction Termiticide Applications. December 15, 1997.

HED reviewed each of these studies and used the registrant-submitted data to estimate exposures to handlers/PCOs applying chlorpyrifos-products in residential settings. A brief summary.of each study is provided below, with reference to HED's memorandum that provides a more detailed review and analysis of the study. It should be noted that a number of the registrant-submitted studies conducted biomonitoring by measuring urinary concentrations of the primary chlorpyrifos metabolite 3,5,6-trichloro-2-pyridinol (3,5,6-TCP), to estimate chlorpyrifos exposures. Prior to the studies, baseline urinary 3,5,6-TCP concentrations were determined in the study volunteers, and these baseline measurements were subtracted from the exposure-related 3,5,6-TCP concentrations measured in the biomonitoring study. It is important to note that most individuals in the U.S., and nearly all the subjects in the Dow AgroSciences biomonitoring studies had low levels of urinary 3,5,6-TCP prior to study commencement, indicating a baseline exposure to chlorpyrifos, which most likely is attributed dietary sources.

In the absence of chemical-specific monitoring data, data obtained from PHED Version 1.1 were used to assess handler exposures for regulatory actions. PHED was designed by a task force of representatives from the U.S. EPA, Health Canada, the California Department of Pesticide Regulation, and member companies of the American Crop Protection Association. PHED is a software system consisting of two parts--a database of measured exposure values for workers involved in the handling of pesticides under actual field conditions and a set of computer algorithms used to subset and statistically summarize the selected data. Currently, the database contains values for over 1,700 monitored individuals (i.e., replicates).

Users select criteria to subset the PHED database to reflect the exposure scenario being evaluated. The subsetting algorithms in PHED are based on the central assumption that the magnitude of handler exposures to pesticides are primarily a function of activity (e.g., mixing/loading, applying), formulation type (e.g., wettable powders, granulars), application method (e.g., aerial, groundboom), and clothing scenario (e.g., gloves, double layer clothing).

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 (e.g., chest, upper arm) is categorized as normal, lognormal, or "other" (i.e., neither normal or 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.

The unit exposure values calculated by PHED generally range from the geometric mean to the median of the selected data set. To add consistency and quality control to the values produced from this system, the PHED Task Force has evaluated all data within the system and has developed a set of grading criteria to characterize the quality of the original study data. The assessment of the data quality is based on a number of observations and the available quality control data. While data from PHED provide the best available information on handler exposures, it should be noted that some aspects of the included studies (e.g., duration, acres treated, pounds of active ingredient handled) may not accurately represent labeled uses in all cases. HED has developed a series of tables of standard unit exposure values for many occupational scenarios that can be utilized to ensure consistency in exposure assessments. This surrogate exposure guide serves as the basis for this assessment. Best available grades are assigned to the unit exposures as follows: matrices with grades A and B data and a minimum of 15 replicates; if not available, then grades A, B and C data and a minimum of 15 replicates; if not available, then all data regardless of the quality and number of replicates. Data confidence are assigned as follows:

High	=	grades A and B and 15 or more replicates per body part;
Medium	=	grades A, B, and C and 15 or more replicates per body part; and
Low	=	grades A, B,C, D and E or any combination of grades with less than 15 replicates.

There are three basic risk mitigation approaches considered appropriate for controlling occupational exposures. These include the use of engineering controls, administrative controls, and the use of personal protective equipment (PPE). Engineering controls are recommended for occupational hazards wherever feasible, because they have the least continual human implementation or intervention necessary in achieving decreased exposure levels. Occupational handler exposure assessments are completed by HED using a baseline exposure scenario and, if required, increasing levels of risk mitigation (PPE and engineering controls) to achieve an appropriate margin of exposure. The baseline clothing/PPE ensemble for occupational exposure scenarios is generally an individual wearing long pants, a long-sleeved shirt, no chemical-resistant gloves (there are exceptions pertaining to the use of gloves and these are noted), and no respirator. The first level of mitigation generally applied is PPE. As reflected in the calculations that follow, PPE may involve the use of an additional layer of clothing, chemical-resistant gloves, and/or a respirator. The next level of mitigation considered in assessing exposure and risk is the use of appropriate engineering controls which, by design, attempt to reduce or

eliminate the potential exposure. Examples of commonly used engineering controls include enclosed tractor cabs, closed mixing/loading/transfer systems, and water-soluble packets. [Note: Administrative controls may include methods such as lowering application rates for handler exposure scenarios.]

Occupational/Residential Handler Exposure/Risk Assessment

The following 11 PCO/residential application scenarios were considered:

(1) Indoor Crack and Crevice or Spot Application

Commercial Applicator (MRID No. 44444801)

The registrant submitted a study that characterizes exposures to professional pest control operators (PCO) during application of 0.29% Dursban Pro® (EPA Reg No. 62719-166) on cracks, crevices, and spot treatment of residential and commercial buildings. The equipment used for spraying the product was a 2-gallon, hand pressurized B&G sprayer. A total of ten professional male PCOs from three state-wide and local pest control companies were evaluated. Five of the ten volunteers performed a second replicate for a total of fifteen replicates. Each volunteer was dressed in long cotton underwear, a cotton overall with long sleeves and long pant legs, cotton socks, chemically-resistant shoes and protective gloves during the mixing process. Eye protection was used by the PCOs when chlorpyrifos was sprayed overhead. HED evaluated this study in DP Barcode 241777 and D241838 (Memorandum from D. Smegal to M. Hartman, April 19, 1999).

Dermal exposure was quantified using passive dosimetry (long cotton underwear, cotton coveralls with long sleeves and long pant legs, and cotton socks; hand washes; and head patches). Inhalation exposure was measured using a personal air pump attached to the test subject's belt. The pump was connected with a cassette containing a polyvinyl chloride filter and a cellulose support pad (37-mm diameter, 0.8-µm pore size) followed by a Chromosorb 102 vapor collection tube to evaluate inhalation exposures in the breathing zone of workers.

The amount of active ingredient (ai) handled per replicate ranged from 0.09 g to 31.04 g (mean = 9.20 g; S.D. = 9.77 g). The volume applied per replicate ranged from 0.02 gallons to 2.8 gallons (mean = 0.84 gal.; S.D. = 0.81 gal.). The sampling time per replicate ranged from 248 to 591 minutes (mean = 378 minutes). Of the sampling time, 2.3 percent (12 minutes) to 43 percent (154 minutes) was used for actual spraying activities (mean = 21 percent, or 76 minutes).

The data were used to estimate dermal and inhalation unit exposures (μg/ lb ai) based on the worker-specific amount handled (lb ai) per day, and the worker-specific total dermal or inhalation exposure based on the dosimetry measurements. The mean dermal and inhalation unit exposures were then used to calculate the total dermal and inhalation doses for three scenarios (average, minimum and maximum) based on the range of chlorpyrifos (lb ai) handled by the PCOs during the 15 replicates. The amount (lb ai) handled per worker varied significantly and ranged from 0.0002 to 0.0684 lb ai, with a mean of 0.02 lb ai.

A summary of the dermal and inhalation dose estimates are presented on Table 2. Because dermal and inhalation unit exposure data sets are lognormally distributed, the current HED policy is to use the geometric mean for assessing exposure. As shown on Table 2, the total dermal dose ranges from 0.005 to 1.75 μg/kg/day, with a geometric mean of 0.51 μg/kg/day. The dose estimates resulting from inhalation range from 0.0015 to 0.52 μg/kg/day, with a geometric mean of 0.15 μg/kg/day. This study demonstrates that on average 71% of the total exposure to PCOs during crack and crevice treatment results from dermal exposure, while inhalation exposure contributes on average approximately 29% of the total dose. The dose estimates from this study were used to assess long-term exposures to a PCO.

The exposure data partially meet the criteria specified in Subdivision U (currently referred to as Series 875 Group A). There is a large variation in the results, due primarily to the large range of chlorpyrifos ai handled (0.09 to 31.04 g), volume applied per replicate (0.02 to 2.8 gallons), sampling time (248 to 591 minutes or 4 to 9.85 hours), spray time (12 to 154 min) and percent chlorpyrifos handled (0.05 to 0.53%). In fact, only two of the fifteen replicates reflect the maximum recommended label concentration of 0.5% chlorpyrifos; an average of 0.29% chlorpyrifos was handled by the fifteen PCOs. In addition, it is possible that different tasks/activities associated with pesticide application in residential and commercial locations contributed to the range of exposures. However, the impact of applicator activities can not be determined due to an absence of study details. Despite the limitations, the data collected in this study are of sufficient scientific quality to be used in the RED document.

Residential Application

In the absence of chemical-specific data, short-term doses to residents that could treat their homes with a crack and crevice product in an aerosol can were evaluated using data from PHED V1.1, and the Residential SOPs. It was assumed that a residential applicator would wear short-sleeves, short pants and no gloves, that an average applicator weighs 70 kg, and applies the entire contents of a 16 ounce aerosol can that contains one percent ai chlorpyrifos (w/w, 0.16 oz or 4.5 g). The estimated doses are presented in Table 2. There is medium confidence in the dermal and inhalation unit exposure estimates from PHED, which are based on 30 dermal replicates of ABC grades, 15 hand replicates of grade A, and 30 inhalation replicates of grade ABC. The representativeness of the PHED data are excellent, as the surrogate study monitored exposures resulting from an insecticide aerosol can while treating baseboards in a kitchen.

(2) Broadcast Turf Application (MRID No. 44729401)

PCO Applicator Exposures

Exposure estimates were derived from a chemical-specific Dow AgroSciences study in which workers were monitored during commercial lawn care application. HED evaluated this study in DP Barcode D252357 (Memorandum from D. Smegal to M. Hartman, April 15, 1999). This study characterizes exposures to lawn care operators that apply an average of 183 gallons of 0.12 percent Dursban Pro (EPA Reg No. 62719-166) by broadcast applications to turf for an average of 6 hours (range of 4.4-8.2 hours). Exposures were estimated based on both dosimetry measurements and biomonitoring of urinary 3,5,6-TCP (the primary metabolite of chlorpyrifos).

The study examined exposures to 15 lawn care insecticide applicators from two different companies in Ohio, that each treated 11-15 turf blocks (one block equals approximately 6,500 ft^2). The total area of treated turf ranged from 74,740 to 97,500 square feet (mean of 95,983 ft^2), while the total amount of chlorpyrifos handled ranged from 1.57 to 2.95 lb ai chlorpyrifos (mean of 2.17 lb ai). In addition, the workers unloaded and reloaded the hose following application to each lawn (i.e., repeated 15 times per replicate). This study does not characterize exposures associated with mixing and loading the insecticide. It was assumed that lawn care professionals could treat lawns for both intermediate and long term durations.

Each PCO wore pre-laundered cotton coveralls, a pre-laundered cotton socks, cotton briefs, and cotton T-shirts (undergarment); and a hat with affixed denim patches. At the end of the application, these dosimeters were collected from each applicator. The coverall and undergarments were sectioned into pieces representing arm, leg, and torso regions. Patches were affixed to the hat to serve as a surrogate for face, head and neck exposure. In addition, each PCO wore chemically-resistant nitrile gloves and knee high chemically-resistant boots (note that knee-high boots are not required by the label).

The total absorbed doses estimated from dosimetry range from 0.21 to 2.24 µg/kg/day, with a mean of 0.88±0.62 µg/kg/day. Approximately 33 percent of the absorbed doses resulted from inhalation and 67 percent from dermal exposure. The total absorbed dose estimated from biomonitoring ranged from 0 to 4.84 µg/kg/day, with an arithmetic mean of 0.65 ± 1.43 µg/kg/day (this average includes seven of the 15 workers that had exposures of zero because the exposure contribution from the application could not be distinguished from the high baseline chlorpyrifos exposure based on pre-study urinary 3,5,6-TCP concentrations). The geometric mean dose for workers who had exposure above baseline levels (n=8) is 0.4 µg/kg/day. In accordance with HED policy, the geometric mean is used to assess exposures because the biomonitoring data are lognormally distributed. The mean values are in somewhat good agreement with the estimates from dosimetry. The biomonitoring arithmetic average for the eight workers who had exposures above baseline was 1.23 µg/kg/day (i.e., excludes the seven workers with no exposure from lawn treatment). The registrant speculated that the highest exposure of 4.84 µg/kg (for OH05) was from a secondary source because 67% of the 3,5,6-TCP was excreted on day 5 post exposure. However, this value was included in the average dose because each volunteer was instructed to avoid chlorpyrifos for 10 days prior and 5 days following the study.

Pre-exposure baseline chlorpyrifos doses ranged from 0.2 to 3.73 µg/kg with a mean of 1.54 µg/kg, despite the fact that workers were instructed to avoid chlorpyrifos exposure 10 days prior to the study initiation. The high baseline chlorpyrifos dose makes it difficult to interpret the biomonitoring results. For example, seven of the fifteen workers had exposure levels (based on urinary 3,5,6-TCP) less than baseline levels, and therefore, their exposure from broadcast turf application is probably within the seven worker-specific baseline range (0.94 to 3.73 µg/kg), and not zero as concluded by the registrant.

The analysis of blood samples drawn from each applicator 24 and 48 hours post exposure indicated that no significant depression in plasma and red blood cell cholinesterase activity, relative to pre-study activity levels, occurred to the applicators after the application of the Dursban Pro insecticide. All of the plasma and red blood cell cholinesterase activities were

within the reference range for the laboratory of 1,000 to 3,500 and 5,300 to 10,000 international units (IU)/ liter (L), respectively except for the plasma pre-exposure level for volunteer OH15 (352 IU/L). It should be noted, however, that in animals peak cholinesterase inhibition occurs 3-6 hours post exposure. In addition, the prior exposure of many of these PCOs may have resulted in suppressed baseline cholinesterase levels.

The lower leg (calves) coverall samples contained approximately 80% of the total coverall chlorpyrifos, despite that only 9% of the dermal dose was attributed to the sock dosimeters. However, it should be noted that each worker wore knee high chemical resistant footwear during application (which is not required by the label). In addition, the exposure from hand washes represented 11% of the total dermal exposure, despite the fact that each worker wore chemically-resistant gloves.

