Section 5
Occupational Health & Safety Assessment

GLOSSARY OF TERMS AND ABBREVIATIONS

ai	Active ingredient
bw	Body weight
d	Day
g	Gram
ha	Hectare
kg	Kilogram
L	Litre
m^2	Square metre
mg	Milligram
mL	Millilitre
µg	Microgram
ng	Nanogram
ChE	Cholinesterase
DFR	Dislodgeable foliar residues
DHAC	Department of Health and Aged Care
EC	Emulsifiable concentrate
ECRP	Existing Chemicals Review Program
EMG	Electromyography
GPS	Geographic Positioning Systems
NOEL	No Observable Effect Level
NOHSC	National Occupational Health and Safety Commission
OHS	Occupational health and safety
OP	Organophosphorus pesticide
OPIDN	Organophosphorus induced delayed neuropathy
POEM	Predictive Operator Exposure Model
PPE	Personal protective equipment
PQ	Performance questionnaires
RBC	Red blood cell
REP	Restricted-entry Period
RfD	Reference Dose
WHP	Withholding Period
WP	Wettable powder

1. INTRODUCTION

Chlorpyrifos is an organophosphate pesticide that is widely used in Australia for crop protection and domestic pest control. It also has a minor veterinary use in pet products.

Chlorpyrifos is one of the agricultural and veterinary chemicals identified as candidates for priority review under the National Registration Authority for Agricultural and Veterinary Chemicals (NRA) Existing Chemicals Review Program (ECRP).

In conducting the occupational health and safety (OHS) review, the National Occupational Health and Safety Commission (NOHSC) obtained information from the following sources: the Department of Health and Aged Care (DHAC) Review of chlorpyrifos, industry submissions, NRA performance questionnaires (PQs) initiated as part of the review of chlorpyrifos, NRA Agriculture Report on chlorpyrifos and the published literature.

2. TOXICOLOGY

2.1 Toxic end points

This section describes the main toxicology findings relevant to assigning the toxic end points for the occupational risk assessment. A detailed review of the mammalian toxicology and toxicokinetic/metabolism data on chlorpyrifos is available in the separate toxicology report (DHAC, 1999).

Technical chlorpyrifos is of moderate acute toxicity. The lowest oral LD_{50} is 102 mg/kg bw in mice (96 mg/kg bw in rats), the lowest dermal LD_{50} is 1580 mg/kg in rabbits and the lowest inhalation LC_{50} is 78 mg/m^3 (65% xylene) or >230 mg/m^3 (4h, undiluted) in rats. Chlorpyrifos is a slight to moderate eye irritant and slight skin irritant in rabbits. It is non-sensitising to guinea pig skin.

Female animals were generally more sensitive to the acute effects of chlorpyrifos exposure than male animals.

A number of chlorpyrifos formulations have been tested for acute and repeat dose toxicity. The acute toxicity of chlorpyrifos formulations was related to the level of the active ingredient. In repeat dose tests the most sensitive indicator of toxicity was the inhibition of plasma ChE, followed by erythrocyte and then brain ChE.

In a number of studies, radiolabelled chlorpyrifos administered orally to rats, was excreted rapidly through the urine (80-90%), faeces (10%) and breath (<1). Analysis of urine for metabolites failed to reveal any unchanged chlorpyrifos. The major urinary metabolites were 3,5,6-trichloro-2-pyridinol (TCP) or its conjugates. Tissue accumulation was shown to be low, with residue levels at 72 h being $\leq$ 2% of total dose. Tissues with the greatest residue levels were fat, liver, kidney, intestine and ovaries. Rats exposed via inhalation showed similar chlorpyrifos elimination to oral administration. Radiolabelled chlorpyrifos fed to laying hens, goats, pigs and calves also showed low tissue residue levels, with chlorpyrifos residues mainly in fat and TCP residues mainly in liver and kidney. In these animals all residues were undetectable 7 days after dosing cessation.

Chlorpyrifos is not carcinogenic or genotoxic. In reproductive studies in rats chlorpyrifos did not induce major malformations or significant effects on most reproductive parameters. Developmental studies in mice, rats and rabbits showed foetotoxicity to occur only at maternotoxic doses.

Chlorpyrifos did not produce any irreversible neurotoxicological effects when given to hens or rats as a single or repeated dose. The potential to induce organophosphorus induced delayed neuropathy (OPIDN) was demonstrated in hens at about 5 times the oral LD_{50}, however at these doses extensive and aggressive antidote treatment was necessary to keep the birds alive. The overall experimental evidence suggests that chlorpyrifos does not cause delayed neuropathy.

Summary of human studies

Dow provided the following study as part of the data call-in.

Kilian et al. (1970) carried out a series of experiments on seven human volunteers to determine the amount of chlorpyrifos necessary to evoke ChE depression. Dursban 6 Insecticidal Concentrate (61% chlorpyrifos and 34% xylene) was applied to the skin of the back and abdomen, occluded with gauze-adhesive tape and left undisturbed for 12 hours. After this period, the degree of skin irritation was noted and the area washed with soap and water. Blood samples were obtained prior to exposure and for varying periods post-exposure to determine plasma and RBC ChE activity. In the first experiment, five volunteers were dermally exposed to single doses of between 1 and 7.5 mg/kg body weight of the product. Pre-exposure ChE activity was monitored in all subjects. Post-exposure blood samples were obtained 24 hours (5 subjects), 48 hours (3 subjects) and 72 hours (1 subject) after application. Plasma and RBC ChE activity was not significantly depressed following single exposures, under experimental conditions.

Following the first experiment, the study authors resorted to multiple dose techniques in order to effect a depression in plasma ChE, as the larger single dose tests required large areas of skin to be treated. The conditions of each subsequent experiment are summarised below. In these experiments, all exposure periods and the period between exposures was 12 hours, respectively.

No of subjects, No of exposures	Dose and duration of post-exposure monitoring	Results
One subject, 2 x 12 hrs	25 mg/kg 4 days	No significant depression of plasma or RBC ChE
One subject 3 x 12 hrs	25 mg/kg 12 days	RBC ChE unaffected, significant depression of plasma ChE after 3 doses, levels recovered in 12 days

One subject 4 x 12 hrs	10 mg/kg 8 days	Minimal RBC and plasma ChE depression
One subject* 20 x 12 hrs	5 mg/kg 32 days	RBC ChE unaffected, depression of plasma ChE after 5 doses and considerable after 15 doses, plasma ChE activity recovered after 32 days

* Chromosomal study conducted on this subject only on day 28 of the experiment.

A lymphocyte tissue culture was carried out during the final experiment, whilst plasma ChE activity was depressed to determine if any alteration to genetic material occurred as a result of exposure. No abnormalities were noted in this subject.

In one study (Coulston et al, 1972, cited in DHAC, 1999), adult male volunteers (4/dose) were given chlorpyrifos in tablet form at dose levels of 0, 0.014, 0.03 and 0.10 mg/kg/day for 9, 20 or 27 days depending on dose (high, mid or low dose, respectively) or 48 days (placebo control). Clinical signs and a decrease in plasma cholinesterase (70% compared to placebo controls) were seen in one subject at 0.1 mg/kg/day. Other subjects in this group showed a decrease in plasma cholinesterase but no clinical signs and treatment was suspended at day 9 when the group mean depression had reached 60%. Depression of mean plasma cholinesterase was demonstrated at the mid dose also (20% compared to control on days 16-20 and 34% compared to pre-treatment baseline at day 18), however statistical difference ($p<0.05$) could only be shown at the high dose level (0.1 mg/kg/day). The NOEL for this study was 0.03 mg/kg/d, based on the inhibition of plasma cholinesterase activity at 0.1 mg/kg/d. The NOEL for inhibition of erythrocyte cholinesterase activity was 0.1 mg/kg/day.

In human volunteers (Nolan et al., 1984, cited in DHAC, 1999) a single oral dose of 0.5 mg/kg resulted in an 85% reduction in plasma ChE levels (within 12-24 h) while a single dermal dose of 5 mg/kg produced a 30% reduction (time not specifed). Based on blood TCP levels, the total absorption following oral and dermal administration was predicted to be 72 $\pm$ 11% and 1.35 $\pm$ 1.0%, respectively. This corresponded to the percentage of administered dose recovered in the urine after oral and dermal administration (70% and 1.28%, respectively). A more detailed description of this study is provided in the DHAC toxicology report (DHAC, 1999).

Discussion

The acute toxicity of chlorpyrifos is moderate, with females more sensitive than male animals. Depression of ChE activity appears to be the most sensitive toxicological endpoint for chlorpyrifos with plasma ChE more sensitive RBC or brain ChE.

Based on the information available, the most relevant NOEL for use in the OHS risk assessment is 0.03 mg/kg/d, established in a human short-term repeated dose study (Coulston et al, 1972), with inhibition of plasma cholinesterase occurring at the next highest dose (0.1 mg/kg/d).

2.1.1 Acute Reference Dose (RfD)

The significance of the acute RfD is to determine safe or acceptable exposure from a single or short exposure to chlorpyrifos. The DHAC has determined the acute RfD from one human study (Coulston et al., 1972).

The oral administration of chlorpyrifos to human volunteers at doses up to 0.1 mg/kg/d for up to 3 days did not result in any significant inhibition of plasma or erythrocyte cholinesterase activity. An acute RfD, based on this study is 0.01 mg/kg/d, derived from the NOEL and a 10-fold safety factor.

2.1.2 Dermal absorption data

In acute animal studies, the relative toxicity of chlorpyrifos via the dermal, oral or inhalation routes suggests a low dermal absorption.

In human volunteers (Nolan et al., 1984, refer to Section 2.1 for details) dermal absorption was predicted to be 1.35 $\pm$ 1.0% of the applied dose.

Conclusion

Based on the available data, 3% is used for dermal penetration in the OHS risk assessment. It is acknowledged that this value may be an overestimate.

It should be noted that the dermal penetration process cannot be described adequately in terms of percentage absorption, since the amount penetrating will depend on the area of skin involved, the amount of pesticide present on the skin acting as a "driving force" for penetration, the duration of the presence on the skin as well as on many other aspects related to the worker (skin) and the work situation.

2.2 Hazard classification

2.2.1 Active constituent

Chlorpyrifos is listed in the National Occupational Health and Safety Commission (NOHSC) List of Designated Hazardous Substances (NOHSC, 1994a). Substances containing chlorpyrifos are classified as hazardous at concentrations greater than or equal to 3%. The risk and safety phrases assigned to chlorpyrifos are as follows:

<u>Risk phrases</u>

3%	R21	Harmful in contact with skin
	R22	Harmful if swallowed
25%	R24	Toxic in contact with skin
	R25	Toxic if swallowed

Safety phrases

S28 After contact with skin wash immediately with plenty of ...(to be specified by manufacturer).

S36/37 Wear suitable protective clothing and suitable gloves

S44 If you feel unwell, contact a doctor or Poisons Information Centre immediately (show the label where possible)

The revised European Commission classification has included the following additional risk and safety phrases (European Commission Directive 96/54/EC, 1996). These revisions have been picked up in the NOHSC List of Designated Hazardous Substances (NOHSC, 1997, draft).

R50 Very toxic to aquatic organisms

R53 May cause long term effects in the aquatic environment.

S1/2 Keep locked up and out of reach of children

S60 This material and its container must be disposed of as hazardous waste

S61 Avoid release to the environment. Refer to special instructions/safety data sheets

S44 is replaced with S45

S45 In case of accident or if you feel unwell, contact a doctor or Poisons Information Centre immediately (show the label where possible)

These risk and safety phrases should be present on the label for technical chlorpyrifos.

2.2.2 End use products

All chlorpyrifos formulations registered in Australia are determined to be hazardous substances, as they contain greater than 3% active constituent.

2.3 Oncogenic classification

Chlorpyrifos is not classified as carcinogenic on the NOHSC List of Designated Hazardous Substances (NOHSC, 1994a) or in the NOHSC Exposure Standards for Atmospheric Contaminants in the Occupational Environment (NOHSC, 1995a).

The International Agency for Research on Cancer (IARC) has not reviewed the carcinogenicity of chlorpyrifos.

2.4 Regulatory standards

Exposure Standard

A NOHSC Exposure Standard of 0.2 mg/m^3, Time -Weighted-Average (TWA) with "sk" skin notation, has been assigned for chlorpyrifos. (The notation "sk" indicates that absorption through the skin may be a significant source of exposure.) NOHSC has not established a Short-Term Exposure-Limit (STEL) for chlorpyrifos.

Biological Exposure Index (BEI)

Neither NOHSC nor the American Conference of Governmental Industrial Hygienists (ACGIH) have established a BEI for chlorpyrifos.

2.5 Poisoning information and illness reports involving workers

There is insufficient information on illness or poisoning associated with use of chlorpyrifos in Australian.

A review of chlorpyrifos poisoning data (Blondell and Dobozy, 1997), cited in DHAC toxicology report (DHAC, 1999), concluded that chlorpyrifos was one of the leading causes of acute insecticide poisoning incidents in the United States. Certain types of usage were considered of greater risk. The greatest concerns were for use of liquid formulations by homeowners and pest control operators (PCOs) indoors or outdoors, termite treatments, and the use of sprays and dips on domestic animals. Most of the more serious poisonings were associated with misuse or inappropriate use.

3. USE PROFILE

3.1 Handling prior to end use

A number of applicants provided Schedule 1 information in response to the data call in. The product and packaging information provided by these applicants is summarised in Table 1.

A & C Rural Pty Ltd formulate one chlorpyrifos product in Australia from imported technical chlorpyrifos.

Cheminova Australia Pty Ltd have two registered products which are formulated overseas. They claim that the end use products (EUPs) will not be marketed in Australia. As Cheminova have responded to the data call in and the products are currently registered with the NRA, the products are included in Table 1.

Crop Care Australasia Pty Ltd formulate one product (suSCon Blue) from imported technical chlorpyrifos (supplied by Dow Australia Ltd).

David Gray & Co Pty Ltd formulate eight chlorpyrifos EUPs in Australia from imported technical chlorpyrifos. Formulation is conducted in a 2000 L or 2000 kg blending tank utilising mechanical transfer, mixing and ventilation. Operators wear personal protective equipment when required.

Davison Industries Pty Ltd formulate one EUP in Australia from imported technical chlorpyrifos.

Dow (formerly DowElanco) Australia Ltd will import seven fully formulated chlorpyrifos products.

Lief Resources Pty Ltd trade imported technical grade active constituent (TGAC) and generic chlorpyrifos formulations. Packaging information was not included.

Nufarm Ltd will formulate four products from imported active ingredient.

R & C Products Pty Ltd will formulate cockroach bait products in Australia.

Rhône-Poulenc Rural Australia Pty Ltd will formulate three products from imported technical material.

Sanonda will import technical chlorpyrifos only (packaging not specified).

SC Johnson Wax & Son Pty import fully formulated and prepackaged cockroach bait products.

Sumitomo Australia Ltd have one registered product, however it is not known whether this product is imported or formulated in Australia.

Table 1: Summary of product and packaging information provided by applicants

Product	**Formulation type/ ai concentration****	**Packaging type**
A & C Rural Pty Ltd * Country Chlorpyrifos 500	EC 500 g/L	5 and 20 L EPON lined steel drums
Cheminova Australia Pty Ltd Cyren 500 EC Insecticide and Cyren PC Insecticide	EC 500 g/L	20 L HDPE, HDPE Coex (or F-HDPE or PET) or lined metal drum
Crop Care Australasia Pty Ltd * suSCon Blue Soil Insecticide	GR 140 g/kg (controlled release)	multi-walled paper valve sack (4 layers); pack sizes not specified (20 kg on label)
David Gray & Co Pty Ltd * David Grays Chlorpyrifos 200 Termite Spray	EC 200 g/L	500 mL amber coloured glass poison bottle with child proof cap (6 to a carton)
* David Grays Antex Granules	GR 30 g/kg	500 g puffer tube with resealable shaker tube
* David Grays Lawn Beetle Granules	GR 40 g/kg	500 g puffer tube with resealable shaker tube
* David Grays Lawn Beetle Spray	EC 200 g/L	500 mL amber coloured glass poison bottle with child proof cap (6 to a carton)
* David Grays PCO Chlorpyrifos 500	EC 500 g/L	1 L tin can (screw cap), 5 L tin can (pouring spout insert and cap) and 20 L drum (bung and cap)

* David Grays Chlorpyrifos 500	EC 500 g/L	5 and 20 L containers
* David Grays Micro-Lo Chlorpyrifos Termiticide and Insecticide	EC 450 g/L	5 and 20 L containers
* David Grays Pre-Construction Chlorpyrifos Termiticide	EC 450 g/L	5 and 20 L containers
Davison Industries Pty Ltd		
* Davison Chlorpyrifos 500 EC (identical to Lorsban 500 EC Insecticide)	EC 500 g/L	1 and 5 L steel cans, 20 and 200 L metal drums
Dow Australia Ltd		***
Dursban Micro-Lo Termiticide and Insecticide	EC 450 g/L	2, 10 and 20 L lined tinplate drums
Dursban PC Termiticide and Insecticide	EC 500 g/L	1, 5, 20 L metal drums
Dursban Pre-Construction Termiticide	EC 450 g/L	20 L lined metal drums
Dursban Turf-500 Insecticide	EC 500 g/L	1, 5, 20 L metal drums
Lorsban 500 EC Insecticide	EC 500 g/L	1, 5, 20, 200 L metal drums
Lorsban 500W Insecticide	WP 500 g/kg	1 and 5 kg packs containing 250 g cold water-soluble sachets inside fibre board drums
Predator 300 Insecticide	ULV 300 g/L	200 L metal drums
Lief Resources Pty Ltd		
Chlorpyrifos 500	EC 500 g/L	no packaging info provided
Nufarm		
* Nufarm Chlorpyrifos 500EC Insecticide } identical formulations	EC 500 g/L	1 and 5 L steel cans, 20 L steel drums
* Nufarm Chlorpyrifos PCO Insecticide } identical formulations		
* Nufarm Chlorpyrifos PCO Micro-Emulsion Insecticide	EC 450 g/L	as above
* Nufarm Chlorpyrifos ULV 500 Insecticide	ULV 500 g/L	20 and 200 L steel drums
Rhône-Poulenc Rural Australia Pty Ltd		
* Deter Insecticide } identical formulations	EC 500 g/L	1, 5, 10 or 20 L HDPE container, or epon lined steel can or HDPE bladder in fibreboard box
* Chlorfos Insecticide } identical formulations		
* Chipco Chlorfos Insecticide } identical formulations		
Chlorfos ULV Insecticide	no details provided (discontinued, some stock remaining)	
R & C Products Pty Ltd		
* Mortein Cockroach Baits	0.5%	6 or 12 welded plastic (black PVC) labyrinths
* Mortein Nest Kill Cockroach Baits		
* Mortein Plus Super Baits		
SC Johnson Wax & Son Pty		
Raid Max 12 Roach Terminators plus Eggstoppers	0.5%	extruded tablets (2.5 g/tablet) packaged in plastic stations
Raid 6 Ultrabaits		
Raid 18 Ultrabaits		
Sumitomo		
Summit Chlorpyrifos Insecticide	EC 500 g/L	lined metal drums (capacity not specified)

* formulated in Australia

** formulation type: EC emulsifiable concentrate, WP wettable powder, ULV ultra low volume water miscible, GR granular; ai concentration: w/v or w/w active chlorpyrifos

*** Dow provided packaging specifications as shown below

Packaging type	**Transfer method**	**Neck size (mm)**
1, 2, 5 L drum	manual pour	44
10, 20 L closed head drum	manual pour (unigrip pourer)	33
200 L metal drum (rheem NZ)	closed transfer	50

3.1.1 Observations at Australian formulation plants

Air monitoring at the Crop Care facility showed levels of chlorpyrifos (0.049 mg/m^3 or less) which were well below the Australian exposure standard (0.2 mg/m^3 TWA). No biological monitoring information was provided for workers at this site.

Chlolinesterase testing at the Nufarm formulation facility in Queensland showed no change in cholinesterase levels (type not specified) for 15 workers over a 3 week period in May 1997. These workers were also involved in the manufacture of other products.

At the R & C Products formulation plant, annual testing is conducted of process workers and mixerpersons for blood cholinesterase and urine metabolites. R & C report no detection of urinary metabolites in tested workers. Results of blood testing were not discussed.

3.1.2 Studies on formulation workers

In a study by Brenner et al. (1989), conducted in the USA, the prevalence of selected illnesses and symptoms over an 8 ½ year period (during 1977-85) was compared between 175 chemical industry workers potentially exposed to chlorpyrifos and 335 matched controls with no history of exposure to organophosphates. Workers in the exposed group were involved in chlorpyrifos manufacture and/or formulation of liquid and granular products containing chlorpyrifos. The exposed workers were grouped according to their potential for exposure to chlorpyrifos (high, medium or low), based on job title and air monitoring data. No description was provided of manufacturing/formulation processes or PPE worn by workers.

Air monitoring data (area, excursion and personal) ranged from 0.01- 1.1 mg/m^3. The greatest air concentrations were observed during chlorpyrifos manufacture (steam and cold cleaning of the floor), during packaging of granular EUP and during palletising of granular EUP (when bags were broken). Mean plasma cholinesterase depression for the low, medium and high exposure groups were 19.1%, 32.1% and 32.0, respectively. No statistically significant differences in illness or prevalence of symptoms were observed between the exposed and control groups or among the three exposure groups. Symptoms of dizziness, malaise and fatigue was reported by a greater proportion of the exposed group than the controls, however further analyses showed no correlation between symptoms and either job title, process site or air monitoring data. No cases of peripheral neuropathy were seen among the exposed workers. It was the author's belief that the cumulative exposures experienced by the study workforce exceeded those expected if the product was used as recommended, however they did not qualify this belief.