The majority of the exposure data meet the criteria specified in Series 875 Group A. The applications used in this study deviated slightly from those recommended by the label, and are likely to underestimate exposure. For example, the label recommends using 0.03 to 0.12% for high volume broadcast sprays at a rate of 10 gallons/1000 ft^2, whereas, the exposures from this study were based on 0.12% applied at 2 gallons/1000 ft^2. The label recommends that higher concentrations of 0.5% chlorpyrifos be applied using low volume sprays (i.e., 2 gallons /1000 ft^2). Therefore, it is possible that this study underestimates the actual exposures to PCOs following the label recommendations for broadcast treatment (i.e., the study should have either used a four-fold more concentrated solution of 0.5% chlorpyrifos, or increased the spray volume five-fold to 10 gallons/1000 ft^2). For comparison purposes, dose estimates were also calculated based on the adjusted flow rate of 10 gallons/1000 ft^2, as shown on Table 2. The flow-rate adjusted dose estimates are five times higher than the estimated biomonitoring exposures, with a geometric mean of 2 μg/kg/day.

PCO Mixer/Loader Exposures

Because the biomonitoring study did not evaluate exposures for mixer and loading activities, these scenarios were evaluated using PHED V1.1. Three unit exposures for a mixer/loader handling liquid were evaluated and are presented in Table 2. One for baseline (no PPE), another for a single layer of clothing and gloves, and the third for two layers of clothing and gloves. There is high confidence in the dermal and inhalation unit exposure estimates from PHED.

Residential Application

HED has no data monitoring chlorpyrifos exposures to residents during broadcast or spot treatment of turf. Therefore, exposures were evaluated based on data obtained from the Residential SOPs (also from PHED V1.1) for mixing/loading and application activities. This assessment evaluates both the broadcast and spot treatment of turf, which are assumed to be short-term scenarios for residents. For the broadcast treatment, it was assumed that a resident would use a hose end sprayer to treat 0.5 acre/day of turf, which represents the mean to upper-percentile range of the distribution of lawn size, with Dursban 1-12 Insecticide (EPA Reg No. 62719-56; 12.6% ai; 1 lb ai/gallon). For spot treatment of turf, it was assumed that a resident would use a low pressure handwand to treat 1000 ft^2 with the same chlorpryifos product. The dose estimates for residential use assume that individuals wear short pants, short sleeves and no

gloves. For the hose-end sprayer, there is low confidence in dermal and inhalation unit exposure estimates, which are based on 8 dermal and inhalation replicates of C grade data, and 8 grade E hand replicates. For the low pressure handwand (liquid/open pour), there is low confidence in dermal unit exposure estimates, which are based on 9-80 dermal replicates of ABC grade data, and 70 hand replicates of all grades. There is medium confidence in the inhalation unit exposure estimates, which are based on 80 inhalation replicates of ABC grade data. The label recommends diluting 3-12 oz of Dursban 1-12 Insecticide (12.6% ai; 1 lb ai/gallon) with1 to 3 gallons of water. As shown on Table 2, a range of dose estimates were calculated for broadcast treatment, assuming application at both the minimum and maximum dilution rates of 3 to12 oz/gallon/ water/ 1000 ft^2. The short-term dermal doses (not adjusted for absorption) range from 214 to 857 μg/kg, while the inhalation exposures range from 0.07 to 0.27 μg/kg/day. For spot treatment, the maximum application rate of 12 oz ai/gallon water 1000 ft^2 resulted in short-term dermal and inhalation doses of 134 and 0.04 μg/kg/day, respectively. These short-term dermal and inhalation dose estimates are presented on Table 2.

(3) Application of a Ready-To-Use Formulated Product (MRID No. 44739301)

Exposure estimates were derived from a chemical-specific registrant-submitted study in which 15 homeowners were monitored during the application of a ready-to-use formulated product, Ortho Ant Stop containing approximately 0.5% chlorpyrifos. HED evaluated this study in DP Barcode D252738 (Memorandum from D. Smegal to M. Hartman, April 29, 1999). In this study, homeowners applied five 24 oz. ready-to-use disposable bottles (with screw on tops) over a one hour duration to the outside foundation and perimeter of the house, and other areas (e.g., flower beds) where ants were present. A total of fifteen adult volunteers (nine females and six males) in the area of Indianapolis, Indiana were evaluated. The volunteers wore standard clothing that consisted of a short-sleeve coveralls with long pants, underwear, and a baseball style hat, but no gloves. Volunteers wore their own uncontaminated shoes. Each volunteer was instructed not to treat their homes or yards with chlorpyrifos containing products either immediately before, during or after the conduct of the study, and to avoid chlorpyrifos-containing products 10 days prior and 4 days after application. The amount of active ingredient (ai) handled per replicate ranged from 0.015 g to 0.038 g (mean = 0.033 g; S.D. = 0.006 g).

Exposures were estimated based on both dosimetry measurements and biomonitoring of urinary 3,5,6-TCP. Dermal exposure was quantified using passive dosimetry [cotton underwear (T-shirt, briefs or women's underwear), short-sleeve cotton coveralls with long pant legs, and hand washes; and a baseball style hat]. Inhalation exposure was measured using a personal air pump attached to the test subject's belt. The pump was connected by tygon tubing with a 37-mm mixed cellulose ester filter (0.8-µm pore size) connected to a Chromosorb 102 vapor collection tube to evaluate inhalation exposures in the breathing zone of volunteers.

The total absorbed dose estimated from passive dosimetry range from 0.03 to 0.86 µg/kg/day, with a mean of 0.25±0.25 µg/kg/day. Approximately 12 percent of the absorbed dose, as estimated from the passive dosimetry data, resulted from inhalation (mean 0.03 µg/kg/day) and 88 percent from dermal exposure (0.23 µg/kg/day). The total absorbed dose estimated from biomonitoring ranged from 0 to 1.9 µg/kg/day, with an arithmetic mean of 0.49 ± 0.59 µg/kg/day, and a geometric mean of 0.24 µg/kg/day. The mean values are in somewhat good agreement with the estimates from dosimetry. The biomonitoring results are slightly higher, but

given that hand wash residues contribute on average 57% of the total dermal exposure, it is possible that the volunteers may have incidentally ingested chlorpyrifos as well (which would only be captured in the biomonitoring results). Baseline chlorpyrifos pre-exposure ranged from 0.05 to 0.3 μg/kg with a mean of 0.12 μg/kg, despite the fact that volunteers were instructed to avoid chlorpyrifos exposure 10 days prior to the study initiation.

The geometric mean biomonitoring dose estimate of 0.24 μg/kg/day is used in this risk assessment in accordance with HED policy for lognormally distributed data sets. This dose estimate was divided into dermal and inhalation doses based on the passive dosimetry results, (i.e., 88% dermal and 12% inhalation), because there are different short-term inhalation and dermal endpoints for risk assessment. The resulting absorbed dose estimates used in the risk assessment are 0.029 μg/kg/day for inhalation and 0.21 μg/kg/day for dermal, as shown on Table 2. For short-term scenarios (such as residents), the absorbed dermal dose estimate from the biomonitoring results (absorbed dose) was further adjusted to an estimated dermal non-absorbed dose of 7 μg/kg/day (using a 3% dermal absorption factor) for direct comparison with the short-term dermal toxicity endpoint. These dose estimates represent a central-tendency to high-end scenario for residential applicators, who are more likely to apply one can of product rather than the five cans used in the study, but could wear shorts rather than long pants. These dose estimates represent a reasonable scenario for a commercial applicator because even though the volunteers wore short-sleeves and no gloves, PCOs would presumably be applying the product more than one hour/day.

This study met most of the requirements contained in the Series 875 Group A, Applicator Exposure Monitoring Test Guidelines, and the data are useful for risk assessment.

(4) Insecticidal Dust Product Application (Bulbous Duster or Shaker Can)

HED has no data monitoring exposures from chlorpyrifos application using a duster. This scenario was evaluated using two methods. First, the residential SOPs were used to evaluate this exposure scenario for both residential applicators (handling dust products that contain 1% ai) and utility workers (i.e., during application of product to underground wires or cables) that could handle a more concentrated product (7% ai, EPA Reg 13283-17). The Residential SOPs recommend that 10% of ai is available for dermal and inhalation exposure to applicator. It was assumed that dermal exposure contributed 99% to the total exposure, while inhalation contributed only 1% based on the relative exposure estimates for a wettable powder during open mixing and loading from PHED V1.1. It was assumed that a residential applicator would be exposed short-term (i.e., 1-7 days), and that a worker could be exposed intermediate-term (i.e., 7 days to several months).

In addition, exposures were derived from 24 replicates obtained from a study in the scientific literature (Kurtz and Bode 1985) in which a dust formulation was applied to a home garden. (This analysis is presented in memo from D. Jaquith to Chlorpyrifos file, June 11, 1996 entitled Documentation of Applicator Exposure Assessment for Chlorpyrifos Reregistration Eligibility Document--Application in the Residential Environment). An assumption of 0.02 lbs ai was used based on the amount of dust handled in each 15 minute replicate. The dose estimates for chlorpyrifos were derived from a surrogate study in which a 5 percent carbaryl dust was applied using a shaker can to corn and beans in a residential. This is conservative for chlorpyrifos

because most of the dust products contain 1% or less of chlorpryifos. Only one product (Rainbow Kofire Ant Killer) intended for commercial use contains 7% chlorpyrifos.

In this study, applicators dispensed 190 to 220 g of the dust product (9.5-11 g ai or 0.021-0.024 lb ai) to either corn or beans. In comparison, a typical dust product that a resident could dispense contains approximately 2.83 g ai, while a worker could dispense up to 7.9 g ai chlorpyrifos to underground wires or cables. Measurements were taken of the total deposition of the material on the skin/clothing surfaces. The product was applied for 15 minutes, enough time to treat an average home garden. The total potential dermal exposure, measured using total deposition was 11 mg per 15 minute treatment (5.0×10^3 mg/lb ai). Respiratory exposure was not measured.

There are no data adequate to determine the amount of protection that clothing offers to dust formulations. It was assumed that areas covered by clothing offer 50 percent protection and that gloves offer 90 percent protection. The estimated exposure for individuals based on total deposition, wearing long pants, long sleeves, and gloves is 4.5 mg per15 minutes ($2.2\text{x } 10^3$ mg/lb ai), while the total deposition for individuals wearing long pants, short sleeves with no gloves is 4.9 mg per 15 minutes ($2.0\text{x } 10^3$ mg/lb ai). As shown on Table 2, the resulting short-term dermal dose estimated from this data range from 64 and 70 μg/kg/day, depending on the clothing worn.

(5) Granular Bait Application by Hand

HED has no data monitoring exposures from chlorpyrifos application of granular bait by hand. Therefore, exposures were evaluated based on data obtained from PHED V1.1. for PCOs, and the Residential SOPs for residential applicators (also from PHED V1.1). The unit exposure estimates for PCOs assume workers wear chemical-resistant gloves plus long-sleeve shirt and long pants. There is medium confidence in the dermal and inhalation unit exposure estimates, which are based on 16 dermal, 15 hand, and 16 inhalation replicates of ABC grade data. It should be noted that the PHED unit exposure estimates are based on a single study in which a test subject wearing chemical-resistant gloves spread the granular bait around the outside of the residence and over 90 percent of the samples contained no detectable material. The dose estimates for residential use assume that individuals wear short pants, short sleeves and no gloves. There is also medium confidence in the unit exposure estimates for residential exposure, which are based on 16 dermal, hand and inhalation replicates each of ABC grade data. It was assumed that an average application dispensed is 0.97 lbs of active ingredient. This was the average amount of active ingredient handled in the 55 replicates for application of granular bait in the studies cited in PHED. It was assumed that a PCO could apply a granular bait for durations greater than 7 days and up to several months (i.e., intermediate term), while a resident is more likely to apply a granular bait once or twice a season (i.e., short-term).

(6) Loading Granular Formulation and Applying with Belly-Grinder Equipment

HED has no data monitoring exposures from chlorpyrifos application of granular bait using a belly-grinder. Therefore, exposures were evaluated based on data obtained from PHED V1.1. for PCOs, and the Residential SOPs for residential applicators (also from PHED V1.1). The unit exposure estimates for PCOs assume workers wear chemical-resistant gloves plus long-sleeve shirt and long pants. There is low confidence in the dermal unit exposure estimates, which are based on 29 to 45 dermal replicates of ABC grade, and 20 hand replicates of all grades of data.

There is high confidence in the inhalation unit exposure estimates which are based on 40 replicates of AB grade data. The unit exposure estimates for residential use assume that individuals wear short pants, short sleeves and no gloves. There is also medium confidence in the dermal unit exposure estimates for residential exposure, which are based on 20 to 45 dermal, and 23 hand replicates each of ABC grade data. There is high confidence in the inhalation unit exposures, which are based on 40 replicates of AB grade data. Similar to the scenario discussed above, it was assumed that an average application dispensed is 0.97 lbs of active ingredient. This was the average amount of active ingredient handled in the 55 replicates for application of granular bait in the studies cited in PHED. It was assumed that a PCO could apply a granular bait for durations greater than 7 days up to several months (i.e., intermediate term), while a resident is more likely to apply a granular bait once or twice a season (i.e., short-term).

(7) Loading Granular Formulation and Applying with a Push-Type Spreader

HED has no data monitoring exposures from chlorpyrifos application of granular bait using a push-type spreader. Therefore, exposures were evaluated based on data obtained from PHED V1.1. for PCOs, and the Residential SOPs for residential applicators (also from PHED V1.1). The unit exposure estimates for PCOs assume workers wear chemical-resistant gloves plus long-sleeve shirt and long pants, while residents are assumed to wear short pants, short sleeves and no gloves. There is low confidence in the dermal unit exposure estimates for PCOs and residential applicators due to inadequate replicate numbers, which are based on 0 to 15 dermal replicates of C grade data, 0 hand replicates for PCOs and 15 hand replicates each of C grade data for residents. There are no head, neck or hand replicates for the PCO clothing scenario. For residents, a 50 percent protection factor was used to back calculate a short-sleeved scenario from the long sleeved data. There is high confidence in the inhalation unit exposure estimates for both PCOs and residents, which are based on 15 replicates of B grade data. Similar to scenario discussed above, it was assumed that an average application dispensed is 0.97 lbs of active ingredient. This was the average amount of active ingredient handled in the 55 replicates for application of granular bait in the studies cited in PHED. It was assumed that a PCO could apply a granular bait for durations greater than 7 days up to several months (i.e., intermediate term), while a resident is more likely to apply a granular bait once or twice a season (i.e., short-term).

(8) Pre-Construction Termiticide Use for Subterranean Termite Control (Mixing/Loading and Applying) (MRID No. 44589001)

Exposure estimates were derived from a chemical-specific study submitted by Dow AgroSciences in which workers were monitored during application of chlorpyrifos, as the termiticide Dursban® TC (43.2% ai), during pre-construction termiticide treatments. HED evaluated this study in DP Barcode D247635 (Memorandum from J. Cruz to M. Hartman, May 24, 1999). This study quantified exposures to a mixer/loader/applicator (M/L/A) during mixing/loading/application and tarp pulling processes.