Discussion

Manufacture of chlorpyrifos will be conducted overseas, however workers will be involved in the formulation of products from imported chlorpyrifos at a number of formulation plants within Australia. Engineering controls and a requirement for personal protective equipment have been demonstrated at many of these sites.

The imported products are pre-packaged, therefore there should be no occupational exposure associated with these products. Exposure of transport and storage workers and retailers may occur if packaging is breached, which may result in exposure to technical material or EUPs.

Workers involved in formulation of EUPs will be potentially exposed to chlorpyrifos in both technical material and EUPs.

The study by Brenner et al. (1989) suggests significant inhalational exposure may occur during formulation in the absence of adequate controls.

Formulation workers require personal protective equipment (PPE) where sufficient engineering controls are not in place. Refer to Section 7.1.3 for details on Commonwealth/State/Territory occupational health and safety legislative requirements.

3.2 Use pattern of end use products

Information on the Australian use pattern of chlorpyrifos was obtained from registered product labels, performance questionnaires obtained through the NRA Existing Chemicals Review Program 1997 (covering the chemical Industry, State Chemical Co-ordinators, Large Scale Users and Commodity/Grower Groups) and the NRA. Refer to Table 3 for details.

There are currently 99 registered products containing chlorpyrifos. The usage pattern can be broadly grouped into crop protection, pest control and other (such as treatment of hides and skin), as well as home garden/home veterinary use (pest control and pet care products).

Product formulations currently registered include emulsifiable concentrates (500 EC), wettable powders (500 WP, 250 WP), ULV formulations (300 ULV, 500 ULV), granules (suSCon blue) and baits (home garden use only). The following product labels were available to NOHSC for this review.

Table 2: Summary of product labels provided for review

Formulation*	**Product name on label**	**Pack size on label**
Commercial products		
EC 500 g/L	Chemspray Argenstem Turf Insecticide	5 L
	David Gray's Chlorpyrifos 500	no pack size on label
	Davison Chlorpyrifos 500 EC Insecticide	no pack size on label
	DowElanco Dursban PC Termiticide and Insecticide	1 L
	DowElanco Dursban Turf-500 Insecticide	5 L
	DowElanco Lorsban 500 EC Insecticide	5 L
	Farmoz Strike-Out 500 EC Insecticide	20 L, 5 L, 1 L
EC 450 g/L	David Gray's Micro-Lo Termiticide and Insecticide	20 L, 5 L
	David Gray's Pre-Construction Chlorpyrifos Termiticide	5 L
	DowElanco Dursban Micro-Lo Termiticide and Insecticide	10 L
	DowElanco Dursban Pre-Construction Termiticide	20 L
EC 225 g/L	Permakill Insecticide	5 L
EC 200 g/L	David Gray's Lawn Beetle Spray	500 mL
WP 500 g/kg	DowElanco Lorsban 500 W Insecticide	5 kg
WP 250 g/kg	Farmoz Strike-Out 250 WP Insecticide	7.5 kg (15 x 500 g water-soluble bags)
	Farmoz Strike-Out Seed Dressing Insecticide	1 kg (2 x 500 g packs)
ULV 500 g/L	Nufarm Chlorpyrifos ULV 500 Insecticide	20 L

ULV 300 g/L	DowElanco Predator 300 Insecticide	1600 L
GR 140 g/kg	suSCon Blue Soil Insecticide	20 kg
Home Garden products		
EC 480 g/L	Chemspray Ant Spider & Cockroach Killer Insecticide	500 mL
EC 250 g/L	Chemspray Chlorban Insecticide	200 mL
EC 240 g/L	Garden King Grubkil Insecticide	200 mL
EC 10 g/L	Brunnings Lawn Beetle Destroyer	2 L
GR 50 g/kg	Garden King Ankil Granular Insecticide	125 g
GR 40 g/kg	David Gray's Lawn Beetle Granules	poor copy
GR 30 g/kg	David Gray's Antex Granules	500 g
Cockroach baits	Baygon 8 Power Baits SC Johnson Wax Raid 6 Cockroach Superbaits Mortein Plus 12 Superbaits	20 g 15 g 42 g

*EC: emulsifiable concentrate, WP: wettable powder, ULV: ultra low volume water miscible, GR: granular; w/v or w/w active chlorpyrifos

3.2.1 Crop protection

Table 3 details the recommended product application rates for each crop group as determined from the label, NRA advice and responses to the performance questionnaires. Due to the large number of horticultural and field crops treated with chlorpyrifos, the data is presented by application methods and product formulations rather than by crop.

Table 3: Crop protection: use pattern for chlorpyrifos formulations obtained from product labels, performance questionnaires and the NRA

Application method / *Crop group*	Crop	Label information: Product rates* 500 EC	Label information: Product rates* 500 WP	Label information: Final ai concentration (max)	Information from performance questionnaires: Work rates	Information from performance questionnaires: Applications/ season	Information from performance questionnaires: Application rates, methods and comments	NRA advice
Airblast								
Tropical fruit	bananas	1-2 L/ha or 200 mL/100 L water	1-2 kg/ha 250 g/125 L	0.1%		2	WP applied at label rates using mister or airblast (500-1000 L/ha)	**
	custard apple	rates for airblast not provided on labels		0.025% (based on user information)	1 ha/h	6-8	50 mL/100 L by air blast; large scale user recommends use of ant barriers on trees to reduce the requirement for spray application	
Berry fruits	kiwifruit	1 L/ha or 50 mL/100 L	50 g/100 L or 1 kg/ha	0.025% 0.05%	0.5 ha/h		label rates, high and low volume spray high volume air blast sprayers or low volume turbomiser-type	**
Pome & stone fruit	pome & stone fruit	100-200 g/100 L (Farmoz 250)		0.05%		1-2	label rates using mister or airblast	
		500 mL/ha 50 or 100 mL/100 L	50 or 100 g/100 L (pome)	0.05%	2-4 ha/h	1-5	label rate (WP) by dilute air blast, electrostatic & Metters airblast or airmist	**
	stone fruit	2 L/ha or 100 mL/100 L spray volume min 2000 L/ha	50 g/100 L	0.05%	2 ha/h	3	high volume orchard sprayer	
Vines	vines	500 mL/ha 50 or 100 mL/100 L water	50 g/100 L	0.05%	1-4 ha/h	1-6	label rates, high volume orchard sprayer to point of runoff or lower volume turbomiser-type sprayers spray volume 500-1000L/ha, applied by misting	**
Vegetables	tomatoes	1.5-2 L/ha or 150-200 mL/100 L	this use not on 500 WP label	0.1%			label rates, high volume air blast spray	**
Oscillating boom								
Citrus	citrus	500 mL/ha	this use not on 500 WP label	0.05% (based on user information)	4 ha/h		60-100 mL/100 L, oscillating boom sprayer (vertical) preferred to air blast sprayers which do not cover tree well above 2½ m	**

* product rates are based on 500 WP or 500 EC products, unless otherwise specified

** use of chlorpyrifos advised as essential for these crops by the NRA (according to information received from state departments of agriculture/primary industries)

Table 3: Crop protection: use pattern for chlorpyrifos formulations obtained from product labels, performance questionnaires and the NRA (continued)

Application method / *Crop group*	Crop	Label information: Product rates* 500 EC	500 WP	Final ai concentration (max)	Information from performance questionnaires: Work rates	Applications/ season	Application rates, methods and comments	NRA advice
Boom								
Tropical fruit	pineapples	50 or 100 mL/100 L min 3000 L spray/ha	this use not on 500 WP label	0.05%		1-2	label rate, ground rig	
		5 L/ha, pre-plant, incorporated immediately into soil with rotary hoe				1	5-6 L/ha, applied at pre-plant by tractor mounted boom	
Berry fruit	kiwifruit	50 mL/100 L or 1 L/ha	50 g/100 L or 1 kg/ha	0.025%	0.5 ha/h		label rate; premix powder in bucket, liquid formulation added directly to spray tank	**
Vegetables	vegetables	500 mL-2 L/ha 50-200 mL/100 L	this use not on 500 WP label	0.1%	5 ha/h		low volume spray	**
					1-2 ha/h		5-6 L/ha at pre-plant; 800 mL/ha at seedling stage equipment capable of treating 5-10 ha/h, but most operators expected to treat 1-2 ha/h, maximum daily work rate of "a few hours each day" expected	
	potatoes	3-6 L/ha, min 3000 L/ha	this use not on 500 WP label	0.05%		1	applied pre-plant by boom spray and incorporated immediately into the soil by rotary hoe	
		900 mL/ha				1	sprayed at tuber initiation	
	tomatoes, cabbage, cauliflower	1.5 or 2 L/ha using 1000 L of water (150 or 200 mL/100 L)	this use not on 500 WP label	0.1%		up to 4	500 mL/ha or 50 mL/100 L of water for localised high vol spraying label rates, tractor-mounted boom most common	**
	cole crops	1.5-2 L/ha, 150-200 mL/100 L	this use not on 500 WP label	0.1%		up to 5	label rates, tractor-mounted boom most common using at least 1000 L of spray/ha	
	sweet corn	no specific label information			2 ha/h			**
	celery seed beds	no label information			4 ha/h	1	applied before transplanting by boom spray	
Broadacre crops	cereals	70 mL – 1.5 L/ha 700 or 900 mL/100 L water	this use not on 500 WP label	0.45%	20 ha/h (wheat)		200 mL/ha (wheat)	**
	pasture	140-900 mL/ha (min 100 L water)	this use not on 500 WP label	0.45%	4 ha/h (lucerne)	up to 3 (lucerne)	boom sprayer (lucerne)	**

* product rates are based on 500 WP or 500 EC products, unless otherwise specified
** use of chlorpyrifos advised as essential for these crops by the NRA (according to information received from state departments of agriculture/primary industries)

Table 3: Crop protection: use pattern for chlorpyrifos formulations obtained from product labels, performance questionnaires and the NRA (continued)

Application method / *Crop group*	Crop	Label information: Product rates*: 500 EC	Label information: Product rates*: 500 WP	Label information: Final ai concentration (max)	Information from performance questionnaires: Work rates	Information from performance questionnaires: Applications/ season	Information from performance questionnaires: Application rates, methods and comments	NRA advice
Boom(continued)								
Cotton	cotton, maize etc	up to 2 L/ha	this use not on 500 WP label					**
Sugarcane	sugarcane	0.35-1.5 L	this use not on 500 WP label			up to 3	70 mL -1.5 L/ha	**
Tobacco	tobacco	3 L/ha	this use not on 500 WP label			1	tractor-mounted boom spray; label rate, applied to cultivated soil surface and incorporated immediately	**
Lawn/Turf	lawn/turf	7-80 mL/100 m^2 (0.7-8 L/ha) or 100 mL/10 L	this use not on 500 WP label	1%		1-2		**
Aerial application								
Tropical fruit	bananas	1-2 L/ha, min 10 L water/ha	this use not on 500 WP label	5%		1-3	label rates, aircraft sprayer	**
Vegetables	vegetables	500 mL-2 L/ha 50-200 mL/100 L	this use not on 500 WP label	0.1%	1-2 ha/h		5-6 L/ha at pre-plant; 800 mL/ha at seedling stage; aerial spray is minor method of application (boom spray used more often)	**
Cereals	cereals ***	ULV formulation: 0.35- 1.5 L/ha (ULV 500)						
		70 mL-1.5 L/ha 10-50 L water/ha	this use not on 500 WP label	7.5%		up to 3	label rates by aerial application	** ****
	rice	60-150 mL/ha (NSW) 1.5 L/ha (QLD)	this use not on 500 WP label			1-2	label rates, no application method provided (one user only)	
Pasture & forage crops	pasture & forage crops	ULV formulation: 0.35- 1.5 L/ha (ULV 500)						
Cotton	cotton	ULV formulation: 0.5-2.5 L/ha (Predator 300)			150-400 ha/h		4-5 L/ha in season (heliothis); closed transfer systems; most applications by air using Micronair sprayers	**
		ULV formulation: 0.35- 1.5 L/ha (ULV 500)						
		0.3-1.5 L/ha	this use not on 500 WP label				0.3-1 L/ha	
Sugarcane	sugarcane	ULV formulation: 0.35- 1.5 L/ha (ULV 500)						
		0.35-1.5 L	this use not on 500 WP label			up to 3	70 mL -1.5 L/ha	

Tobacco	tobacco	3 L/ha	this use not on 500 WP label			1	label rate by aerial application	**
Turf	turf farms	700 mL-6 L/ha	this use not on 500 WP label				label rates, aerial application	

* product rates are based on 500 WP or 500 EC products, unless otherwise specified
** use of chlorpyrifos advised as essential for these crops by the NRA (according to information received from state departments of agriculture/primary industries)
*** including barley, maize, millet, oats, rice, rye, sorghum, triticale and wheat
**** use on rice is 1-4% of total chlorpyrifos usage

Table 3: Crop protection: use pattern for chlorpyrifos formulations obtained from product labels, performance questionnaires and the NRA (continued)

Application method *Crop group*	Crop	Label information: Product rates* 500 EC	500 WP	Final ai concentration (max)	Information from performance questionnaires: Work rates	Applications/ season	Application rates, methods and comments	NRA advice
Handspray								
Tropical fruit	bananas (spot spray)	150-200 mL/100 L	10 g/5 L or 500 g/100 L	0.25%				**
Berry fruit	kiwifruit	50 mL/100 L or 1 L/ha	50 g/100 L or 1 kg/ha	0.025%	0.5 ha/h	2 or every 3-4 weeks	label rates; powder premixed in bucket, liquid added directly to spray tank (knapsack avoided due to possible spill on operator)	**
Vegetables	ginger	700-900 mL/ha	this use not on 500 WP label				EC applied at label rates by knapsack sprayer	
Lawn/turf	lawn/turf (spot spray)	2 L/ha, 10 mL/10 L; 7-80 mL/100m^{2}, 10-15 mL/10 L	this use not on 500 WP label	0.05%			label rates, knapsack sprayer	**
Ornamentals	ornamentals	this use not on labels (see basal application below)		0.1%			2 L/ha, 200 mL/100 L; hand gun mister	**
Basal application								
Tropical fruit	bananas	1 or 1.8 L/100 L water at base of tree	500 g/100 L or 4 kg sand, 600 mL spray or 30 g sand as 30 cm band at tree base	0.9%		1 post-harvest	EC applied at label rates	**
	custard apple	0.2-2 L/100 L, applied to trunk and ground beneath tree at rate of 1000 L/ha	this use not on 500 WP label	1%		1	sprayed on ground around trees; hand gun on 100 L spray tank mounted on 4 wheel RG bike; coarse spray to avoid spray drift	
	passion fruit	this use not on 500 EC label	120 g plus 600 mL yeast hydrolysate/30 L water/ha	0.2%				** ***
	passion fruit, avocado	240 g/30 L with 600 mL yeast hydrolysate (StrikeOut 250)		0.2%		every 7 - 10 days	50-100 mL strip or patch low on tree	**
Pome & stone fruit	stone fruit	240 g/30 L with 600 mL yeast hydrolysate (StrikeOut 250)		0.2%		7 - 10 d	50-100 mL strip or patch low on tree	**

		this use not on 500 EC label	120 g plus 600 mL yeast hydrolysate/30 L water, 50-100 mL/tree	0.2%			label rates, pneumatic hand sprayer hand held unit (for use on stone fruit)	** ***
	pome fruit	400 mL plus 2 L yeast autolysate/100 L water	this use not on 500 WP label	0.2%			label rates, pneumatic hand sprayer hand held unit	**
Citrus	citrus	240 g/30 L with 600 mL yeast hydrolysate (StrikeOut 250)		0.2%		7 - 10 d	50-100 mL strip or patch low on tree	**
Vegetables	cabbage, cauliflower, tomatoes	300 mL/100 L (100 mL to base of plant)		0.15%			applied as drench at label rates	**

*product rates are based on 500 WP or 500 EC products, unless otherwise specified

** use of chlorpyrifos advised as essential for these crops by the NRA (according to information received from state departments of agriculture/primary industries)

*** bait sprays (spot sprays) especially important in IPM programs

Table 3: Crop protection: use pattern for chlorpyrifos formulations obtained from product labels, performance questionnaires and the NRA (continued)

Application method *Crop group*	Crop	Label information Product rates* 500 EC	 500 WP	 Final ai concentra-tion (max)	Information from performance questionnaires Work rates	 Applica-tions/ season	 Application rates, methods and comments	NRA advice
Basal application (continued)								
Ornamentals	ornamentals (potted plants)	20-40 mL/100 L	250 g/25 L	0.5%	30 m^3 /h	as required	25 mL/L, drench through PTO driven spray unit	**
							200 mL/100 L, applied to lower butt to a height of 1 m to point of run-off, drill and pour or inject into trunk	
Seed treatment								
Vegetables	vegetables (carrots, beetroot, turnips onions, shallots, radish)	500 g/10 kg seed (1 kg/10 kg seed for Strike-Out 250)		50% (undiluted)		1	mixed in seed box in powder form; applied immediately prior to sowing	**
Cereals and oil seed crops	cereal	120 mL/100 kg seed (sowing rate min 95 kg/ha)	this use not on 500 WP label	50% (undiluted)			seed dressing equipment	**
		160-800 g/100 kg seed (Strike-Out 250) (sowing rate min 95 kg/ha)		25% (undiluted)		1	mixed in seed box in powder form; applied prior to sowing	**
	oil seeds	160 g/100 kg (Strike-Out 250) half fill seed box and treat seed		25% (undiluted)		1	mixed in seed box in powder form; applied prior to sowing	** (canola)
Soil baits								
Berry fruit	strawberries	10 kg bran bait/ha 10 mL/kg bran	this use not on 500 WP label	50% (undiluted)		1-2	used at label rate by 2 users	
Stone fruit	stone fruit	5 kg bait/ha (40 mL/kg wheat/sorghum bait)	this use not on 500 WP label	50% (undiluted)			fertilizer spreader	**
Vegetables	vegetables	10 kg bran bait/ha 10 mL/kg bran	this use not on 500 WP label	50% (undiluted)				**
Cotton, legumes, cereals, oil crops	cotton, sorghum	2.5 or 5 kg bait/ha, 40 mL/ kg wheat/sorghum bait/ha	this use not on 500 WP label	50% (undiluted)			label rates	**
	maize, soybean, sunflower	2.5 kg bait/ha, 40 mL/ kg wheat/sorghum bait/ha	this use not on 500 WP label	50% (undiluted)		1 at crop planting	cracked wheat or sorghum bait, fertilizer spreader or by hand	**
	sunflower	2.5-5 kg cracked wheat or sorghum bait/ha (40 mL/kg wheat/sorghum bait)	this use not on 500 WP label	50% (undiluted)		1 or 2 ***	2.5 kg/ha, fertiliser spreader behind planters or aerial application	

	cowpeas, chickpeas, mungbeans, navy beans	2.5 kg bait/ha, 40 mL/ kg wheat/sorghum bait/ha	this use not on 500 WP label	50% (undiluted)			label rates	** (legumes)

* product rates are based on 500 WP or 500 EC products, unless otherwise specified
** use of chlorpyrifos advised as essential for these crops by the NRA (according to information received from state departments of agriculture/primary industries)
*** 1st at planting, 2nd at seedling stage

Table 3: Crop protection: use pattern for chlorpyrifos formulations obtained from product labels, performance questionnaires and the NRA (continued)

Application method *Crop group*	Crop	Label information: Product rates* 500 EC	Label information: Product rates* 500 WP	Label information: Final ai concentra-tion (max)	Information from performance questionnaires: Work rates	Information from performance questionnaires: Applica-tions/ season	Information from performance questionnaires: Application rates, methods and comments	NRA advice
Soil baits (continued)								
Turf	turf (farms only)	2.5 kg bait/ha	this use not on 500 WP label	50% (undiluted)		1-2 (as required)	12.5 g ai/2.5 kg bait/ha; ground spreader	**
Treatments at sowing								
Vegetables	tomatoes	5 L/ha, min 20 L spray/ha, 10 cm band to open furrow	this use not on 500 WP label	12.5%			350-1000 g ai/ha or 35-100 g ai/100L water, applied by band spray	**
Cotton	cotton	5-15 mL/100m row or 500-1500 mL/ha for 1 m row spacing, 20 L spray/ha	this use not on 500 WP label	3.75%		1 at planting	500 mL/ha, at planting - injected with sead - mix product prior to loading into tractor saddle tanks	**
					4-5 ha/h		750 mL/ha	
		ULV formulation: 8-25 mL/100 m row or 0.8-2.5 L/ha for 1 m row spacing (Predator 300)			10 ha/h		in furrow using 12 Volt pump with agitation through TX# insecticide nozzles	
Sugarcane	sugarcane	1.5-2 L/ha	this use not on 500 WP label		2 ha/h ***	1 at planting and 1 at 30-45 cm	low pressure (< 35 kPa) or gravity feed spray onto plant sett and adjacent soil through nozzle placed above planter boards single spray into cane drill from 120 mm above the ground, gravity fed from single drum on the tractor planter	**
		granular product: 21 or 28 kg/ha, up to 420 g/100m row (suSCon, 140 g/kg)		14%	4 ha/d	1 at planting	granule loaded directly into application box, applied by calibrated gravity feed (through plastic tube) to the soil and covered immediately by soil	
					4 ha/d (Trash); 10 ha/d (Billet)		21-28 kg/ha, 315-430 g/100 m row, "Trash Planter" or "Billet Planter" granule applicator in-furrow and covered by soil at same time	
Cereals and oil crops	maize, sunflower, sorghum	5-15 mL/100m row or 500-1500 mL/ha for 1 m row spacing, 20 L spray/ha	this use not on 500 WP label	3.75%		1 at planting	label rates, tractor mounted in-furrow (nozzle directed) spray rig	**
	maize	20 mL/100m row or 2 L/ha for 1 m row spacing; applied as 15-20 cm band spray	this use not on 500 WP label		no information received for band spray method (soil baits appear to be used instead)			**
Miscellaneous								

Bell injection	bananas	no label rates for this method; Qld state coordinator survey states that bell injection of bananas is used instead of aerial application	** ****
Irrigation	potatoes	no label rates for this method; WA state coordinator survey states that some potato growers apply chlorpyrifos through irrigation systems and recommend a statement be included on the label to warn users not to use this method	** *****

* product rates are based on 500 WP or 500 EC products, unless otherwise specified
** use of chlorpyrifos advised as essential for these crops by the NRA (according to information received from state departments of agriculture/primary industries)
*** few farmers would treat more than 20 ha per year
**** expected application rate 1 kg ai/ha
***** expected application rate 3 kg ai/ha

A review of the labels and performance questionnaires suggests that there is no ULV product applied by boom.