The M/L/A performed an open-pour mixing/loading task in which a PCO loaded Dursban® TC concentrate into a mixing tank containing the appropriate amount of water. After mixing, the diluted product was sprayed onto the tarp using a hand-held sprayer. After the termiticide was applied to the tarp, two workers (tarp pullers) laid the tarp over the excavated area where the concrete foundation was to be poured.

The product was diluted to a nominal rats of 1% (actual 1.44%) prior to application. All applications were made with a low pressure spray equipment fitted with a hand-held hose-end sprayer or spray wand fitted with a shrouded rose nozzle. The flow rates at which the spray was applied to the sites varied depending on the truck, but in general applications were between 8 to 12 gallons/minute. There were 17 M/L/A replicates, representing at least three hours exposure time. There were16 tarp puller replicates each representing 6-7 minutes. Each worker completed 8 tarp pulling replicates in less than one hour. M/L/A wore long underwear, a long sleeved shirt, long pants, and PPE consisting of rubber boots, tyvek or cotton coveralls, and arm-length gloves (note the label only requires a single layer of clothes; the coveralls and arm-length gloves are not required). Each worker removed their PPE after the spray operation was concluded. The tarp pullers wore a long sleeved shirt, long pants socks, leather and/or rubber boots, and a hat. In addition, one half (8) of the workers wore arm-length chemical resistant gloves, while the other half (8) did not wear gloves.

Dermal exposure was quantified using whole body dosimeters, and hand washes. For M/L/A, each participant wore a whole body dosimeter consisting of a long sleeved shirt and pants which were segmented and analyzed to determine potential exposures for the arms, upper legs, lower legs and torso. In addition, an undergarment consisting of one-piece cotton long underwear was collected to determine the penetration of chlorpryifos through outer clothing onto skin. Note that M/L/A replicates also wore a Tyvek (9 replicates) or cotton (8 replicates) coverall on top of the whole body dosimeter as personal protective clothing. A hat with a denim patch was analyzed to quantify head, neck, and face surface deposition.

Air samples were collected using a personal air sampling pump connected to a 37-mm GN-4 filter in series with a Chromosorb 102 tube. The filters were used to collect particulates while sorbent tubes were used to trap vapors. Samples were analyzed using GC-ECD.

As shown on Table 2, the average dermal absorbed dose (assuming a 3% dermal absorption rate) for the M/L/A wearing a single layer of clothes is 1.57 μg/kg/day, while the average inhalation dose is 0.45 μg/kg/day, based on passive dosimetry. The average dermal absorbed dose for the M/L/A wearing a double layer of clothes is 0.477 μg/kg/day, while the average inhalation dose is 0.45 μg/kg/day, based on passive dosimetry. These exposure estimates are for a 3 hour exposure measured in the study.

As shown on Table 2, the average dermal absorbed dose for the tarp pullers contacting one tarp without gloves is 0.081 μg/kg/day, while the average inhalation dose is 0.015 μg/kg/day, based on the passive dosimetry measurements. In addition, it was assumed that a worker could pull 8 tarps in one work day, which the study evaluated for construction of townhouses, or other homes under construction in close proximity. Therefore, the average 7 minute exposure for each tarp was multiplied by a factor of 8. The average dermal absorbed dose for the tarp pullers contacting eight tarps without gloves is 0.644 μg/kg/day, while the average inhalation dose is 0.122 μg/kg/day. The average dermal absorbed dose for the tarp puller wearing arm-length chemical-resistant gloves and contacting one tarp is 0.023 μg/kg/day, while the average inhalation dose is 0.021 μg/kg/day based on passive dosimetry. The average dermal absorbed dose for the tarp puller wearing arm-length chemical-resistant gloves and laying eight tarps is 0.177 μg/kg/day, while the average inhalation dose is 0.168 μg/kg/day based on passive dosimetry. It was

assumed that these workers could be exposed for more than several months a year (i.e., long term).

(9) Post Construction Termiticide Use (Mixing/Loading and Applying) for Subterranean Termite Control (MRID No. 44729402)

Exposure estimates were derived from a chemical-specific study submitted by Dow AgroSciences in which workers were monitored during application of chlorpyrifos, as the termiticide Dursban® TC (43.9% ai), during post-construction termiticide treatments. HED evaluated this study in DP Barcode D252357 (Memorandum from G. Bangs to M. Hartman and D. Smegal, April 29, 1999). This study quantified potential pesticide applicator inhalation, dermal, and biological exposure to chlorpyrifos. Post-construction treatments were applied to various construction styles of residential housing (i.e., slab-on-grade, basement, crawlspace and combinations thereof) in Virginia, Alabama, and Georgia. The applicators applied termiticide at a rate of approximately 4 gallons of ~1 percent a.i. dilution (range 0.71-1.24%) per 10 linear feet to an average of 124 gallons per structure (range 40-325 gallons). Mixer/loader/applicator exposures during actual structural work using hand held spray gun or injection rod were monitored by passive dosimetry and limited biomonitoring of volunteer PCO. During applications, the PCOs wore the label-required protection, including a cotton coverall, chemically resistant nitrile gloves, a hat, protective eyewear and a half-facepiece respirator (if working in confined spaces). During mixing/loading, subjects wore *additional* PPE: chemically resistant footwear and an extra coverall or a chemically resistant apron (not required by the label). There were a total of 15 replicates representing 9 different volunteers, from 3 companies in three cities. The study was conducted in compliance with most, but not all, OPPTS guidelines. The biomonitoring was very limited (5 replicates) and mixing/loading exposures were not measured separately from application exposures.

Higher inhalation exposures were encountered in basement and crawlspace applications than during slab treatments. The arithmetic mean inhalation dose is 1.48 μg/kg/day (normalized 70 kg body weight), and ranged from 0.17 to 3.18 μg/kg/day normalized body weight (N=14). The geometric mean dose is 0.91 μg/kg/day. The arithmetic mean value is based on data from 14 replicates because the fifteenth replicate had an unusually high dermal dose (50 μg/kg) resulting from an accident with a broken hose. Average inhalation exposure/hour (average 6.62 hours worked) was 15 μg/hr, with a range of 1.67 to 25.84 μg/hr.

During crawlspace treatments, workers experienced the greatest amount of dermal exposure to the head/neck (~48 percent of the dermal exposure on average). During slab and basement treatments, workers experienced the highest levels of dermal exposure to the legs (~63 percent and ~51 percent respectively on average). During basement treatments, exposure to the hands was greatest (~23 percent of total dermal exposure on average), however the number of application replicates was low (N=3). The arithmetic average dermal absorbed dose (N=14) based on passive dosimetry was 3.28 μg/kg/day with a range of 0.45 to 13.85 μg/kg/day, and excluding the 49.9 μg/kg/day dose due to one replicate being sprayed by a broken hose. The geometric mean absorbed dermal dose is 2.48 μg/kg/day, including the individual sprayed with a broken hose. These values utilize the current HED dermal absorption factor of three percent.

The total mean dose, calculated by addition of average inhalation and absorbed dermal doses,

was estimated to be 4.76 μg/kg/day (normalized 70 kg body weight; N=14; range: 0.82 to 16.7 μg/kg/day), with inhalation representing 31 percent and dermal representing 69 percent of total dose measured via passive dosimetry. Total estimated dose (dermal and inhalation) for the 15th replicate was 50.50 μg/kg/day, which may be considered a typical worst-case exposure because it represents an equipment malfunction (i.e., broken hose).

Total mean absorbed chlorpyrifos dose of 4.27 μg/kg/day measured via the biological monitoring of the five workers in Georgia is slightly higher than the total absorbed chlorpyrifos dose calculated as the sum of 3 percent of total potential dermal dose (corrected for dermal absorption; measured via passive dosimetry) and potential inhalation dose for the same 5 replicates (3.24 μg/kg/day). Total absorbed dose was estimated directly by biomonitoring of the chlorpyrifos metabolite 3,5,6-TCP in the urine samples of five volunteer applicators at the Georgia location (it is unclear why the fifth replicate had the same weight as another, unless one volunteer was monitored for 2 days). The volunteers were told to avoid chlorpyrifos exposure for ten days before the exposure application and for five days after the exposure. Each applicator collected all the urine voided on the day before application, the day of application, and for four consecutive days after initial exposure. The urine was collected at 12-hour intervals. The first day's collection was used as the baseline for correcting exposure calculations. The baseline chlorpyrifos ranged from 0.39 to 3.4 μg/kg(actual body weight)/day, with a mean of 1.1 μg/kg/day. The difference in estimated absorbed dose levels between biomonitoring and passive dosimetry may be due to various factors, including: incidental oral exposure to chlorpyrifos; field spike recovery from coveralls was consistently low (mean = 22 % ± 13%), so losses may not have been fully accounted for, or; subjects participating in biological monitoring experienced exposure to chlorpyrifos outside the study setting. (Note: the low field recovery data were factored into the dose estimates).

In at least three cases (replicates AL03, GA13, GA14), significantly more ai was reportedly applied than was handled, and the study report does not explain how that is possible (i.e., did the applicators use other, previously prepared solution in addition to their own?). In order to analyze the unit dose per pound ai handled, the average of the pounds "handled" and "applied" was utilized. A range of unit dose based on passive dosimetry was obtained by applying the mean exposure of the 14 replicates to the high (32.7 lb), low (4.0 lb), and mean (10.72 lb) amount of material handled.

(10) Paintbrush Application

HED has no data monitoring exposures to chlorpyrifos resulting from a paintbrush application to treat insect-infested wood. Therefore, exposures were evaluated based on data obtained from the Residential SOPs for residential applicators (also from PHED V1.1). These data represent a worker painting a bathroom with a fungicide-treated latex paint. PCOs were not evaluated for this scenario because they are assumed to treat larger surfaces of wood with rollers or a spray, rather than a paintbrush. The unit exposure estimates for residential use assume that individuals wear short pants, short sleeves and no gloves. There is low to medium confidence in the dermal unit exposure estimates for residential exposure, which are based on 14 to 15 dermal replicates of grade C data, and 15 hand replicates of B grade data. There is medium confidence in the residential inhalation unit exposure estimates, which are based on 15 inhalation replicates of C grade data. For this scenario, it was assumed that an individual could apply one gallon of diluted

chlorpyrifos product (as Dursban 1-12 Insecticide; EPA Reg No. 62719-56) to treat wood infested with insects. The label recommends diluting 5.33 oz of Dursban 1-12 Insecticide (12.6% ai; 1 lb ai/gallon) with 1 gallon of water. The resulting short-term dermal and inhalation dose estimates of 137 and 0.17 μg/kg/day are presented on Table 2.

(11) Ornamental Application

HED has no data monitoring chlorpyrifos exposures to residents during mixing/loading or application to ornamentals (flowers, shrubs, evergreens, vines, shade and flowering trees and other ornamental plants). Therefore, exposures were evaluated based on data obtained from the Residential SOPs (also from PHED V1.1) for mixing/loading and application activities. This assessment evaluates application via both a low pressure handwand and a hose end sprayer, which are assumed to be short-term scenarios for residents. A range of exposure estimates were evaluated for both application methods, the minimum, typical and maximum dilution rates of 1 oz, 4 oz and 1 quart of product per 3 gallons of water. The maximum rate is recommended for beetles. It was assumed that a resident would apply 5 gallons of diluted Dursban 1-12 Insecticide (EPA Reg No. 62719-56; 12.6% ai; 1 lb ai/gallon), in accordance with the residential SOPs for treatment of ornamental trees. The unit exposure estimates for residential use assume that individuals wear short pants, short sleeves and no gloves. For the hose-end sprayer, there is low confidence in dermal and inhalation unit exposure estimates, which are based on 8 dermal and inhalation replicates of C grade data, and 8 grade E hand replicates. For the low pressure handwand (liquid/open pour), there is low confidence in dermal unit exposure estimates, which are based on 9-80 dermal replicates of ABC grade data, and 70 hand replicates of all grades. There is medium confidence in the inhalation unit exposure estimates, which are based on 80 inhalation replicates of ABC grade data. As shown on Table 2, the dermal dose estimates range from 5.6 to 594 μg/kg/day, while the inhalation dose estimates range from 0.0018 to 0.18 μg/kg/day. The use of the low pressure handwand results in higher exposures.

Table 2 presents the exposure scenarios and exposure calculations using the above data sources for the residential uses of chlorpyrifos. Children are not included in this table since children would not be expected to apply this material, although they might be exposed after application.

3.2 Residential Postapplication Exposures & Assumptions

EPA has determined that there is potential exposure to the general public (adults and children) following applications at residential and public sites - indoors and outdoors. Postapplication exposure data were required for chlorpyrifos in a reregistration DCI issued September 19, 1991 during the reregistration process, since, at that time, one or more toxicological criteria had been triggered for chlorpyrifos. The dose estimates are presented in Tables 3 and 4.

The following studies were submitted by the registrant:

- MRID No. 40094001 Airborne Chlorpyrifos Concentrations Measured During and Following Applications of Dursban TC Insecticide to Residential Dwellings. GH-P 1310.

- MRID No. 430135-01 Vaccaro et al. 1993. Chlorpyrifos: Exposure to Adults and Children Upon Reentry to Domestic Lawns, Following Treatment with a Chlorpyrifos-Based Mixture. Study ID No. DECO-HEH2.1-1-182(121).

- MRID No. 441671-01 Vaccaro et al. 1996. Chlorpyrifos: Exposure to Adults and Children Upon Reentry to Domestic Lawns, Following Treatment with a Chlorpyrifos-Based Granular Insecticide.

- MRID No. 444582-01 Byrne et al. 1998. Residential Exposure to Chlorpyrifos from Reentry to Structures Treated with Crack and Crevice and Spot Applications of Dursban Pro.

HED reviewed each of these studies and used the registrant-submitted data to estimate exposures to adults and children in residential settings. A brief summary of each study is provided below, with reference to HED's memorandum that provides a more detailed review and analysis of the study. As noted previously, a number of the registrant-submitted studies conducted biomonitoring by measuring urinary concentrations of the primary chlorpyrifos metabolite 3,5,6-trichloro-2-pyridinol (3,5,6-TCP), to estimate chlorpyrifos exposures. Prior to the studies, baseline urinary 3,5,6-TCP concentrations were determined in the study volunteers, and these baseline measurements were subtracted from the exposure-related 3,5,6-TCP concentrations measured in the biomonitoring study. It is important to note that most individuals in the U.S., and nearly all the subjects in the Dow AgroSciences biomonitoring studies had low levels of urinary 3,5,6-TCP prior to study commencement, indicating a baseline exposure to chlorpyrifos, which most likely is attributed dietary sources.