Seed treatment is conducted at planting only. Chlorpyrifos is not used in the protection of stored grains.

The following withholding periods (WHP) exist for chlorpyrifos:

Crop	*Days between application and harvest*
Mango	21
Stone fruit asparagus, custard apples	14
Cereal grain crops (except sorghum grain), oilseeds (except cotton), rice, maize	10
Apples, pears, bananas, citrus, grape vines, kiwifruit, pome fruit,	7 or 14
Avocado, cotton, sugarcane, passion fruit	7
Cole crops,	5
curcurbits	3 or 5
Tomatoes	3
Sorghum grain crops	2
Leafy vegetables	Nil or 7
Legume vegetables, beans, peas, root and tuber vegetables	Nil
Lucerne, forage crops, pasture, turf, cereals (except grain sorghum), oilseeds (except cotton), rice, maize, sugarcane	Do not graze or cut for stock food for 2 days after application

(Source: Lorsban 500EC, Lorsban 500W, Davison Chlorpyrifos 500 EC, David Grays Chlorpyrifos 500, Nufarm Chlorpyrifos ULV 500 and Strike-Out 500 EC labels)

No re-entry period (REP) is provided on any of the chlorpyrifos crop protection product labels available for the review.

3.2.2 Pest control

Information from the performance questionnaires indicate that chlorpyrifos is used in pre- and post-construction for termite control in all Australian states. State departments have advised that the use of chlorpyrifos for termite control is regarded as essential in Qld, VIC, SA, WA and NT. The NRA estimate that approximately 29% of all chlorpyrifos used in Australia is for termite control.

For pre-construction use one treatment is applied to soil just before the waterproofing membrane is positioned and just prior to pouring of the concrete slab. For post-construction use treatment is repeated as required, which the chemical industry has indicated to be every 3-10 years.

Application methods for termite treatment of existing buildings include hand held pneumatic sprayers or bucket/watering cans, soil injection using rodding equipment with high pressure, hand lance with low pressure high volume sprayer (rose head nozzle), and under slab reticulation systems.

Alternatives to chemical barrier use in buildings were presented by the Northern Territory. Use of baits and physical barriers are currently under investigation.

Pole treatment for termite control is achieved by rodding or trenching and puddle treating as a continuous barrier.

For general pest control of buildings (such as cockroach control) application is more frequent. Information from the performance questionnaires indicate one application per year during spring or summer.

Products used for pre-construction termite control carry the following re-entry/re-handling statement:

> **Suspended floors:** allow treated areas to completely dry (normally 3-4 hours) and ventilate buildings before re-occupying
> **Concrete slabs:** cover immediately after treatment with a moisture membrane

Products used for post-construction termite control and general pest control carry the following re-entry/re-handling statement:

> **Re-entry to treated areas:** allow treated areas to completely dry (normally 3-4 hours) and ventilate buildings before re-occupying

The use pattern of chlorpyrifos in pest control is summarised in Table 4.

Table 4: Pest control: use pattern for chlorpyrifos formulations obtained from product labels and performance questionnaires

Situation/pest		Label information		Information from performance questionnaires	
		Product rates*	**Final ai concentration**	**Work rate and application frequency**	**Application method**
Buildings	Pre-construction termite control (slab, suspended floor)	horizontal barrier: 220 or 440 mL/10L or 110 mL/m^2 (5 L emulsion/m^2)	1 or 2%	1 commercial domestic site/2h one treatment at construction	*handspray*: handheld pneumatic sprayer, handlance, tractor-mounted (most common method hand lance with rose head nozzle) *soil injection* using rodding equipment one treatment applied to soil prior to waterproofing membrane
		Vertical barrier: 220 or 440 mL/10L (100 L emulsion/m^3)	1 or 2%		
	Post-construction termite control (slab, suspended floor, external barrier)	Horizontal barrier: 220 mL/10 L or 110 mL/m^2; 440 mL/10 L or 220 mL/m^2 (5 L emulsion/m^2)	1 or 2%	1 commercial domestic site/2h one treatment every 3-10 yrs	soil injection rodding equipment with high volume ion pressure; pneumatic hand sprayer; hand lance with rose head nozzle; reticulation systems scarify the soil surface to a depth of 8 cm and apply as a continuous chemical barrier (vertical and horizontal)
		Vertical barrier: 220 mL/10 L; 440 mL/10L (100 L emulsion/m^3)	1 or 2%		
Termite nest or colony		50 g ai/10 L water (nests or colony)	0.5%	as required	break up the nest or colony and apply as flood treatment refer to AS 3660**
Pole treatment (termites)		100 g ai/10 L water or creosote (100 L emulsion per m^3 of soil)	1%		pole treatment: rod or trench and puddle treat as continuous barrier refer to AS 3660**
Industrial/domestic (general pest control - spot spray)		100 mL/10L (Dursban Turf 500) 50-95 mL/10L (Dursban PC) (1 L/m^2) 55-110 mL/10L (Dursban Micro-Lo) for ants 1L/100L (EC) (cockroaches, spiders, silverfish: coarse low pressure spray to point of run-off in places were pests occur; spiders: overall band spray in addition to coarse spot spray, fleas: fine particle spray; ants: 30 cm band to paths and bases of structures and plants to a height of 30 cm))	0.5%	1 commercial domestic site/2h 1 treatment/yr	knapsack or rega pressure sprayer (5-9 L); hand lance with light volume pump pneumatic hand sprayer hand held unit, boom sprayer - vehicle/tractor mounted, aircraft sprayer
Vegetation, hedges and polluted water (mosquito control)	Vegetation	30-120 mL/ha		as required	knapsack or rega pressure sprayer (5-9 L); hand lance with light volume pump
	Polluted water	2 mL/10000 L or 20 mL/ 100 m^3 of water (1 g ai/10000 L of water or 10 g ai/100 m^3)	0.00001%		label rates, no application methods specified
	Swamps and water ways	30-120 mL/ha		as required	applied as spray also fogging apparatus used by council operators in wetlands

* all products are emulsifiable concentrates
** Standards Australia (1993) AS 3660, Protection of buildings from subterranean termites – Prevention, detection and treatment of infestation, SAA, Sydney.

3.2.3 Other uses

Table 5 details the recommended product application rates for each end use situation as determined from the labels, NRA advice and responses to the performance questionnaires.

Table 5: Other uses for chlorpyrifos obtained from product labels, performance questionnaires and the NRA

Situation		**Label information** (product rates and final ai concentration)	**Information from performance questionnaires** (application method, work rate and application frequency)
Hides and skins		200 mL/100L (EC 500 g/L) (0.1%)	spray flesh side of skins or hides sufficient to moisten them (or 30 mL spray per skin), repeat every 3 months
Home	baits	5 g/kg (0.5%)	
	handspray	10 mL/L (EC 200 g/L) (1%)	handspray, watering can
	granules	GR 30, 40 or 50 g/kg (3-5%)	500 g/100 m^2 shaker tube - direct application
	pet collars	cats 0.52 g/collar; dogs 2.8 g/collar	
Garden	handspray (lawn)	100 mL/20L/100m^2 (EC 200 g/L) (0.1%)	1 ha/h, pneumatic handheld sprayer
Railway wagons		**NRA Advice:** Permit use only. Product (500 EC) applied at a rate of 20 mL/L of water (final ai concentration 1%). Permit Critical Use Comments: "Spray infested areas to point of run-off. 5L of diluted spray will treat approximately 100 m^2. Repeat application at 6 week intervals when required."	

Use in hides and skins is expected to be minor in relation to total chlorpyrifos use, even though a large number of chlorpyrifos products are registered for this situation. Only one State co-ordinator survey noted hides and skins as a current practice and none of the performance questionnaire responses (seven in total) were from end users.

Home garden/home veterinary products will not be considered in this review.

Discussion

The use pattern information provided on the product labels and obtained from the performance questionnaires shows a wide variation within Australian use parameters, work practices and crop sizes.

Based on the use pattern information available (Tables 2-4) the risk assessment utilises the representative application rates, work rates and spray volumes indicated below (Tables 5-7). Crops are grouped where possible based on application method and work practices. It should be noted that based on survey information some end users apply chlorpyrifos at rates greater than those specified on the label. These rates are not considered in this review.

Table 6: Use pattern parameters used in exposure assessment - Crop protection

Application method	Crop groups	Application rate (kg ai/ha)	Work rate (ha/6 h application period)	Spray volume (L/ha)	Comments
Airblast	Tropical & berry fruit	0.5	6	1000	application rate within label rates for bananas, custard apples and kiwifruit; work rate is maximum on performance questionnaires; most representative spray volume on label and performance questionnaires
*	Pome & stone fruit	1	15	2000	application rate as per labels; work rate within range on performance questionnaires; minimum spray volume on label for stone fruit, suitable also for pome fruit
	Vines	0.25	15	1000	application rate as per label; work rate within range on performance questionnaires (as for pome); spray volume as per label and performance questionnaires
Oscillating Boom	Citrus	0.25	24	>1000	application rate as per label; work rate as indicated for citrus on performance questionnaires; performance questionnaires state spray volume of 500-800 L/ha, but NOHSC expects higher volumes to be used
Boom	Tropical fruit, berry fruit, vegetables	0.75	6	2000	application rate based on label average (not including pre-plant); work rate consistent with same crops by airblast (although spray period expected to be less than 6 h for some crops); spray volume within label and performance questionnaire ranges
	Cereal, pasture, forage crops, sugarcane	0.45	50	1000	application rate within label range; work rate within range on performance questionnaires (NOHSC acknowledges that this may be an underestimate in cases where more sophisticated equipment is used); spray volume according to Banks et al. (1994)
**	Lawn/Turf	2	20	400	application rate within label rates; work rate based on 50 ha/6 h, area not expected to be more than 20 ha and spraying time ~2-3 h; spray volume as per label
Aerial	Bananas, cereals (including rice), cotton, sugarcane, tobacco, lawn/turf	0.5	1200	≥10	application rate within label range; work rate within range on performance questionnaires for cotton; spray volume as per label
Aerial ULV	Cereals, pasture, forage crops, cotton	0.5	1200	undiluted	application rate within label rates; work rate within label rates; no information for spray volume on labels or performance questionnaires, expected to be applied undiluted in most cases
Handspray	Berry fruit & vegetables	0.4	1 (vehicle mounted) 0.25 (knapsack)	1600	application rate within label rates; work rate expected to be 0.5 ha/h with vehicle mounted equipment for part of the day only (performance questionnaires), knapsack work rate expected to be less (based on POEM default maximum of 400 L spray/d, equivalent to 0.25 ha/d); spray volume as per label

* airblast scenario with the greatest exposure potential
** boom scenario with the greatest exposure potential

Table 6: Use pattern parameters used in exposure assessment - Crop protection (continued)

Application method	Crop groups	Application rate (kg ai/ha)	Work rate (ha/6 h application period)	Spray volume (L/ha)	Comments
Basal application (tree base or surrounding soil)	Custard apple, passion fruit, bananas, pome & stone fruit, citrus, cabbage, cauliflower, tomatoes, potted plants	qualitative risk assessment only			application rates as per labels (0.06-10 kg ai/ha); work rates expected to be low based on performance questionnaires with small areas treated (~100 m^2/d) and work intermittent; spray volumes varied with maximum spray concentration 1%
Seed treatment	Vegetables, cereals and oil seed crops	qualitative risk assessment only			0.2-2.5 kg ai/100 kg seed, applied undiluted through seed dressing equipment; no work rate information available, expected to be ~30 ha/d based on work rates for other ground application methods
Soil baits	Strawberries, stone fruit, vegetables, cotton, legumes, cereals, oil crops, turf	qualitative risk assessment only			50 g ai/10 kg bran/ha, 50 g ai/2.5 kg wheat/sorghum per ha (or 100 g ai/5 kg/ha) mixed in bait, applied aerially, by fertilizer spreader or by hand
Bandspray at sowing (in furrow)	Vegetables, cotton, cereals and oil crops	0.75 0.75 quantitative risk assessment for mixing/loading only	30 60 (ULV)	20 2.5 (ULV)	application rate within label rates; work rate as per performance questionnaires for cotton, spray volume as per label based on performance questionnaires, if ULV product is used (30% ULV) a greater work rate is expected (60 ha/d) and the product will be applied undiluted
Gravity feed at sowing	sugarcane	qualitative risk assessment only			14% granular product or 50% EC product loaded into drum and gravity fed onto plant sett and immediately covered by soil
Bell injection and irrigation	bananas, potatoes	no label uses			inadequate information

Table 7: Use pattern parameters used in exposure assessment - Pest control

Pest **Situation**	**Maximum application rate**	**Maximum work rate (per day)**	**Spray volume**	**Comments**
Termites				
Buildings (pre- and post-construction)	100 or 200 g ai/10L	390-450 m^2 (3 sites, 130-150 m^2 each)	horizontal: 5 L/m^2 vertical: 100 L/m^3	Application rate and spray volume as per label; work rate based on performance questionnaires
Termite nests or colonies	200 g ai/10L	various	not provided	Application rate as per label
Pole treatment	100 g ai/10 L water or creosote	various	100 L/m^3	Application rate and spray volume as per label
General household pests (including. ants, cockroaches, spiders, fleas, silverfish))				
Buildings	50 g ai/10 L	780-900 m^2 (6 sites, 130-150 m^2 each)	1L/m^2	Application rate and spray volume as per label; work rate expected to be at least twice the rate for termite control based on relative application rates and volumes
Mosquitoes				
Vegetation	0.015-0.06 kg ai/ha	various	not provided	Application rate and spray volume as per label (maximum); work rate dependant on application method
Water impoundments	10 g ai/ 100 m^3	various	no dilution	Application rate and spray volume as per label; work rate dependant on application method.

Table 8: Use pattern parameters used in exposure assessment - Other uses

Situation	**Maximum application rate**	**Maximum work rate (per day)**	**Spray volume**	**Comments**
Handspray of hides and skins	200 mL product/100 L (0.1% ai)	various	30 mL/hide or until saturated	inadequate information
Railway wagons	not a registered use (permit use only)			not considered in this review

4. OCCUPATIONAL EXPOSURE ASSESSMENT

4.1 Measured end use exposure studies

Dow Australia Ltd provided a number of worker exposure studies in response to the data call-in by the NRA. These are described here along with relevant literature studies.

Both passive dosimetry and biomonitoring techniques are employed to estimate worker exposure. Estimates using biomonitoring are achieved by measuring levels of the metabolite 3,5,6-trichloro-2-pyridinol (TCP) voided in the total urine excreted over the first few days post-exposure. The TCP levels are then converted into measures of absorbed chlorpyrifos dose using one of two methods described by Nolan et al. (1984), namely the urinary excretion factor method (multiplying the total amount of TCP excreted in the first 2 days post-treatment by the molecular weight ratios of chlorpyrifos to TCP (350.6/198.5) and dividing by 0.70 (average fraction excreted) or by pharmacokinetic modelling. Some of the studies discussed below present data generated both ways.

Data presented in the following study summaries have been standardised, where necessary, by NOHSC based on the following assumptions:

> 10% penetration (default) through cotton overalls or equivalent clothing, consistent with Shurdut et al. (1993) and Stamper et al. (1989a);
>
> 10% penetration (default) of liquid products through PVC (or other chemically resistant) gloves, consistent with Thongsinthusak et al. (1993) and POEM default parameters;
>
> 1% penetration (default) of dry products through PVC (or other chemically resistant) gloves, consistent with POEM default parameters;
>
> 10% penetration (default) through respirator, based on 10% through half face respirator, Thongsinthusak et al. (1993);
>
> 3% dermal absorption, as discussed in Section 2.1.2;
>
> 100% respiratory absorption, consistent with Thongsinthusak et al. (1993);
>
> an average body weight of 60 kg, consistent with the World Health Organisation;
>
> an average respiratory rate of 29 L per minute, based on Durham and Wolfe (1962); and
>
> average body surface areas based on Berkow (1931), cited in US EPA Subdivision U Guidelines (US EPA, 1987), ie total body area 21,110 cm^2, hands 820 cm^2, feet 1310 cm^2, head/neck/face 1300 cm^2.

4.1.1 Crop protection

Airblast application

(1) Bohl RW, Nolan RJ and Saunders JH (1985) Evaluation of Tractor/Sprayer Operator Exposures to Chlorpyrifos during Orchard Spraying with Lorsban 50W Wettable Powder Insecticide, Dow Chemical USA, A1A-481 HEH2.1-1-182(42), August 1985.

This study evaluated exposure to chlorpyrifos during product mixing/loading operations and spray application to orchards. The study was sponsored by the US Agricultural Products Department and was conducted for the purpose of product registration and labeling. The study was conducted at US orchards owned by Hilltop Orchards Inc and Dow Chemical. The tree types were not identified.

Study details

Lorsban 50W (a wettable powder containing 50% chlorpyrifos) was used to treat orchards at three sites with a total of four applications. The product was packaged in 1.36 kg bags and was applied at a rate of 3.36 kg/ha (1.68 kg ai/ha). The application details are described below.

> Site 1: one Dow employee (Operator A) prepared and applied product to the Dow experimental orchard using a covered but open seat tractor and a one directional air sprayer. This site was treated on two separate occasions (runs 1 and 2) by the same operator. The spray tank volume was 397 L and the application volume 467 L/ha.
>
> Site 2: two operators (B and C) prepared and applied product to a Hilltop orchard using an open cab tractor and large commercial two directional air sprayer. The spray tank volume was 1893 L and the application volume 935 L/ha.
>
> Site 3: two operators (D and E) prepared and applied product to a Hilltop orchard using an closed cab tractor and large commercial two directional air sprayer. The spray tank volume was 1893 L and the application volume 935 L/ha.

All operators where involved in both mixing/loading and application of the product. Each spray cycle started with the operators adding water and product to the spray mix tank (bags of product were opened and then ‘dumped’ one by one into the opening at the top of the mix tank), mixing the product, towing the sprayer to the orchard, spraying the crop and returning to the mixing area for another cycle.

All operators wore their own clothing (type not specified). Operator A wore white cotton glove liners (for sampling purposes) but no protective gloves. Operators at sites 2 and 3 also wore no protective gloves. All operators except for Operator D wore half face respirator masks with fresh dust and organic vapour cartridges while adding product into the spray tank.

Personal air and potential dermal exposures were evaluated for each operator. Biomonitoring was also conducted and included measurement of plasma and red blood cell cholinesterase as well as blood and urinary TCP levels.

Data collection and analysis

Personal air monitoring was conducted for each operator using air samplers attached to the collar. Three samples were taken for each spraying cycle, one during the spray time, one during the product loading time (addition to water in spray tank) and one during the entire spray cycle excluding the loading period. All three samplers were worn during the entire spray cycle but switched off when not required. As most operators (4 of 5) wore respirators during product loading, estimates of potential respiratory exposure obtained during this task were not included in the estimate of total actual respiratory exposure, for the purpose of comparison with biomonitoring data.

Potential dermal contamination was sampled during the total spray cycle using dermal patches attached to the outside of each operator's clothing. Patches were located on the upper centre of the back, upper centre of the chest, right and left shoulder, upper midpoint of each forearm, front of each thigh, front of each ankle and on the hands (when gloves not worn). Dermal patches were also placed under the work shirt of Operator A during run 2 to evaluate clothing penetration. These patches were placed on the chest and back, however the location relative to outer patches was not specified. The authors calculated total dermal contact in mg per hour per standard body surface area (as described by Durham and Wolfe, 1962).

Cotton glove liners were worn by Operator A for the estimation of hand exposure. The other operators wore dermal patches on their hands, however the exposure estimates resulting from these were not presented.

Blood was collected prior to spraying (1-2 samples) and after spraying (1 sample) for estimation of plasma and erythrocyte cholinesterase activity as well as blood TCP levels. Sampling times differed for each replicate and ranged from 24 to 1 hours pre- and 0 to 14 hours post-application. The limit of detection of TCP in blood was 5 ng/mL blood.