3.2.1 INDOOR POSTAPPLICATION EXPOSURES.

(1) Crack, Crevice and Spot Treatment of Kitchen and Bathroom (MRID 44458201)

Dow AgroSciences submitted a study designed to estimate chlorpyrifos exposure to adults conducting normal daily activities following treatment of the kitchen and bathroom of three houses with crack and crevice and spot applications of Dursban Pro insecticide (0.5% chlorpyrifos dilution with water) for cockroach control. HED evaluated this study in DP Barcode D242444 (Memorandum from D. Smegal to M. Hartman, December 3, 1998). Between 0.663 and 0.787 L of product (3.32 g to 3.94 g chlorpyrifos) was applied to the houses. Six adults (four women and two men), two from each of the three treated houses, were monitored 1 day pre-application and for 10 days postapplication via urine collection and analysis. The urine was analyzed for 3,5,6-TCP, the primary metabolite of chlorpyrifos. The volunteers were instructed to perform normal activities and to spend at least 12 hours per day inside the treated house. Air monitoring was conducted at two heights in the kitchen (site of application) and family room (adjacent room). In addition, deposition measurements and dislodgeable residues were collected in the family room and a bedroom of each treated house. Dislodgeable residues were measured on hard plastic toys (balls), and also on carpets in the family room and bedroom, to determine the amount of chlorpyrifos available for absorption.

Dislodgeable residues from the carpet and hard toy wipes in non-treated rooms were generally non detectable, indicating that the potential for dermal absorption is low. Based on the

biomonitoring and environmental data collected in this study, the maximum one-day chlorpyrifos dose for the 6 adult volunteers, corrected for baseline exposure, is 0.39 μg/kg/day which is comparable to or less than estimated chlorpyrifos baseline doses of 0.1 - 0.86 μg/kg/day. The overall mean dose to the six volunteers is 0.18 μg/kg/day based on the biomonitoring data, while the mean baseline dose is 0.4 μg/kg/day. The method used to estimate exposures directly measures internal dose and does not differentiate between routes of exposure. However, the study results indicate that the predominant route of exposure is through inhalation.

Exposures to young children were estimated using air concentrations measured 15 inches above the floor, and conservative EPA default exposure assumptions (i.e., breathing rate, body weight and duration of exposure). Dermal and oral exposures were assumed to be negligible based on an absence of detectable dislodgeable residues in the carpet wipes or on hard plastic toy wipes in all three houses, except for a negligible quantity of residue detected on a hard ball in the family room of house #3. For example, if a child ingested the entire residue present on the toy, the resulting dose would be approximately 0.089 μg or 0.006 μg/kg, which is negligible relative to the estimated exposures from inhalation (10 -100 fold less). The estimated 10 day mean doses to children are 0.08, 0.28 and 0.22 μg/kg/day, while the highest one-day doses are 0.27, 0.76 and 0.61 μg/kg/day for houses #1, #2 and #3, respectively. These exposure estimates are also within the background range observed for adults. The one day exposure estimates are conservative, because they assume a child could spend 21 hours exclusively in the room with the highest detected concentration. However, this study did not evaluate chlorpyrifos residues on soft plush toys, which could also contribute to child exposure.

In conclusion, these data demonstrate that exposures to adults and children following crack, crevice and spot applications of chlorpyrifos in the kitchen and bathroom by a licensed applicator are comparable to typical background exposures levels. However, these data do not support the use of crack and crevice or spot treatment in bedrooms, living rooms, closets, day care centers, schools, playhouses, on furniture or draperies, or in other rooms that could result in higher exposure to individuals, particularly children. In addition, these data do not support the indoor application of up to 1% Dursban Pro for the treatment of exposed wood surfaces, voids and channels in damaged wood, wall voids, and junctions between wood and foundation that are currently listed on the label.

In addition, low air concentrations of chlorpyrifos were still present in all three homes 10 days post treatment, however some of the current labels allow re-treatment every 7 days. In one house, the highest daily average air concentrations were detected on the 6th day following chlorpyrifos treatment, indicating possible sinks and resuspension. The results of this assessment are presented in Table 3. This study has not addressed the possible cumulative effects of multiple treatments over time, although, additional information has been requested from the registrant to support a 7 day re-treatment interval as proposed in the Dow AgroSciences submission (MRID 44331901).

(2) Crack and Crevice Treatment of Other Rooms Using Residential SOPs

HED also assessed potential short-term exposures to adults and children using the Draft Residential SOPs (December 18, 1997), to supplement the evaluation of crack and crevice

treatment based on the registrant-submitted biomonitoring study discussed above. This additional assessment was conducted due to the concerns that the registrant-submitted biomonitoring did not adequately evaluate exposures that could occur following treatment of baseboards and window and door frames in family rooms, bedrooms, living rooms or other treatments that could occur in schools, day care centers, playhouses, or the many other buildings listed on the labels.

The highest deposition residue detected in the family room of house #3 (room adjacent to treated kitchen) from the registrant-submitted biomonitoring study was used in this analysis (i.e., 2.298 μg/100 cm^2 collected one day postapplication). This assumption was considered reasonable, although it would have been preferable to have actual residue data from the treated kitchen (these data were not provided). Exposures were estimated for both adults and children, assuming that 50% of the residue is available as dislodgeable residue. The standard default assumptions recommended in the Residential SOPs were used, which include: body weights of 70 and 15 kg for adults and children, respectively, transfer coefficients of 48,000 and 8,700 cm^2 for adults and children, respectively, exposure time of 8 hours for contact with carpet and 4 hours for contact with surfaces, child hand surface area of 350 cm^2, and a frequency of entire hand to mouth activity of 1.56 times/hour. Inhalation exposures were not calculated using the SOPs, because comprehensive air monitoring was conducted in the registrant-submitted biomonitoring study, and HED believes inhalation exposures were adequately characterized. The estimated doses for dermal and oral exposures are presented on Table 3. As shown on the table, the estimated doses are significantly higher than those estimated from the biomonitoring study, suggesting that dermal and oral exposures are of concern in rooms treated with chlorpyrifos.

Scientific Literature on Indoor Broadcast Application

In 1998, scientists at Rutgers University published a study that evaluated exposure to children following a single broadcast use of chlorpyrifos in two apartments by a licensed pesticide applicator (Gurunathan et al. 1998). The Gurunathan et al. (1998) study evaluates a broadcast application, a method which the registrant voluntarily canceled in 1997, that raises some exposure issues not fully addressed by a crack and crevice application study discussed above (MRID No. 44458201). For example, the broadcast study detected chlorpyrifos residues in plush toys placed in treated rooms one hour after application, whereas, the crack and crevice study only measured dislodgeable residues from carpets and hard plastic toys 1 hour to 10 days post-treatment that were placed in untreated rooms (i.e., bedroom and family room) prior to treatment. In addition, the broadcast study accounted for the frequent hand-to-mouth activity of children based on videotaping, which the crack and crevice study could not adequately address because it estimated adult exposures (whose activity patterns are different) based on biomonitoring data. Gurunathan et al. (1998) measured chlorpyrifos in air, plastic and plush toys, and in dust in and on smooth surfaces. This study estimated child doses of 208 μg/kg/day (or 634 μg/kg/day for high hand to mouth contact) based on environmental measurements and conservative exposure assumptions. However, these exposure estimates were not validated by actual measurements of absorbed doses based on urinary excretion of 3,5,6-TCP (as was done for the crack and crevice study discussed above). The study concluded that dermal and oral exposures via toys and other surfaces may present greater risk than inhalation, and that potential inhalation exposure was negligible. In addition, this study observed continued deposition on surfaces in treated rooms 2 weeks postapplication, and demonstrated that chlorpyrifos may adhere to objects brought into a

room hours or days after pesticide application. Peak deposition on surfaces (of plastic toys) occurred 36 hours postapplication (0.043 $\mu g/cm^2$). The authors suggest that the current labels specifying a re-entry time for residents of 1-3 hours based on air measurements may be inadequate, and that routine application could lead to the accumulation in toys or other sorbant surfaces (i.e., pillows). The authors recommend that toys should not be stored in open rooms at least one week after broadcast application of chlorpyrifos.

HED evaluated this study, and concluded that it significantly overestimates the typical child doses resulting from currently registered indoor uses. In addition, the estimates in this study are significantly higher than those estimated based on a broadcast application biomonitoring study submitted by the registrant (MRID No. 42008401), and reviewed by HED (memo from D. Jaquith to D. Edwards, DP Barcode: D168824, August 18, 1995). For example, HED estimated child doses of 23 $\mu g/kg/day$ on day one and 14 $\mu g/kg/day$ on day two following a broadcast application. The following is a list of refinements that need to be considered, or uncertainties that exist in the Gurunathan et al. (1998) study:

- A total of 12 g of chlorpyrifos was applied directly to entire floor surfaces of each room, which is approximately three times more than the amount applied for crack and crevice treatment (3.32-3.94 g based on the study above).
- The toys (plush and plastic) were placed directly on treated surfaces 1 hour postapplication, which enhances the quantity of chlorpyrifos sorbed to the toys, relative to the amounts found from air deposition in the crack and crevice study. Current registered uses (i.e., crack and crevice) are not likely to result in toys contacting treated areas.
- A hexane-methanol solvent was applied to the dresser surfaces and was used in the wipe samples, while hexane was used to extract dust and toy residues. The solvent enhances chemical availability from the surfaces resulting in higher residue measurements than are likely to be absorbed by an individual contacting or handling these surfaces/toys.
- The bioavailability of chlorpyrifos in the toys (i.e., amount available for absorption) was not addressed, as noted by the study authors.
- The exposure estimates assumed that children touch a contaminated surface 366 times/hour and put their contaminated hand in their mouth 70 times/hour. However, it is unlikely that chlorpyrifos concentrations are replenished on the entire hand surface every time a child touches a surface.
- The hand surface area and inhalation rate used to estimate child exposures are higher than EPA's recommended values in the Draft Residential Exposure SOPs or the Exposure Factors Handbook (i.e., study used 400 cm^2 for hand surface area and 12 m^3/day for inhalation rate compared to the mean EPA-recommended values of 350 cm^2 and 8.3 m^3/day, respectively).

The Agency concludes that the screening-level estimate derived in this study can be better refined using values from the EPA's Exposure Factors Handbook, conducting biomonitoring to determine absorbed dose, and using more realistic sampling methodologies.

(3) Pet Collar Uses

A number of pet collars are currently registered. HED has no chemical-specific data that

evaluate exposures to individuals from the use of pet flea collar products. Therefore, HED conducted this analysis in accordance with HED's 1997 Draft SOPs for Residential Exposure Assessments. HED evaluated three pet collars that contained 3-9% ai chlorpyrifos, considered to be representative of these products, in DP Barcode D2532246 (Memorandum from D. Smegal to J. Rowland, March 1, 1999). Exposures were estimated assuming that one percent (0.01) of the active ingredient applied to the pet to be available for dermal and inhalation exposure from handling flea collars. This assumption is based on the best professional judgement of the OPP/HED staff and is assumed to be an upper-percentile value. For this analysis, a range of exposure estimates were calculated. One estimate assumed that exposure was equally divided between the inhalation and dermal routes (i.e., 50% dermal and 50% inhalation), while the other assumed that exposure was exclusively through dermal contact. In addition, EPA-recommended default mean body weights of 70 kg for adults and 15 kg for children age 1-6 years of age were used to estimate dose.

Additional refinements were incorporated into this analysis to account for the duration of exposure (i.e., labeled efficiency of the product is 11 months or 330 days), and to account for the amount of chlorpyrifos that could be dermally absorbed through the skin of humans. A dermal absorption factor was used because the long-term dermal no-observed-adverse effect level (NOAEL) used to calculate MOEs is based on an oral two-year dog study and route-to-route extrapolation. This refinement assumes steady-state exposure to chlorpyrifos. Dermal absorption was estimated to be 3 percent based on the ratio of the oral lowest-observed-adverse effect level (LOAEL) of 0.3 mg/kg/day from the rat developmental neurotoxicity study (MRID Nos. 44556901, 44661001) to the dermal LOAEL of 10 mg/kg/day from the 21-day dermal study (MRID No. 40972801) for plasma and red blood cell cholinesterase inhibition. This absorption factor is comparable to the dermal absorption estimated from human data of 1-3% (MRID No. 00249203). The dose estimates and MOEs for two pet collar products for each age class are presented in Table 3.

(4) Residential Treatment for Subterranean Termite Control (MRID No. 40094001)

A study submitted by the registrant (MRID No. 40094001) was used to determine the respiratory exposures of the residents of homes treated with chlorpyrifos (0.5-1% Dursban TC) for subterranean termite control. Thirty two homes, 8 each of plenum, crawlspace, slab, and basement construction, were treated at several different locations throughout the country. Applications were made by licensed professional applicators using conventional equipment and following the label instructions. Air in the kitchen, one bedroom, and the basements of basement construction homes was monitored before treatment and at various intervals after application for one year.

Treatment of homes with chlorpyrifos for subterranean termite control appears to result in a slightly increased exposure over background levels soon after treatment. Exposures return to background levels within a few days after the application for slab, crawlspace, and the first floor rooms of basement homes. Basements showed higher concentrations of the chemical than first floor rooms. The concentrations in basements declined slowly over time, reaching first floor levels within one year after application. Treatment of plenum structures appears to result in airborne concentrations in first floor rooms that are slightly higher than those observed in other construction types. These increased levels return to background within a few months after

application.

Adults and children were assumed to be in the residence for 16.4 and 21 hours per day, respectively based on EPA default assumptions. The resulting respiratory doses are presented in Table 4. As shown on Table 4, the maximum 1 year average air concentrations ranged from 0.11 to 0.29 $\mu g/m^3$ in the study submitted by the registrant. These concentrations represent the average of the highest detected concentration from 8 homes. However, studies in the published literature measured slightly higher air concentrations (average of kitchen and bedroom) of 1.32-3.13 $\mu g/m^3$ at 1 year postapplication, and similar concentrations of 0.1 to 0.3 $\mu g/m^3$ up to 8 years postapplication in homes of similar construction (slab and crawl construction) (Wright et al. 1988, 1994).

It should be noted that all of these studies only evaluate exposures resulting from treatment of soil outside the home, and do not evaluate the potentially higher exposures that could result from indoor treatment of a termite infestation.

(5) Insecticidal Dust Products

No data are available to evaluate the postapplication residential exposures and risks associated with the use of insecticidal dust products indoors. In addition, there are no recommended procedures for evaluating these products in the Residential SOPs. Nevertheless, HED has concerns about the use of these products based on the very low MOEs (i.e., < 10) calculated using the Residential SOPs for residents or workers that could apply these products. HED recommends that the registrant provide additional information on the potential postapplication residential exposures associated with these products.

3.2.2 OUTDOOR POSTAPPLICATION EXPOSURES

(6) Lawn Treatment using a Liquid Spray (MRID No. 43013501)

Residential exposures following lawn treatment with a liquid chlorpyrifos spray were quantified based on a chemical-specific biomonitoring study submitted by Dow AgroSciences (MRID No. 43013501). In this study, eight volunteers performed activities intended to mimic a child walking/running, sleeping, crawling, and sitting on the turf following a broadcast treatment with 0.29 percent liquid chlorpyrifos spray (as Dursban Turf Insecticide). The insecticide was applied at the maximum label rate of 3 ounces per 1000 ft^2. The activities were performed for a period of four hours, beginning when the turf had dried, four hours after application. Exposures were monitored by measurement of urinary 3,5,6-TCP concentrations. Dislodgeable residues were monitored over the 48 hour period following drying of the turf, and were determined by dragging a weighted patch ("DOW Sled") over the treated surface at various time intervals. It must be recognized that the "Sled" dosimeter represents new technology and that the relationship between dragging a denim patch and transfer to actual human skin has not been established. No data are available for further dissipation after 48 hours, making extended exposure analyses impossible. Due to the design of the biological monitoring study, it was not possible to derive separate exposure values for subsequent days.

The registrant attempted to address the issue of possible exposure of children through hand/oral contact following contact with a treated surface by washing the hands and assuming that all of the material rinsed from the hands was available for oral ingestion. The oral exposure, however, was adjusted for hand surface area (i.e., a child's hand is 41% of an adults hand). There are no quantitative data addressing the possible exposure via the hand/oral route currently available. The assumption was considered to provide a reasonable estimate of exposure via this route.

As shown on Table 3, tor adults, the mean total estimated dose, corrected for baseline, is 6.3 μg/kg/day with a range of 3.5 to 10.1 μg/kg/day for a single exposure event immediately after drying of the treated turf. The extrapolated mean dose estimate for a 1-6 year old child is 10 μg/kg/day with a range of 7.9 to 13 μg/kg/day. This extrapolation to child may underestimate exposure because it neglects incidental ingestion of soil, and/or mouthing grass.

(7) Lawn Treatment using a Granular Product (MRID No. 44167101)

In addition, residential exposures following lawn treatment with chlorpyrifos were quantified for a granular insecticide (MRID No. 44167101). In this study, nine volunteers performed activities intended to mimic a child walking/running, sleeping, crawling and sitting on turf following application of a granular formulation of 0.5% chlorpyrifos at a rate of 1.8 lb active ingredient (ai) per acre. The activities were identical to those evaluated in the liquid lawn study discussed above.

Absorption of chlorpyrifos was determined by monitoring the amount of metabolite 3,5,6-TCP excreted in the urine over an average of 5.5 days following exposure. Based on the biomonitoring and environmental data collected in this study, the mean total dose to 8 adults (4 male and 4 female), corrected for baseline exposure is 1.4 μg/kg/day with a range of 0.56 to 3.7 μg/kg/day. The extrapolated estimate of a child's dose (1-6 yrs old) based on the adult data is a mean of 2 μg/kg/day, with a range of 0.75 to 5.1 μg/kg/day. The method used to estimate exposures directly measures internal dose and does not differentiate between routes of exposure. This extrapolation to child may underestimate exposure because it neglects incidental ingestion of granules or soil. In addition, the exposures may be underestimated for individuals that follow the label because only 75% of the theoretical recommended label rate was applied to the field where exposure activity occurred. However, the amount applied is within the typical variation for the equipment used.

(8) Mosquitocide Uses

HED evaluated potential postapplication bystander exposure to chlorpyrifos from the mosquito control applications. Chemical-specific data are not available. Therefore, literature studies, the AgDrift Model (V1.0) that was developed by the Spray Drift Task Force, and the Residential SOPs were used to develop a screening-level assessment. The use of the literature and Ag Drift Model is consistent with the assessment that was developed in the fenthion RED. No proprietary data from the model library were used in this assessment. The purpose of these model calculations is to refine the turf deposition factor for aerial application of chlorpyrifos in mosquito control public heath treatments. Details of this analysis are presented in DP Barcode D252022, Memorandum from J. Dawson and D. Smegal to S. Knizner and M. Hartman, April 6, 1999.

HED evaluated potential postapplication exposures to adults and child residents entering treated lawns following ground-based fogger Mosquitomist One ULV mosquito control uses. Potential exposures were estimated because of the concern for the residues that may be deposited during the ultra low volume (ULV) ground-based fogger applications in the vicinity of residential dwellings or other recreational areas (e.g., schools, playgrounds, parks, athletic fields). Exposure from ULV aerial applications of Mosquitomist One was evaluated and determined to be negligible. This assessment has been developed to ensure that the potential exposures are not underestimated and to represent a conservative model that encompasses potential exposures received in other recreational areas (e.g., school playgrounds, parks, athletic fields). The evaluated scenarios that could result in postapplication are as follows:

- Dermal exposure from residues deposited on turf (adult and child);
- Incidental non-dietary ingestion of residues deposited on lawns from hand-to-mouth transfer (toddler);
- Ingestion of treated turfgrass (toddler); and
- Incidental ingestion of soil from treated areas (toddler).

Chemical-specific data for mosquito uses are not available. Therefore, the equations and assumptions used for each of these four scenarios were taken from the Draft SOPs for Residential Exposure Assessments guidance document. Although the SOPs were initially developed for direct turf applications, the models are used in this assessment to determine if there is a potential concern using a screening level approach (i.e., tier 1). In addition to the use of the SOPs, the unique nature of the mosquito control uses requires additional information in determining the deposition rate of chlorpyrifos (i.e., amount of ai deposited on residential turf). The determination of the deposition rates are consistent with HED's assessment developed in the fenthion RED. HED did not calculate airborne concentrations and complete an inhalation-based risk assessment because of the infinite dilution that is anticipated in an outdoor application and based on the very low application rate. The dose estimates for adults and children, by pathway, are presented on Table 3.

(9) Yard and Ornamental Sprays

Yard Application

The potential exposures associated with chlorpyrifos-containing yard and ornamental products were evaluated based on a comparison to the exposures associated with liquid and granular insecticidal products for turf (MRID No. 43013501, for liquid insecticide, and 44167101 for granular insecticide). Details of this evaluation are presented in HED Review DP Barcode D2532246 (Memorandum from D. Smegal to J. Rowland, March 1, 1999).

A typical yard and ornamental spray product recommends that a 5.3% ai chlorpyrifos product be diluted at a rate of 4 oz/15 gallons of water, and applied to 500 ft^2 of yard (Ortho® Lawn Insect Spray, EPA Registration No. 239-2423, 1996). In the absence of product density information, the density of water (8 lb/gal) was assumed to estimate a total application rate of 0.0265 lb ai /1000 ft^2 (1.15 lb ai/acre). Therefore, this product application rate is approximately 3.5 times less than the application rate for the liquid turf product of 0.0937 lb ai/1000 ft^2 (i.e., 4.1 lb ai/acre) (MRID No.43013501), and approximately 64 percent of the application rate for the

granular product of 0.0413 lb ai/1000 ft^2 (MRID No. 44167101).

Another turf and ornamental product recommends that a 24.64% ai chlorpyrifos product be applied from 1.5- 6 oz/1,000 ft^2 of yard (Dursban® 2E, EPA Registration No. 9404-66). This product contains 2 lb ai/gallon of chlorpyrifos. Therefore, the product application rate would range from 0.023 to 0.0936 lb ai/1,000 ft^2 (1.0 to 4.1 lb ai/acre), which is similar to the liquid and granular turf application rates.

By analogy, therefore, exposures resulting from the use of these yard insect sprays are expected to be similar or less than those resulting from the lawn insecticides. Average doses for adults are expected to range from 1.4 to 6.3 μg/kg/day for a 4 hour exposure the day of product application. Extrapolated mean doses to children are expected to range from 2 to 10 μg/kg/day. Exclusive ornamental use is expected to result in lower exposures; however, because the labels allow both yard and ornamental uses, the yard use (which results in the higher potential exposures) has been evaluated.

4.0 OCCUPATIONAL AND RESIDENTIAL RISK CHARACTERIZATION

Margins of exposure (MOEs) for occupational and residential exposure were calculated for short-term (one to seven days), intermediate-term (one week to several months), and long-term exposure (several months to lifetime), depending on the scenario. The MOE is calculated by dividing the NOAEL by the daily exposure. The NOAELs presented on Table 1 were used to calculate risks.

The acceptable margin of exposure (MOE) is 300 for oral, dermal and inhalation exposures for all residential populations, including infants and children (including residents). This factor includes 10X for interspecies extrapolation, 10X for intraspecies variation and a 3X Food Quality Protection Act (FQPA) factor. The acceptable MOE for commercial PCOs is 100 for all routes of exposure.

A total MOE is also calculated because there is a common endpoint (i.e., cholinesterase inhibition). Route-specific data are available for the dermal, inhalation and oral routes of exposure, therefore, the following reciprocal MOE calculation is used:

$$MOE_{Total} \quad \frac{1}{\frac{1}{MOE_{(Oral)}} + \frac{1}{MOE_{(Dermal)}} + \frac{1}{MOE_{(Inhalation)}}}$$

4.1 Risk and Uncertainty Characterization of Handler Exposures

MOEs for occupational and residential handler exposure were calculated for short-, intermediate and long-term exposure. Table 2 presents the exposure scenarios and exposure calculations using the above data sources for the non-agricultural occupational uses of chlorpyrifos. Children are not included in this table since children would not be expected to apply this material, although they might be exposed after application.

(1) Indoor Crack and Crevice Treatment. The long-term MOEs for PCOs were calculated

based on passive dosimetry measurements obtained from a chemical-specific registrant-submitted study in which 0.29% Dursban Pro® was applied using a 2-gallon, hand pressurized B&G sprayer. As shown on Table 2, the mean dermal and total MOEs are less than 100 and exceed HEDs level of concern (range from 17 to 59, with total MOEs of 13 and 45) for PCOs that could handle more than 0.02 lb ai per day (the average quantity in the study). Inhalation MOEs are above 100 (197 to 20,000), except for PCOs that handled the maximum quantity in the study (0.0684 lb ai) (MOE is 58). However, the total MOE is 4500, and does not exceed HED's level of concern if a minimal quantity of 0.0002 lb ai chlorpyrifos is handled. Risks were calculated for the full range of exposures evaluated in the registrant-submitted study because there is insufficient information available on the distribution of actual product used by PCOs during crack, crevice and spot treatments. It should be noted that these risk estimates are based on PCOs that wore a double layer of clothes, chemically-resistant boots and gloves and eye protection.

These risk estimates represent an average scenario because only two of the 15 worker replicates reflect the maximum recommended label concentration of 0.5%; an average of 0.29% chlorpyrifos (as Dursban Pro®) was handled by the fifteen PCOs. In addition, as noted previously, there was a large variation in exposure results due primarily to the range of chlorpyrifos ai handled (0.09 to 31.04 g), volume applied per replicate (0.02 to 2.8 gallons), sampling time (248 to 591 minutes or 4 to 9.85 hours), spray time (12 to 154 min) and percent chlorpyrifos handled (0.05 to 0.53%). In addition, it is possible that different tasks/activities associated with pesticide application in residential and commercial locations contributed to the range of exposures. However, the impact of applicator activities can not be determined due to an absence of study details.

The short-term exposures and MOEs for a resident that could apply a crack and crevice aerosol spray to their home were evaluated using PHED V1.1., in the absence of chemical-specific data. As shown on Table 2, the dermal, inhalation and total MOEs are all less than 300, and therefore exceed HEDs level of concern. The total MOE of 100 is due primarily to dermal exposure. These risk estimates are conservative, and assume that a resident will apply an entire 16 oz aerosol can in one day.

(2) Broadcast Turf Applications

Lawn Care Professional

The intermediate and long-term exposures and MOEs were based on a chemical-specific registrant-submitted study that evaluated exposures to 15 lawn care applicators based on both passive dosimetry measurements and biomonitoring of urinary TCP. The geometric mean dose estimate of 0.4 μg/kg/day, used in this assessment is based on the biomonitoring results, which are considered to be more reliable that the passive dosimetry results. However, because the biomonitoring data do not differentiate between route of exposure, only a total exposure estimate and MOE could be calculated. The total MOE of 75 for the lawn care applicator exceeds HEDs level of concern (i.e., less than 100). In addition, risks were calculated for potential chlorpyrifos exposure at the maximum label-recommended application rate of 10 gallons/1000 ft^2, because the study only evaluated an application rate of 2 gallons/1000 ft^2. This results in an approximate MOE of 15, which also exceeds HED's level of concern. These risks are based on workers that

wore a single layer of clothes, chemically-resistant knee-high boots and gloves and a hat.

Because there is insufficient information to determine if lawn care professionals are exposed for intermediate (7 days- several months) or long-term durations, the long-term toxicity endpoints were conservatively used to calculate the MOEs based on the biomonitoring results for applicators. However, the intermediate and long-term dermal endpoints, and long-term inhalation endpoints are identical (30 μg/kg/day) because they are based on the same chronic oral dog study.

Risks were also evaluated for a mixer/loader that could handle liquids using surrogate exposure data obtained from PHED, Version 1.1. As shown on Table 2, the total and dermal intermediate, and long-term MOEs exceed HED's level of concern for the baseline (no PPE) scenario (total MOEs range from 2 to 8) and are dominated by dermal exposure. All of the inhalation MOEs, including baseline, are above 100, and therefore do not exceed HED's level of concern. The use of PPE increases the total and dermal MOEs to levels above 100 for both intermediate- (i.e., 680 to 1400) and long-term (i.e., 380-1400) exposures based on the application rate of 2 gallons/1000 ft^2 used in the registrant-submitted study, and 140 to 280 for intermediate-term and 75 to 280 for long-term exposures based on the maximum label-recommended application rate of 10 gallons/1000 ft^2. The MOEs for mixer/loader activities, which are based on route-specific PHED data, were calculated for both intermediate- and long-term exposures using the appropriate toxicity values (i.e., the intermediate and long term inhalation endpoints of 100 and 30 μg/kg/day, respectively). In conclusion, MOEs do not exceed HED's level of concern for mixer/loaders that wear PPE and only mix/load lawn treatment products less than several months a year.