Complete urine specimens were collected for the estimation of TCP levels on the day preceding spraying and on the first 2 or 3 days post spraying. Absorbed chlorpyrifos levels were estimated by the urinary excretion factor method of Nolan et al. (1984), ie multiplying the total amount of TCP excreted in the first 2 days post-treatment by the molecular weight ratios of chlorpyrifos to TCP (350.6/198.5) and dividing by 0.70 (average fraction excreted). Estimation of absorbed chlorpyrifos using pharmacokinetic modelling was not conducted as the specimen collection intervals were unsuitable for most operators. The limit of detection of TCP in urine was 2 ng/mL urine.

Table 9: Exposure of mixer/loader/applicators during airblast application of WP chlorpyrifos to orchards

Operator	Identification and equipment type	PPE	Total ai sprayed (kg)	Spray concen-tration (g ai/L)	Potential respiratory exposure[2]						Total actual respiratory exposure[4] M/L/A (mg/ replicate)	Potential dermal exposure M/L/A				Total absorbed chlorpyr- ifos based on urinary TCP (mg)	% reduction in ChE	
					M/L			Appl				whole body		hands			plas-ma	RBC
					(mg/ m³) ***	TWA over 8 hrs ***	(mg/ repli-cate)[3]	(mg/ m³) ***	TWA over 8 hrs ***	(mg/ repli-cate)[3]		(mg/ h) ***	(mg/ repli-cate)[5]	(mg/ h) ***	(mg/ repli-cate)[5]			
A run 1	low pressure (40+ psi), open/covered cab, one directional sprayer[1]	own clothing, cotton gloves, half face respirator*	2.04	3.60	0.12	0.001	0.017	0.031	0.013	0.181	0.182	19.2	66	51.9	176	1.61	12	2
A run 2	low pressure (40+ psi), open/covered cab, one directional sprayer[1]	own clothing, cotton gloves, half face respirator*	2.04	3.60	8.5	0.136	1.89	0.027	0.010	0.14	0.329	15.1	47	46.6	144	1.81	7	0
B	high pressure (200 psi), open cab, two directional sprayer	own clothing, half face respirator*	7.95	1.80	11.5	0.297 **	4.13	0.34	0.302 **	4.18	4.59	177	1273	NM	NM	26.4	82	0
C	high pressure (250 psi), open cab , two directional sprayer	own clothing, half face respirator*	6.81	1.80	25.6	0.565 **	7.86	0.14	0.130	1.81	2.60	136	980	NM	NM	18.1	54	3
D	high pressure (250 psi), closed cab (vent windows open) , two directional sprayer	own clothing	4.54	1.80	4.5	0.077	1.07	0.065	0.067	0.927	2.00	9.7	79	NM	NM	2.15	6	0
E	high pressure (250 psi), closed cab, two directional sprayer	own clothing, half face respirator*	4.54	1.80	3.4	0.038	0.53	0.040	0.039	0.54	0.596	7.1	55	NM	NM	1.05	7	0

M/L – mixer/loader; Appl – applicator; M/L/A – mixer/loader/applicator
* respirators worn only during mixing/loading
** these values are above the NOHSC TWA Exposure Standard for chlorpyrifos of 0.2 mg/m^3
*** values as presented in report
(1) the spray equipment allowed Operator A to use the prevailing wind to minimise exposure
(2) M/L exposure estimated from breathing zone samples taken during loading operations; Appl exposure estimated from breathing zone samples taken during total spray cycle (excluding loading) and samples taken during each spray application within the spray cycle (2 or 3 applications per cycle)
(3) calculation assumes 29 L/min respiratory air volume rate (authors used 20.8 L/min) and 100% respiratory absorption; actual air monitoring times were 4.7, 7.7, 12.4, 10.6. 8.2 and 5.4 min for mixing operations and 3.3, 2.9, 7.1, 7.4, 8.2 and 7.8 h for spray application for Operators A (runs 1 and 2), B, C, D and E, respectively
(4) assumes 10% of airborne chlorpyrifos is absorbed through the respirator during mixing/loading (ie, 10% passes through and 100% of this is absorbed); 100% is assumed for Operator D who did not wear a respirator
(5) based on total exposure periods of 3.4, 3.1, 7.2, 7.2, 8.1 and 8.1 h for Operators A (runs 1 and 2), B, C, D and E, respectively
NM not measured

Results

The results of the study are presented in Table 9. Potential respiratory exposure levels were high during product mixing. Although mixing operations took only about 10 minutes, when corrected for an 8 hour day (ie. divided by monitoring time and multiplied by 8 hours), the resultant TWA exposures were greater than the NOHSC TWA Exposure Standard for chlorpyrifos of 0.2 mg/m^3 for two operators. These workers however wore a respirator, therefore actual respiratory exposure is expected to be below the reported level.

The greatest respiratory exposures for applicators occurred for operators using high pressure two directional sprayers with open cabs. One of these workers was exposed at a TWA level which exceeded the NOHSC Exposure Standard.

Individual body patches indicated that contamination was greatest on the front torso, thighs and lower legs compared to other parts of the body (results not shown). The dermal exposure results for operator A (2 runs) showed that potential hand exposure accounted for approximately 75% of total potential dermal exposure (whole body plus hands but not including head and neck).

The internal patches worn by operator A (chest and back) each contained 0.2 $\mu g/cm^2$ of chlorpyrifos. The external patches worn by the same worker contained 3.1 and 1.6 $\mu g/cm^2$ chlorpyrifos in chest and back patches, respectively. This represents a clothing penetration factor of 6-13%.

Total absorbed chlorpyrifos calculated from urinary TCP excretion correlated well with dermal (potential) and respiratory (actual) exposure, as did reduction in plasma ChE levels. Erythrocyte ChE levels were unaffected by exposure. Blood TCP correlated well with urinary TCP (results not presented).

The authors estimated the percentage of internal chlorpyrifos dose resulting from dermal and inhalation exposure by subtracting the estimated amount inhaled from the total amount absorbed (as measured in the urine as TCP). The percentage absorbed through the skin for workers wearing respiratory protection during mixing operations ranged from 60-92%. Dermal absorption accounted for only 33% of total absorbed dose for Operator D, who wore no respirator.

Discussion

The number of replicates in the study was low (six) and the work conditions varied considerably for each replicate. The study does not specify which study guidelines were observed, however the sampling methods used were appropriate and all analytical methods were adequately validated.

The product used in this study (500 WP) is similar to products registered in Australia for similar uses. The study product was packaged in 1.36 kg bags. The Australian products *are available in 500 or 250 g water-soluble packs. Study participants used open mixing techniques. This method of mixing is not likely for use in Australian orchards.*

Australian orchards will be treated at a rate of 1 kg ai/ha. Therefore, the application rate used in the study (1.68 kg ai/ha) is relevant for our assessment.

The study utilized a one directional air sprayer (Hanson) as well as two directional air sprayers (Friend and Metter) air sprayers, with operators either in open, closed or covered/open cabs. Australian operators have indicated that they use high volume orchard sprayers (including Metters) or lower volume turbomiser-type sprayers. Cab types were not specified in the performance questionnaires.

The study participants covered a work area of 1.2-4.0 ha (total ai sprayed divided by 1.68 kg/ha). Based on performance questionnaire information, Australian workers are expected to cover an area of 6-24 ha/d. A work rate of 15 ha/d is used in the risk assessment.

The study results are therefore considered adequate for use in the risk assessment. However, due to the incompleteness of dermal exposure estimates (no hand exposure estimates for operators B, C, D and E and no head and neck estimates for any), the risk assessment will be conducted using the total absorbed chlorpyrifos dose based on urinary TCP.

(2) Murphy PG, Berryman KS and Hugo JM (1992) Lorsban 4E Insecticide: Results of the Analyses of Inhalation and Dermal Exposure Assessment Samples From the Replicates of the High Crop Study DECO-HEH2.1-1-182(125) Completed in the Fall of 1991, DECO-HEH2.1-1-182(115), The Dow Chemical Company, Midland, Michigan, November 1992.

This is an analytical study which was conducted for Dow by Hazard Evaluation & Regulatory Affairs Company (H.E.R.A.C.) for the purpose of product registration and was conducted in accordance with GLP standards.

The study describes the methodology for sample collection and analyses only. The results from this study, along with those from the next study (Murphy PG and Birk KH, 1993), are presented in Honeycutt and Day (1994) and discussed in (4) below.

Samples were collected for six replicates each of mixer/loaders, applicators and clean-up personnel, along with five re-entry replicates (orange pickers).

The following samples were collected for each replicate:

handwashes
external dosimeters (coveralls)

internal dosimeters (T-shirt and briefs)
denim patches (on hat)
personal air monitoring samples
(GN-4 membrane filter)

In addition leaf punch and tank samples were also taken.

A total of 87 field spike analyses were performed with average recoveries ranging from 98-102%. Laboratory spikes were also used to test the performance of the analytical system used (gas chromatography).

The results are expressed as µg chlorpyrifos on a per sample basis, corrected for the appropriate method recovery.

(3) Murphy PG and Birk KH (1993) Lorsban 4E Insecticide: Results of the Analyses of Inhalation and Dermal Exposure Assessment Samples From the Replicates of the High Crop Study DECO-HEH2.1-1-182(125) Completed in the Spring of 1992, DECO-HEH2.1-1-182(122), The Dow Chemical Company, Midland, Michigan, March 1993.

The sampling and reporting methodology in this study is identical to that described in Murphy et al., 1992. Samples were collected for 9 replicates each of mixer/loaders, applicators and clean-up personnel, along with 10 re-entry replicates (tree pruners). A total of 198 field spike analyses were performed with average recoveries ranging from 92-105%.

The results from this study, along with those in the previous study (Murphy et al., 1992), are presented in Honeycutt and Day (1994) and discussed in (4) below.

(4) Honeycutt RC and Day EW Jr (1994) Evaluation of the Potential Exposure of Workers to Chlorpyrifos during Mixing and Loading, Spray Application, and Clean-Up Procedures during the Treatment of Citrus Groves with Lorsban 4E Insecticide, DowElanco (USA), January 1994.

This study evaluated exposure to chlorpyrifos by mixer/loaders, applicators, and clean-up personnel during application to citrus groves. The study was conducted by DowElanco for the purpose of product (Lorsban 4E) reregistration and was conducted largely in accordance with US EPA GLP standards. Deviations from the Standards were minor and are not expected to alter the interpretation of results.

The data presented in this study have been reported in the two previous analytical studies by Murphy et al. (1992) and Murphy and Birk (1993).

Study details

Lorsban 4E (an emulsifiable concentrate containing 40.7% chlorpyrifos) was applied to lemons and oranges at 15 plots (11 sites) across California. The application rate was 6.72 kg ai/ha nominal (the calculated calibrated rate ranged from 5.42-8.04 kg ai/ha) with the average final spray concentration measured at 1.19 g ai/L (range 0.92-1.54 g ai/L) and average volume of 5647 L/ha.