Residential Applicator

The short-term total MOEs for residents that mix/load and apply chlorpyrifos to their lawns range from 6 to 37, and therefore exceed HED's level of concern for residents (MOEs less than 300). This assessment evaluated both broadcast and spot treatment using the hose end sprayer, and low pressure handwand, respectively, and used exposure assumptions recommended in the Residential SOPs because of the lack of chemical-specific information. The majority of the exposure results from dermal exposure, as all the inhalation MOEs exceed 300.

As noted previously, there is low confidence in dermal and inhalation unit exposure estimates for the hose-end sprayer scenario. In addition, there is low confidence in dermal unit exposure estimates, and medium confidence in the inhalation unit exposure estimates for the low pressure handwand. These MOEs are based on central tendency exposure estimates of the unit exposure, area treated, and body weight, and a central to upper-percentile assumptions for the application rate recommended in the Residential SOPs. Therefore, these MOEs are considered to be representative of central tendency to high-end estimates.

(3) Ready-to-Use Formulated Product. The short-term doses and MOEs were based on a chemical-specific registrant-submitted study that evaluated exposures to 15 homeowners based on both passive dosimetry measurements and biomonitoring of urinary TCP. The geometric mean of the lognormally-distributed dose is estimated to be 0.24 μg/kg/day. This assessment is

based on the biomonitoring results, which are considered to be more reliable that the passive dosimetry results. However, because the biomonitoring data do not differentiate between route of exposure, and the short- and intermediate-term toxicity endpoints are different for dermal and inhalation exposure, the passive dosimetry results were used to segregate the total exposure estimate. As discussed previously, based on the dosimetry data approximately 88% of the total dose was from dermal exposure, while approximately 12% was from inhalation.

As shown on Table 2, the resulting absorbed dose estimates used in the risk assessment are 0.029 µg/kg/day for inhalation and 0.21 µg/kg/day for dermal. For short-term scenarios (such as residents), the absorbed dermal dose estimate was further adjusted to an estimated dermal dose (non-absorbed) of 7 µg/kg using a 3% dermal absorption factor for direct comparison with the short-term dermal toxicity endpoint. The resulting combined dermal and inhalation MOEs are above 100 for PCOs (140) and above 300 for a resident (590), and therefore do not exceed HED's level of concern. These exposure estimates represent a central-tendency to high-end scenario for residents, who are more likely to apply one can of product rather than five cans in a given day, but could wear shorts, rather than long pants. These exposure estimates represent a reasonable central-tendency scenario for a commercial applicator because the volunteers wore a short-sleeve shirt, long pants, and no gloves, but a commercial applicator could apply this product for more than one hour/day.

(4) Insecticidal Dust Products. The exposures and risk estimates resulting from use of insecticidal dust products were evaluated using both the residential SOPs, due to an absence of chemical-specific data, and the scientific literature. As shown on Table 2, the short-term MOEs for both residents and utility workers (i.e., treating underground wires) that could apply dust products are below 100, and therefore exceed HED's level of concern (range of 0.1 to 7.5, with total MOEs in the range of 0.09 to 0.8). These estimates could overestimate exposures and risks because they are based on conservative default assumptions recommended in the residential SOPs (i.e., that an individual will be exposed to 10% of the active ingredient). It was assumed that dermal exposure represents 99% of the total exposure based on wettable powder, open mixing and loading data from PHED. The MOEs based on the scientific literature study that evaluated a 15-minute application of a 5% dust formulation to the garden (Kurtz and Bode 1985) also resulted in MOEs below 100 (71-78), that exceed HED's level of concern. As noted previously, the MOEs from the literature study are high end estimates for a resident who is likely to apply three to four times less active product (i.e., 2.8 g ai.) than the quantity evaluated in this study (9.5-11 g ai). However, these estimates may be reasonable for a utility worker, who is likely to apply a dust product for more than 15 minutes a day.

(5) Granular Bait by Hand. Due to an absence of chemical-specific data, the exposures and risks resulting from hand application of granular bait were evaluated using data from PHED V1.1 and the residential SOPs. As shown on Table 2, the intermediate-term MOEs for a PCO (range from 1-15) and the short-term MOEs for a resident (range from 1 to 15) are less than 100 and 300, respectively and therefore, exceed HED's level of concern. The risk estimates are driven by dermal exposure. As noted previously, there is medium confidence in the unit exposure estimates from PHED that are based on a single study in which a test subject wearing chemical-resistant gloves spread the granular bait around the outside of the residence and over 90 percent of the samples contained no detectable material.

(6) Granular Bait Application with Belly Grinder. Due to an absence of chemical-specific data, the exposures and risks resulting from hand application of granular bait were evaluated using data from PHED V1.1 and the residential SOPs. As shown on Table 2, the total intermediate-term MOEs for a PCO (7) and the short-term MOEs for a residential applicator (3) are less than 100 and 300, respectively and therefore exceed HEDs level of concern. The risks are dominated by dermal exposure. As noted previously, there is low and medium confidence in the dermal unit exposure estimates for PCOs and residents, respectively, and high confidence in the PHED inhalation unit exposure estimates used to evaluated PCOs and residents.

(7) Granular Bait Application with Push-type Spreader. Due to an absence of chemical-specific data, the exposures and risks resulting from hand application of granular bait were evaluated using data from PHED V1.1 and the residential SOPs. As shown on Table 2, the total MOEs for both a PCO (54) (intermediate-term) and residential applicator (110) (short-term) are less than 100 and 300, respectively and therefore exceed HEDs level of concern. The risk estimates are driven by dermal exposure. The inhalation MOEs for both PCOs and residents are 1150, and therefore do not exceed HEDs level of concern. As noted previously, there is low confidence in the dermal unit exposure estimates from PHED and high confidence in the PHED inhalation unit exposure estimates.

(8) Pre-Construction Termiticide Treatment. The long-term doses and MOEs were based on a chemical-specific registrant-submitted study that evaluated exposures to mixer/loader/applicators (M/L/A) and tarp pullers based on dermal passive dosimetry measurements and air monitoring. As shown on Table 2, the mean doses to M/L/A resulting from a 3 hour exposure resulted in MOEs that exceed HED's level of concern of 100 (range 15-33) regardless of clothing (one or two layers). (Note the label requires only one layer of clothing, and does not require forearm length gloves, as worn by the workers). The MOEs a tarp puller were also below 100 for a tarp puller that could contact 8 tarps in one day (as was done in the study), and exceeded HED's level of concern even when the worker wore forearm-length chemical resistant gloves (range of 39-87). However, the MOEs are above 100 for workers that could lay only one tarp (approximately 7 minute duration), with and without gloves (range from 310 to 690). These exposures and MOEs are considered low-end estimates for workers that wore a double layer of clothing and forearm length gloves (not required by the label) and central tendency estimates for the workers that wore single layer of clothing and forearm length gloves (only regular gloves required by the label). These data could underestimate risks to a worker that is exposed for more than 3 hours per day.

(9) Post-Construction Termiticide Treatment. The long-term doses and MOEs were based on a chemical-specific registrant-submitted study that evaluated exposures to 15 PCOs mixing, loading and applying a chlorpyrifos product based on both passive dosimetry measurements and biomonitoring of urinary TCP. Because the biomonitoring measurements were only available for 5 individuals, the risks were calculated using both biomonitoring and dosimetry results. As shown on Table 2, the arithmetic mean biomonitoring dose is 4.27 μg/kg/day and the resulting total MOE is 7 and therefore, exceeds HED's level of concern. The geometric mean absorbed dermal and inhalation dose estimates based on the passive dosimetry are 2.48 and 0.91 μg/kg/day, respectively. The dosimetry dose estimates also result in MOEs that exceed HEDs level of concern (range from 12 to 33, with a total MOE of 9). It should be noted that during application the workers wore the label-specified PPE which includes long pants, long sleeve

shirt, chemically resistant gloves, eye protection, a hat and a half face-piece respirator in confined spaces. In addition, during mixing and loading the workers also wore a second layer of clothes or apron and chemically resistant boots (not required by the label). These dose estimates and MOEs are considered central-tendency values and exclude exposure to a worker whose hose broke during the study, resulting in a dose that was ten times greater than the mean dose of the other 14 workers.

(10) Paint Brush Applications. Due to an absence of chemical-specific data, the exposures and risks resulting from a paintbrush application to treat insect-infested wood by a resident were evaluated using data from the residential SOPs. As shown on Table 2, the total short-term MOE is 35 and therefore, exceed HED's level of concern. The risks are dominated by dermal exposure, which has an MOE of 35. The inhalation MOE is well above 300 (590). There is low to medium confidence in the dermal unit exposure estimates and medium confidence in the inhalation unit exposure estimates. The unit exposure estimates recommended by the residential SOPs are central tendency (i.e., unit exposure values and body weight), and the amount applied (i.e., 1 gallon of diluted product) is also considered an average quantity. Therefore, the MOE is considered to be central tendency value.

(11) Ornamental Application. The exposures and risks to residents during the mixing/loading and application of chlorpyrifos to ornamentals were evaluated using the residential SOPs, due to an absence of chemical-specific data. As shown on Table 2, the total short-term MOEs based on application via the low pressure handwand and hose end sprayer are below 300 (range from 8 to 270), and therefore exceed HED's level of concern. However, the total MOE is greater than 300 (880) if only the minimum rate (1 oz product/3 gallons of water) is applied to ornamentals via the hose end sprayer. These estimates are considered central tendency to high-end values. As noted previously, there is low confidence in dermal and inhalation unit exposure estimates for the hose-end sprayer. For the low pressure handwand, there is low confidence in dermal unit exposure estimates, and medium confidence in the inhalation unit exposure estimates.

4.2 Risk and Uncertainty Characterization of Postapplication Residential Exposures

To calculate the potential risk to persons from postapplication exposures to chlorpyrifos HED used the NOAELs discussed previously. Average body weights of 70 and 15 kg were assumed for adults and children, respectively. As noted previously, the registrant submitted four studies addressing residential postapplication exposures. These studies were used to estimate exposures and risks to residents. One study evaluated residential exposures following crack, crevice and spot treatment of the kitchen and bathroom for cockroach control. Two additional studies, evaluated lawn application (liquid and granular), while another study monitored air levels for one year following termiticide treatment. Where relevant, exposure estimates were based on biological monitoring data (i.e., lawn studies, crack and crevice study) and hand/oral exposure derived from handwash data (i.e., lawn studies). Other exposures were calculated based on environmental measurements (i.e., termiticide use). In the absence of data, the Draft Residential SOPs were used to estimate exposures and risks. The risk estimates are presented in Tables 3 and 4.

HED is in the process of revising the Residential Exposure Assessment SOPs and plans to present some of the major issues to the Science Advisory Panel (SAP) in July 1999. This

process may identify specific areas of further concern with respect to chlorpyrifos and exposure to the general population. For example, some of the secondary exposure pathways that EPA is currently addressing and that will be presented to the SAP include exposures resulting from residue tracked into homes from outdoor use, indoor dust, and spray drift. In a recent study, polycyclic aromatic hydrocarbons (PAHs) that are abundant in house dust were shown to increase the toxicity of chlorpyrifos in vitro, particularly at low levels (i.e., 2-50 μM PAHs with 1-180 nM chlorpyrifos-oxon, a metabolite of chlorpyrifos that inhibits acetyl cholinesterase) (Jett et al. 1999). Currently, there are no SOPs available to evaluate these potential exposure pathways. These scenarios however, may be evaluated in the future pending revisions to the residential SOPs.

There is insufficient use information and exposure data to assess exposure resulting from use in vehicles (i.e., planes, trains, automobiles, buses, boats) and other current label uses such as treatment of indoor exposed wood surfaces, supermarkets, restuarants, theaters, furniture, and draperies. However, HED has concern for these uses based on the scenarios assessed within this document.

(1) Crack and Crevice Treatment of Kitchen and Bathroom. The risks to residents following crack and crevice and spot treatment were evaluated based on a chemical-specific registrant-submitted biomonitoring study that evaluated treatment in the kitchen and bathroom. In this study, biomonitoring results were within the typical pre-exposure baseline levels and HED concluded that the dermal and oral doses were negligible based on dislodgeable residue data and toy wipe samples in rooms adjacent to treatment. Therefore, only passive dosimetry inhalation dose estimates based on air sampling were available. As shown on Table 3, short- and intermediate-term inhalation MOEs for doses following crack and crevice treatment range from 560 to 670 for adults to 130 to 360 for children. Only the child inhalation MOE for the maximum 1 day exposure exceeds HEDs level of concern of 300. As noted previously, the one day dose estimate for a child may be conservative because it assumes a child spends 21 hours exclusively in the room with the highest detected air concentration.

However, the Dow AgroSciences study only evaluated exposures following treatment of the kitchen and bathrooms, while the label for this and similar products allow use in bedrooms, living rooms, closets, schools, day care centers, etc that could result in higher risks to children. Also the Dow study only evaluated small hard ball toys, and not plush toys that could possibly act as a sink for chlorpyrifos (as shown in the published literature). In addition, the study only evaluated use of 0.29% Dursban Pro, which could underestimate exposure because the label recommends concentrations up to 0.5% Dursban Pro for indoor crack and crevice treatments, and up to 1% for the control of wood-infesting insects on wood surfaces, wall voids, and voids and channels in damaged wood.

Low air concentrations were still present 10 days post treatment, however the current labels allow re-treatment every 7 days. This study has not yet addressed the possible cumulative effects of multiple treatments over time. (This information has been requested from the registrant). In one house, the highest daily average air concentrations were detected on day 6 indicating possible sinks, or resuspension.

(2) Crack and Crevice Treatment of Other Rooms. Because the registrant-submitted study

does not adequately address exposures associated with all the uses listed on this and similar product labels, HED also evaluated exposures using the Residential SOPs in conjunction with residue data from this biomonitoring study. The resulting MOEs are all less than 300, and therefore exceed HEDs level of concern. The SOP-calculated values are, however, considered conservative because they use high-end exposure assumptions (i.e., transfer coefficients, and exposure time for contacting a surface). Nevertheless, in the absence of additional data, these SOP-estimated MOEs suggest a health concern for crack and crevice treatment in schools, day care centers, playhouses or other rooms that children may occupy for extended periods of time.

(3) Pet Collar Uses. The residential SOPs were used to assess pet collar exposures due to an absence of chemical-specific data. Residential postapplication MOEs for both cat and dog pet collar products containing 3-9% ai chlorpyrifos are below 300 (MOEs range from 8 to 150) if long-term exposure is assumed to occur through both dermal and inhalation exposure. However, pet collar MOEs are all above 300 (range from 530-2500) if exposure is assumed to be exclusively through the dermal route, except for children exposed to the 9% a.i. dog collar (MOE is 140). Because the Residential SOPs were used to evaluate pet collar use, using conservative assumptions, it is likely that these values over estimate the true exposure and risk. However, at this time HED does not have information that could further refine these estimates. This analysis also does not evaluate potential oral exposures that could result from a child mouthing or chewing on the flea collar, although most labels explicitly state that children should not be allowed to handle or play with the flea collar. Scientists at the Mississippi State initiated a study in April 1999 to evaluate exposures from pet collars containing chlorpyrifos (Personal communication D. Smegal with J. Scott Boone, Research Toxicologist, Center for Environmental Health Sciences, College of Veterinary Medicine, Mississippi State, March 17, 1999).

(4) Termiticide Treatment. Based on a chemical-specific registrant-submitted study, the short-, intermediate- and long-term MOEs for adult residents exposed to chlorpyrifos vapor concentrations for various time intervals following a subterranean termiticide control treatment are above 300 for crawlspace, basement, plenum and slab construction homes and range from 420 to 3700. Therefore, these MOEs do not exceed HEDs level of concern. In addition, the inhalation MOEs for a child in a crawlspace home are above 300 (410 to 770). However, some of the MOEs for children are below 300 for basement, plenum and slab construction homes (MOEs range from 130 to 1100). These MOEs maybe conservative because they assume a child spends 21 hours per day at home.

The Dow AgroSciences study measured air concentrations for up to one year postapplication in four types of homes (n=8/house type). The maximum one year average air concentrations ranged from 0.11 to 0.29 $\mu g/m^3$. Studies in the published literature measured slightly higher air concentrations (average of kitchen and bedroom) of 1.32-3.13 $\mu g/m^3$ at one year postapplication, and 0.1 to 0.3 $\mu g/m^3$ eight years postapplication in homes of similar construction (slab and crawl construction) (Wright et al. 1988, 1994). It should be noted that all of these studies evaluate exposures resulting from treatment of soil outside the home, and do not evaluate the potentially higher exposures that could result from indoor treatment of a termiticide infestation.

(5) Insecticidal Dust Treatment. No data are available to evaluate the postapplication residential exposures and risks associated with the use of insecticidal dust products indoors. In addition, there are no recommended procedures for evaluating these products in the Residential

SOPs. Nevertheless, HED has concerns about the use of these products based on the very low MOEs (i.e., < 10) calculated using the Residential SOPs for residents or workers that could apply these products. HED recommends that the registrant provide additional information on the potential postapplication residential exposures associated with these products.

(6) Lawn Treatment with a Liquid Spray. A chemical-specific registrant-submitted biomonitoring study was used to assess residential exposure following lawn treatment with a liquid spray. The total short-term MOEs for adults and children exposed to lawn treated with 0.29% chlorpyrifos spray range from 7.5 to 9, and exceed HEDs MOE level of concern (i.e., MOE less than 300). Both the dermal and inhalation MOEs also exceed HEDs level of concern and range from 10 to 190. The oral MOE for children of 400 is not of concern.

(7) Lawn Treatment with a Granular Insecticide. A chemical-specific registrant-submitted biomonitoring study was used to assess residential exposure following lawn treatment for a granular insecticide. The total MOEs for adults and children exposed to lawn treated with a 0.5% granular formulation of chlorpyrifos range from 73 to 120, and also exceed HEDs MOE level of concern (i.e., MOE less than 300). The dermal MOEs, which range from 90 to 190, contribute most to the total MOEs, and also exceed HEDs level of concern. The inhalation MOEs range from 330 to 400 while the oral MOE for children is 6000.

It should be noted that the MOEs are based on central tendency dose estimates the day of treatment from state-of-the art biomonitoring studies, and therefore are not conservative. In fact, HED has concerns that the MOEs could be underestimated for young children because both lawn studies did not adequately address incidental ingestion of soil/granules or the more frequent hand to mouth activity of children compared to adults. Oral exposures to children were estimated to be 41% of the residue on an adult's hands (based on a surface area conversion) from a one-time washing. In addition, exposures could be underestimated in some instances because these lawn-care products are used in residential areas, playgrounds, recreational areas, school yards, and golf courses, etc., and it was assumed that a child could be exposed to only one treated turf for 4 hours per day.

The Dow AgroSciences Studies (granular and liquid application) evaluated a 4 hour exposure immediately following treatment (or 4 hours after the liquid insecticide had dried). However, 2 of the hours were spent on a blanket (while sunbathing and picnicking). Also, due to the design of the biological monitoring studies, it was not possible to derive separate exposure values for subsequent days. Furthermore, transferable residue data were not available for the liquid lawn treatment beyond 48 hours after application, making extended exposure analyses impossible. In this study, there was no clear decline in residues during the 48 hours after the turf treated with liquid chlorpyrifos had dried, possibly because of technical problems associated with using a drag over a turfgrass medium. The registrant should conduct transferable residue studies on turf for a period of more than 48 hours and with more samples collected to allow the derivation of a regression for decline of transferable residues over time.

(8) Mosquitocide Use. In the absence of chemical-specific data, the scientific literature, AgDrift Model and the Draft Residential SOPs were used to assess chlorpyrifos as a mosquitocide. The resulting screening-level short-term MOEs for chlorpyrifos mosquito control uses indicate that MOEs are greater than 2300 for all postapplication exposure scenarios for

adults and toddlers for the ground-based fogger mosquito control applications. Exposure resulting from aerial applications of Mosquitomist One ultra low volume (U.L.V) were evaluated and determined to be negligible.

(9) Yard and Ornamental Spray Treatment. By analogy, yard and ornamental spray products were evaluated and determined to result in comparable doses and short-term MOEs with the lawn care products based on label uses and application rates. Therefore, use of many of these products is likely to result in MOEs that exceed HEDs level of concern.

Table 2. Estimates of Exposures and Risks to Commercial Applicators and Residents Applying Chlorpyrifos in the Residential Environment								
Application Scenario	**Unit Exposure (μg/lb ai)**		**Lb ai Handled**	**Central Tendency Dose (μg/kg/day) (a)**		**MOE (b)**		
	Dermal	**Inhalation**		**Dermal**	**Inhalation**	**Dermal**	**Inhalation**	**Total**
(1) Indoor Crack & Crevice Treatment								
Long term PCO with PPE (double layer clothes, chemically-resistant boots and gloves, eye protection) (c)	1790	532	Mean = 0.02	0.51	0.15	59	197	45
			Min = 0.0002	0.005	0.0015	5900	20000	4500
			Max = 0.0684	1.75	0.52	17	58	13
Short-term Residential Applicator (SS, SP, no gloves) (Residential SOPs) (p)	220000	2400	0.01	31.4	0.34	159	292	100
(2) Broadcast Turf Application (Intermediate and Long-Term for PCOs; Short-Term for Residential Applicators)								
Applicator with PPE (d) (single layer clothes, chemically-resistant boots and gloves, hat)	NA	NA	Mean= 2.17 (1.57-2.95)	Total: 0.4 (biomonitoring)		Biomonitoring: 75		
				2 (adjusted to label-recommended max application rate) (j)		Label Max: 15 (j, k)		
Mixer/Loader (liquid) (Baseline)(I)	2900	1.2	2.95 (l)	3.7 (m)	0.05 (m)	8.1	1980 (IT)	8 (IT & LT)
							600 (LT)	
				18.3 (j)	0.25 (j)	1.6	400 (IT)	2 (IT & LT)
							120 (LT)	
Mixer/Loader (liquid) (Single layer clothes, gloves)(I)	23	1.2	2.95 (l)	0.029(m)	0.05 (m)	1032	1980 (IT)	680 (IT)
							600 (LT)	380 (LT)
				0.145 (j)	0.25 (j)	206	400 (IT)	140 (IT)
							120 (LT)	75 (LT)

Table 2. Estimates of Exposures and Risks to Commercial Applicators and Residents Applying Chlorpyrifos in the Residential Environment								
Application Scenario	**Unit Exposure (μg/lb ai)**		**Lb ai Handled**	**Central Tendency Dose (μg/kg/day) (a)**		**MOE (b)**		
	Dermal	**Inhalation**		**Dermal**	**Inhalation**	**Dermal**	**Inhalation**	**Total**
Mixer/Loader (liquid) (double layer clothes, gloves)(I)	17	1.2	2.95 (l)	0.021(m)	0.05 (m)	1400	1980 (IT) 600 (LT)	820 (IT) 420 (LT)
				0.105 (j)	0.25 (j)	280	400 (IT) 120 (LT)	160 (IT) 83 (LT)
Residential Mixer/Loader/Applicator Broadcast with Hose End Sprayer (SS, SP, no gloves) (Residential SOPs)	30000	9.5	0.5 (min. 3 oz/gal)	214 (f)	0.07	23	1470	23
			2 (max 12 oz/gal)	857 (f)	0.27	6	368	6
Residential Mixer/Loader/Applicator Spot treatment with Low Pressure Handwand (SS, SP, no gloves) (Residential SOPs)	100000	30	0.094	134 (f)	0.04	37	2490	37
(3) Ready-to-Use Formulated Product (n)								
Intermediate-term PCO Baseline (SS, LP, no gloves)	NA	NA	7.3E-5	0.21	0.029	143	3,448	140
Short-term Residential Applicator (SS, LP, no gloves)	NA	NA	7.3E-5	7	0.029	714	3,448	590
(4) Insecticidal Dust Product (Shaker Can or Bulbous Duster)								
Residential Applicator (1% ai chlorpyrifos; 2.83 g ai)								
Short-term-Residential SOPs	NA	NA	NA	4000 (f,s)	40	1.2	2.5	0.8

Table 2. Estimates of Exposures and Risks to Commercial Applicators and Residents Applying Chlorpyrifos in the Residential Environment								
Application Scenario	**Unit Exposure (μg/lb ai)**		**Lb ai Handled**	**Central Tendency Dose (μg/kg/day) (a)**		**MOE (b)**		
	Dermal	**Inhalation**		**Dermal**	**Inhalation**	**Dermal**	**Inhalation**	**Total**
Worker (7% ai chlorpryifos; 7.91 g ai)								
Short-term-Residential SOPs	NA	NA	NA	11190 (f,s)	13	0.4	7.5	0.42
Intermediate-term-Residential SOPs	NA	NA	NA	340 (f,s)	13	0.1	7.5	0.09
Kurtz and Bode (1985) 5% ai; 9.5-11 g ai (o) (short-term 15 minute application)								
Residential Applicator (SS, LP, no gloves)	2200000		0.024	70		71		71
PCO (LS, LP, gloves)	2000000		0.024	64		78		78
(5) Granular Bait (Hand Application) (PHED V1.1, Residential SOPs)								
PCO (LS,LP, gloves) (intermediate-term)	71000	470	0.97	30 (g)	6.5	1	15	1
Residential Applicator (SS, SP, no gloves) (short-term)	430000	470	0.97	5960 (f)	6.5	1	15	0.8
(6) Granular Bait (Belly Grinder) (PHED V1.1, Residential SOPs)								
PCO (LS,LP, gloves) (intermediate-term)	9300	62	0.97	3.9 (g)	0.9	8	120	7
Residential Applicator (SS, SP, no gloves) (short-term)	110000	62	0.97	1520 (f)	0.9	3	120	3
(7) Granular Bait (Push-type Spreader) (PHED V1.1, Residential SOPs)								
PCO (LS,LP, gloves) (intermediate-term)	1270 (h)	6.3	0.97	0.5 (g)	0.09	57	1150	54
Residential Applicator (SS, SP, no gloves) (short-term)	3000	6.3	0.97	42 (f)	0.09	120	1150	110

Table 2. Estimates of Exposures and Risks to Commercial Applicators and Residents Applying Chlorpyrifos in the Residential Environment								
Application Scenario	**Unit Exposure (μg/lb ai)**		**Lb ai Handled**	**Central Tendency Dose (μg/kg/day) (a)**		**MOE (b)**		
	Dermal	**Inhalation**		**Dermal**	**Inhalation**	**Dermal**	**Inhalation**	**Total**
Termiticide Treatments (PCOs with PPE)								
(8) Pre-Construction (e) (Long-term)								
M/L/A (single layer clothes; forearm length gloves) (3 hour average exposure) (dosimetry)	NE	NE	NE	1.57	0.45	19	67	15
M/L/A (double layer clothes; forearm length gloves) (3 hour average exposure) (dosimetry)	NE	NE	NE	0.477	0.45	63	67	33
Tarp puller (with forearm-length gloves) (dosimetry)	NE	NE	NE	1 tarp: 0.023	1 tarp: 0.021	1322	1430	690
				8 tarps: 0.177	8 tarps: 0.168	169	179	87
Tarp puller (without gloves) (dosimetry)	NE	NE	NE	1 tarp: 0.081	1 tarp: 0.015	373	1961	310
				8 tarps: 0.644	8 tarps: 0.122	47	245	39
(9) Post-Construction (1% chlorpyrifos as Dursban TC) (long-term) (r)								
Mixer/Loader/ Applicator (PPE =LS, LP, chemically resistant gloves, hat, eye protection and half facepiece respirator in confined spaces; during M/L: 2 layers clothes and chemically-resistant shoes)	NA	NA	10.72 (4-32.7)	biomonitoring: 4.3		7		7
				Dosimetry: 2.5	Dosimetry: 0.91 (no protection)	12	33	9

Table 2. Estimates of Exposures and Risks to Commercial Applicators and Residents Applying Chlorpyrifos in the Residential Environment								
Application Scenario	Unit Exposure (μg/lb ai)		Lb ai Handled	Central Tendency Dose (μg/kg/day) (a)		MOE (b)		
	Dermal	Inhalation		Dermal	Inhalation	Dermal	Inhalation	Total
(10) Paint Brush (Residential SOPs) (Short-term)								
Residential Applicator (SS, SP, no gloves)	230000	284	0.0416	140 (f)	0.17	37	590	35
(11) Ornamental Application (Residential SOPs) (Short-term)								
Residential Mixer/Loader/Applicator Low pressure Handwand (SS, SP, no gloves)	100000	30	0.013 (min. 1 oz/3 gal H20)	18.6 (f)	0.0056	269	17950	270
			0.05 (typical 4 oz/3 gal H20)	71 (f)	0.021	70	4670	69
			0.416 (max. 1 qt/3 gal H2O)	594 (f)	0.178	8	561	8
Residential Mixer/Loader/ Applicator Hose End Sprayer (SS, SP, no gloves)	30000	9.5	0.013 (min. 1 oz/3 gal H20)	5.6 (f)	0.0018	897	56700	880
			0.05 (typical 4 oz/3 gal H20)	21 (f)	0.0068	233	14700	230
			0.416 (max. 1 qt/3 gal H2O)	178 (f)	0.0565	28	1770	28

SS= short-sleeves; LS = long sleeves; LP= long pants, SP = short-pants; IT = intermediate term; LT = long term.

NA = Not applicable

NE = Not evaluated in residential SOPs.

M/L/A = Mixer/Loader/Applicator

(a) Average dose presented, unless otherwise specified. Range of exposure is presented in parentheses. Average dose (μg/kg/day) = average unit exposure (μg/lb ai) * Lb ai handled * dermal absorption factor (intermediate and long term) / 70 kg body weight. Data from PHED is the "best fit" mean exposure (i.e., geometric mean for lognormal distributions, arithmetic mean for normal distributions and median for other distribution types).

(b) MOE = NOAEL/ Dose, where the acute oral NOAEL is 500 μg/kg/day (1 day); short-term dermal NOAEL is 5000 μg/kg/day (less than 7 days), intermediate- and long-term dermal NOAELs are 30 μg/kg/day (greater than 7 days), short- and intermediate inhalation NOAEL is 100 μg/kg/day (1day to several months), and long-term inhalation NOAEL is 30 μg/kg/day (greater than several months). Acceptable MOE ≥ 100 for commercial PCOs and ≥ 300 for residents, which accounts for 10X for interspecies 10X extrapolation for intra-species variability and an FQPA factor of 3. Values rounded to two significant figures.

(c) Exposures based on MRID No. 444448-01 biomonitoring study of PCOs applying 0.29% ai chlorpyrifos wearing the label-specified PPE for crack and crevice applications; therefore no baseline is available. The full range of exposures and MOEs are reported, because there is insufficient information available on the distribution of actual product handled by PCOs in the field.

(d) Exposures based on MRID No. 447294-01, biomonitoring study using 0.12 Percent Chlorpyrifos Spray with PCOs wearing the label-specified PPE for turf application; therefore no baseline is available.

(e) Exposures based on registrant study MRID No. 44589001. Average exposure for M/L/A is 3 hours. Average 7 min exposure for tarp pullers were multiplied by 8, to assume a worker could pull 8 tarps in a work day.

(f) Short-term dermal dose does not adjust for dermal absorption because the short-term dermal NOAEL of 5 mg/kg/day is based on a 21-day rat dermal study.

(g) Intermediate-term dermal dose was adjusted for absorption assuming 3% dermal absorption for comparison with the intermediate-term oral NOAEL of 0.03 mg/kg/day.

(h) Unit exposures from PHED were adjusted to account for 90% protection from gloves.

(i) In the absence of chemical-specific data, surrogate unit exposures obtained from PHED, Version 1.1 were used.

(j) The biomonitoring study applied the 0.12% Dursban Pro at a rate of 2 gallons/1000 ft2, when the label recommends a maximum application rate of 10 gallons/1000 ft2. Therefore, the exposures were conservatively adjusted upwards by a factor of 5 (i.e., normalized to the maximum rate) to account for the difference in application rate.

(k) The exposure estimates were compared to the intermediate and long-term dermal and long-term inhalation NOAEL of 30 μg/kg/day because there is insufficient information to determine if exposures are intermediate or long-term.

(l) Maximum quantity handled from biomonitoring study (MRID No. 44729401).

(m) Absorbed Dermal Dose (μg/kg/day) = Unit exposure (μg/lb ai) * amount handled (2.95 lb ai) * dermal absorption factor (0.03) / 70 kg body weight.

(n) Exposures based on biomonitoring data from MRID No. 44739301, using the geometric mean of 0.24 ug/kg. Passive dosimetry results were used to segregate exposure into dermal and inhalation components due to different toxicity endpoints (see text). Short-term dermal exposure was further adjusted using a 3% dermal absorption factor to obtain a dermal exposure estimate for comparison with the short-term dermal endpoint of 5000 ug/kg.

(o) Short-term exposure estimates based on a study that evaluated the application of a dust product to a home garden (Kurtz and Bode 1985). Exposures are predominantly dermal. See text. Dose (μg/kg/day) =(deposition in study (4.5 or 4.9 mg/15 min) * 1000 μg/mg) / 70 kg

(p) Exposure based on Residential SOPs, and assumes the application of a 16 oz aerosol can that contains 1% ai chlorpyrifos.

(q) Value based on the average amount of active ingredient handled in the 55 replicates of dispensing granular bait from the studies in PHED.

(r) Exposure estimates based on MRID No. 44729402. Biomonitoring results based on 5 individuals, dosimetry data based on 15 individuals.

(s) Dose estimated assuming 10% of ai available for exposure. Dose (μg/kg) = (product ai (g) * 1E+6 μg/g * 0.1 (10% available) * 0.03 (dermal absorption for intermediate duration only)) / 70 kg. Assumes 99% of total exposure is from dermal route (see text).

Table 3. Estimates of Postapplication Exposures and Risks to Residents				
Reentry Scenario	**Central Tendency Dose (μg/kg/day) (a)**		**MOE (b)**	
	Adult (70 kg)	**Child (15 kg)**	**Adult**	**Child**
(1) Crack & Crevice Treatment of Kitchen and Bathroom (c) (Short-term)				
Maximum 1-Day Inhalation Exposure:	0.18 (0.075- 0.39)	0.76 (g)	560	130
10-Day TWA Inhalation Exposure	0.15 (g)	0.28 (g)	670	360
(2) Crack & Crevice Treatment of Other Rooms Using Residential SOPs (o) (Short-term)				
Dermal Exposure From Carpets (p)	56.5	53.4	88	94
Dermal Exposure From Surfaces (p)	28.2	26.7	177	187
Oral Exposure (f)	NE	1.67	NE	299
(3) Pet Collar Uses (11 month efficiency) (long-term)				
Dog: Collar (EPA No. 45087-49; 3.44 g ai)				
Dermal	0.022 (I)- 0.045 (h)	0.1 (I)- 0.21 (h)	670 (h) - 1300 (I)	140 (h) -290 (I)
Inhalation	0.74	3.47	40	9
Total Exposure (l)	0.76	3.6	39	8
Cat Collar (EPA No. 4306-16; 0.93 g chlorpyrifos)				
Dermal	0.006 (I)- 0.012 (h)	0.028 (I)- 0.056 (h)	2500 (h) - 5000 (I)	530 (h) -1100 (I)
Inhalation	0.20	0.93	150	32
Total Exposure (l)	0.206	0.96	150	31
(4) Termiticide Treatment (See Table 4)				
(5) Insecticidal Dust Products (Insufficient data to evaluate; see text)				
Broadcast Turf Application (Short-term)				
(6) 0.29 Percent Chlorpyrifos Spray (d)				
Inhalation	0.59	5	170	20
Dermal (k)	510	414	10	12
Oral	NE	1.26	NE	400
Total Absorbed Dose	6.3 (3.5-8.9)	10 (7.9-13)	9 (m)	7.5 (m)

Table 3. Estimates of Postapplication Exposures and Risks to Residents				
Reentry Scenario	Central Tendency Dose (μg/kg/day) (a)		MOE (b)	
	Adult (70 kg)	Child (15 kg)	Adult	Child
(7) Granular Formulation of 0.5% Chlorpyrifos (e)				
Inhalation	0.3	0.25	330	400
Dermal	27	56	190	90
Oral	NE	0.085	NE	6000
Total Absorbed Dose	1.4 (0.56 - 3.7)	2 (0.75 - 5)	120 (m)	73 (m)
(8) Aerial and Ground-Based Fogger Mosquitocide Application (n) (short-term)				
Dermal	1.38	1.3	3600	3800
Oral (hand to mouth)	NE	0.0816	NE	6100
Oral (Turfgrass Ingestion)	NE	0.0093	NE	54000
Oral (Soil Ingestion)	NE	0.000025	NE	2000000
Total Exposure	1.38	1.39	3600	2300
(9) Yard and Ornamental Sprays (Evaluated based on analogy to Lawn Products; see text)				

NE = Not evaluated because exposure not of concern for adults
TWA = Time weighted average.

(a) Average dose presented, unless otherwise specified. Range of doses is presented in parentheses

(b) MOE = NOAEL/ Dose, where the acute oral NOAEL is 500 μg/kg/day (1 day); short-term dermal NOAEL is 5000 μg/kg/day (less than 7 days), intermediate- and long-term dermal NOAELs are 30 μg/kg/day (greater than 7 days) (absorbed dose), short- and intermediate inhalation NOAEL is 100 μg/kg/day (1day to several months), and long-term inhalation NOAEL is 30 μg/kg/day (greater than several months). Acceptable MOE ≥ 300, which accounts for 10X for interspecies 10X extrapolation for intra-species variability and an FQPA factor of 3. Values rounded to two significant figures.

(c) MRID 44458201. Doses based on biomonitoring and environmental measurements.

(d) MRID 43013501. Doses based on oral, dermal and inhalation exposure based on biomonitoring and environmental measurements. Dose estimated for the day of application only. (See text). Child doses adjusted from original HED review to reflect 1-6 year old child (1.24 m3/day, 15 kg body weight and 0.41 child hand factor ratio relative to adult).

(e) MRID 44167101. Oral, dermal and inhalation dose based on biomonitoring and environmental measurements. Dose estimated for the day of application only. (See text). Dermal absorbed dose from biomonitoring data adjusted to dermal exposure, assuming 3% absorption factor, for direct comparison with dermal NOAEL of 5000 ug/kg from rat dermal study.

(f) Oral hand to mouth dose (μg/kg/day) = available surface residue (1.15E-2 μg/cm2) * surface area of hands (350 cm2) * frequency of hand contact (1.56 events/hr) * exposure time (4 hrs/day) / body weight (15 kg for a child)

(g) Estimate based on the air concentrations detected in house #2, which were higher than those detected in houses #1 and 3.

(h) Dose estimates modified from EPA Review DP Barcode: D253246 (D. Smegal to J. Rowland, March 1, 1999), based on body weight. Assumes 100% dermal exposure.

(i) Dose estimates modified from EPA Review DP Barcode: D253246 (D. Smegal to J. Rowland, March 1, 1999), based on body weight. Assumes 50% dermal exposure and 50% inhalation exposure.

(j) Mean dose is based on mean biomonitoring data. Assumes 100% inhalation exposure.

(k) Absorbed dermal dose readjusted to dermal exposure for direct comparison with the dermal NOAEL of 5000 μg/kg from the dermal rat study. Original HED review estimated absorbed dermal dose assuming a 1% dermal absorption factor.

(l) Total dose assuming 50% dermal and 50% inhalation exposure.

(m) Total MOE = 1 / [(1/MOE inhalation) + (1/MOE dermal) + (1/MOE oral)].

(n) Doses and MOEs based on the application rate of 0.01 lb ai/acre. Inhalation dose was considered to be negligible because of infinite dilution that is anticipated in an outdoor application and based on the very low application rate.

(o) Doses estimated using the highest deposition residue of 2.298 μg/100cm2 in the family room of house number (room adjacent to the treated kitchen). It was assumed that 50% of the residue is available as dislodgeable residue in accordance with the Residential SOPs.

(p) Dermal dose from carpet/surfaces (μg/kg/day) = [available surface residue (0.0115 μg/cm2) * TC (cm2/hr) [43,000 for adults and 8700 for children] * Exposure time (hr/day) [8 hrs/day for carpet and 4 hr/day for surfaces]] / body weight (70 kg for adults and 15 kg for a child).

Table 4
Indoor Chlorpyrifos Air Concentrations and Estimated Exposures and Risks to Residents After Subterranean Termite Control Treatment (a)

Construction Type	Air Concentration (μg/m3) (b)	Dose (μg/kg/day) (d)		MOE (e)	
		Adult (70 kg)	Child (15 kg)	Adult Male	Child
Crawlspace					
Day 1 (c)	0.31	0.046	0.15	2200	670
Day 7 (days 2-7)	0.33	0.049	0.16	2000	630
Day 30 (days 8-30)	0.26	0.039	0.13	2600	770
Day 90 (days 31-90)	0.34	0.05	0.16	2000	630
1 year (days 91-365)	0.15	0.022	0.073	1400	410
Basement					
Day 1 (c)	1.36	0.2	0.66	500	150
Day 7 (days 2-7)	0.77	0.11	0.37	910	270
Day 30 (days 8-30)	0.7	0.1	0.34	1000	290
Day 90 (days 31-90)	0.41	0.061	0.2	1600	500
1 year (days 91-365)	0.29	0.043	0.14	700	210
Plenum					
Day 1 (c)	1.6	0.24	0.77	420	130
Day 7 (days 2-7)	1.56	0.23	0.76	430	130
Day 30 (days 8-30)	1.37	0.2	0.66	500	150
Day 90 (days 31-90)	0.23	0.034	0.11	2900	910
1 year (days 91-365)	0.17	0.025	0.082	1200	370
Slab					
Day 1 (c)	0.87	0.13	0.42	770	240
Day 7 (days 2-7)	0.46	0.068	0.22	1500	450
Day 30 (days 8-30)	0.18	0.027	0.087	3700	1100
Day 90 (days 31-90)	0.32	0.047	0.15	2100	670
1 year (days 91-365)	0.11	0.016	0.053	1900	570

(a) Estimates were derived from a registrant-submitted air monitoring study (MRID No. 40094001)

(b) Air concentrations represent the mean value of the maximum detected concentration from 8 houses of similar construction type.

(c) Time weighted average of the 2, 4, 8 and 24 hour measurements.

(d) Dose calculated as follows: dose (μg/kg/day) = air conc (μg/m^3) * inhalation rate (m^3/day) * hours per day in house/24 hours * 1/body weight (kg). Assumptions are as follows: respiratory volumes of 15.2, and 8.3 m^3/day for an adults and 3 yr old child (average of male and female), respectively (Exposure Factors Handbook 1997 p. 5-24), and body weights of 70 and 15 kg, respectively. In addition, it assumes that adults and children spend 16.4 and 21 hours per day at home, respectively (Exposure Factors Handbook 1997 p.15-17, 15-147)

(e) MOE = NOAEL / dose, where short- and intermediate-term inhalation NOAELs =100 μg/kg/day (1 day to several months) and long-term inhalation NOAEL =30 μg/kg/day (several months to years). Acceptable MOE $\geq$ 300, which accounts for 10X for interspecies extrapolation, 10X for intra-species variability and an FQPA factor of 3. Values rounded to two significant figures.

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