Mixer/loaders handled the product in 9.5 kg plastic containers using open loading techniques. The amount of product handled each day averaged 33.6 kg ai (range 24.1-49.0 kg ai). Applicators sprayed the product using an open cab airblast sprayer with nozzle pressures maintained over a range of 100-200 psi for each application. Work rates ranged from 2.9-5.4 ha/hr across the plots with an average area of 5.1 ha (range 4.0-7.3 ha) being treated per day.

The study was conducted under actual use conditions using experienced workers (either usual work crew or volunteers with previous chemical use experience). A total of 46 subjects were used in the study. Fifteen replicates (replicates 1-15) were studied for each worker category (applicators, mixer/loaders and clean-up workers) with one additional clean-up worker (replicate 6A). Different workers were used for each replicate.

The work practices differed between the sites. Table 9 below details the different work tasks performed by each replicate.

Table 10: Work tasks performed by each replicate

Worker category	Work tasks[1]	
	Lemon grove sites (replicates 1-3, 14, 15 and 6A)	Orange grove sites (replicates 4-13)
Mixer/loader	product (~5.7 L) was poured into a pail and added to a nurse tank with water and other additives the mixture was then transported by truck to the citrus grove where it was transferred to the airblast sprayer tank (1890 L) and water added to overflow (hose couplings from nurse tank to spray tank were handled by the applicator, the cap of the spray tank was also tightened by the applicator) the nurse tank was returned to the loading site and the process repeated	product (~5.7 L) was poured into a pail and added to the spray tank with other additives (if called for) the spray tank was filled to the top with water using hose and coupling
Applicator	drove the spray rig to the application site where the nurse tank was delivered, assisted with the loading (see above) and operated the spray equipment spraying into the wind at all times	drove the loaded spray rig to the spray site, applied the spray and returned to the loading site
Clean-up worker	hosed down the spray rig (and occasionally removed leaves from the spray tank fan and drove the nurse tank back to the loading area from the citrus grove	hosed down the spray rig (and occasionally removed leaves from the spray tank fan) at the loading site

(1) 12 to 20 cycles were performed per replicate - equivalent to a working day

The length of time monitored was considered to be equivalent to one work day for each replicate. For mixer/loaders the total monitoring time (average 8 h 28 min, range 5 h 53 min to 9 h 46 min) included gathering the materials and product, the trip to the mixing site in a company truck, mixing and loading, sitting between loads, and the trip back to the spray company in a truck. For applicators the total monitoring time (average 8h 36 min, range 7 h 10 min to 9 h 45 min) included preparation for work and transport to the citrus grove in a company truck, application of spray and trip back to the spray company in a truck. Total monitoring time for clean-up personnel (average 40 min, range 15 min to 1 h 35 min) covered the time taken to clean one airblast sprayer at the spray company after its return from the test. However, for applicator replicates 1, 2, 3, 14, 15 and clean-up replicate 6A the monitoring period included the trip to and from the sprayer in a truck.

Each worker wore a short sleeved T-shirt and briefs, a short sleeved shirt and long pants, a coverall, chemical resistant gloves, boots, goggles, helmet and respirator.

Potential and actual dermal exposure measurements were made for mixer/loaders, applicators and clean-up personnel using internal and external dosimeters and handwashes. Biomonitoring was also conducted.

Data collection and analysis

Each worker's T-shirt and briefs served as an internal dosimeter, while their coverall was the external dosimeter. Two denim patches positioned on the front and back of each helmet were used to measure head and neck exposure. Goggles and respirator were removed during idle times (between loads for mixer/loaders and while waiting for loading operations to be complete for applicators). The shirts and pants from replicates 7-15 and 6A were also analysed for chlorpyrifos content to determine penetration of chlorpyrifos through outer overalls. The limit of detection was 19.5-24 µg/sample for external dosimeters, 1.6-2 µg/sample for internal dosimeters and 0.3 µg/sample for head patches.

Respiratory exposure was estimated by attaching personal air pumps fitted with particulate filters and vapour tubes (Chromosorb 102) to each worker (location not specified). Air pumps were turned on after dressing or just prior to commencing work and were turned off after completing the tasks or just prior to performing the final hand wash of the day. Replicates 8-15 also had the pumps turned off during work breaks and lunch breaks. Airflow rates were calibrated to 1 L/min. The limit of detection for air samples was 0.03 µg/sample for filter cassettes and 0.3-0.4 µg/sample for chromosorb tubes.

Hand washes (two rinses in 0.008% dioctyl sodium sulfosuccinate and one rinse in distilled water) were conducted for all participants before starting work, at the lunch break and at the end of work. The limit of detection for handwashes was 1.6-2 µg/sample.

Urine was collected from all mixer/loaders, applicators and clean-up workers for 3,5,6-trichloro-2-pyridinol (TCP) determination. Two 6 h urine samples were collected from replicates 1-6 on the day prior to application and on day 4 after application. Twelve 6 h urine samples were collected from replicates 7-15 and 6A, two per day from day -1 to 4. The limit of quantitation for TCP was 1-3 ng/mL.

Blood samples were collected from each worker from 1 to 18 days prior to application and on the day after the application. Analyses of RBC and plasma ChE were subsequently conducted.

Results

All results were available as µg/sample. The authors estimated total absorbed dose by the combined dermal and respiratory routes expressed as µg/kg BW based on 3% dermal absorption, 70 kg body weight and 10% respiratory absorption through the respirator. Total absorbed dose based on passive dosimetry was also provided by the authors as mg chlorpyrifos per lb ai handled and µg chlorpyrifos per hour. The units have been changed for this report.

Total absorbed dose based on urinary TCP (expressed as µg/d) was estimated using both the urinary excretion factor method and pharmacokinetic modelling method of Nolan et al. (1984). The results obtained by both methods were compared and the greater of the two are presented in Table 11. These estimates assume a body weight of 70 kg.

Table 11: Summary of exposure of mixer/loaders, applicators and clean-up personnel during application of EC chlorpyrifos to citrus groves

Worker category	Potential respiratory exposure			Actual dermal exposure					Absorbed chlorpyrifos based on passive dosimetry[7] (µg/kg ai handled)[3]	Absorbed chlorpyrifos based on urinary TCP[8]	
	mg/m^3 [1] *	µg[2] *	µg/kg ai handled[3] *	Body[4] (µg/ sample) *	Hands[5] (µg/ sample) *	Head and neck[6] (µg/ sample) *	Total (µg/ sample) *	Total (µg/kg ai handled)[3]		µg/d *	µg/kg ai handled[3]
Mixer/ loader	15.6	223	6.64	838	431	12594 [5]	14033	418	13.2	567	16.9
Applicator	53.2	756	22.5	1038	327	18135	18784	559	19.0	669	19.9
Clean-up worker	10.7	18.4	0.55	131	42	1209	1325	39	1.2	80.5	2.4

* 75th percentile
(1) µg/sample of cassette and air tube (corrected for spike recovery) ÷ total air volume (m^3)
(2) mg/m^3 adjusted for actual monitoring time and respiratory rate of 1.74 m^3/h
(3) based on average amount of chlorpyrifos handled (33.6 kg ai)
(4) corrected for clothing penetration (penetration factor derived by dividing T-shirt and brief exposure by coverall torso exposure)
(5) estimated from handwashes
(6) this value represents potential exposure as it is based on external headpatch exposure $µg/cm^2$ x 1300 cm^2
(7) potential respiratory exposure (µg/kg ai handled) x 10% absorption plus total actual dermal exposure (µg/kg ai handled) x 3% absorption

(8) based on either urinary factor or kinetic model, greater of the two
For samples that were not detected, ½ the detection limit was used as the estimate

Average penetration factors through two layers of clothing were estimated at 1.47%, 0.29% and 1.19% for applicators, mixer/loaders and clean-up workers respectively. These values were used to calculate actual body exposure in Table 11.

For all worker categories, the greatest source of dermal exposure was on the head and neck (~90%), followed by body (~7%, through clothing) and hands (~3%, through gloves). Across all participants, the distribution of chlorpyrifos on the coveralls was greatest on the torso and legs, and less on the arms.

RBC and plasma ChE levels were not affected by exposure.

Discussion

The study design is appropriate for regulatory purposes. An adequate number of replicates were used, with each replicate performed by a different worker.

The concentration of chlorpyrifos in the study product is close to Australian products used for similar situations (41% compared to 50%, respectively). Spray rates were higher in the study, however due to differing spray volumes, final spray concentrations were comparable. Packaging and mixing techniques (open mixing) were also similar.

The study participants treated an average of 5.1 ha/d, which equates to ~34 kg ai handled per day. Australian workers are expected to handle less than this amount, 15 kg ai/d (a maximum rate of 1 kg ai/ha for 15 ha). In the OHS risk assessment, exposures are standardised for amount of chlorpyrifos handled.

Absorbed dose calculated from urinary TCP correlated well with total dermal and inhalation exposure. The passive dosimetry results are based on the penetration through two layers of clothing (through layers 3 and 2 onto layer 1), while the biomonitoring results take into account three layers of clothing (layers 3, 2 and 1). Most Australian workers are expected to wear coveralls over their own clothing and underwear, which is consistent with the biomonitoring results. Some workers however may wear coveralls over only their underwear. As the body contributes only 10% to the total actual dermal exposure for all worker categories, the difference between 2 or 3 layers will not impact greatly on the overall dermal dose.

The OHS risk assessment is based on the absorbed dose values only.

<u>Boom application</u>

Shurdut BA, Murphy PG, Nolan RJ and McNett DA (1993) Lorsban 4E and 50W Insecticides: Assessment of Chlorpyrifos Exposures to Applicators, Mixer/Loaders, and Re-entry Personnel During and Following Application to Low Crops, DowElanco (USA), HEH2.1-1-182(118/124), September 1993.

This study evaluated exposure to chlorpyrifos by mixer/loaders, applicators, and re-entry scouts. The study was conducted by DowElanco for the purpose of product registration and was conducted in accordance with US EPA Pesticide Assessment Guidelines, Subdivision U: Applicator Exposure Monitoring (US EPA, 1987) and Re-entry Protection Guidelines, Subdivision K (US EPA, 1991).

Study details

Lorsban 4E (an emulsifiable concentrate containing 40.7% chlorpyrifos) and Lorsban 50W (a wettable powder containing 50% chlorpyrifos) were used to treat various crops at three test sites across the USA, as shown below.

Site 1 (Michigan): three applications of Lorsban 4E were made to vegetation (Christmas trees and bare ground for cover crops), ranging from 1.77-3.10 kg ai/ha at a spray volume of 92-281 L/ha.

Site 2 (Arizona): three applications of Lorsban 50W were made to cauliflower at a rate of 0.97-1.71 kg ai/ha and spray volume of 354-428 L/ha.

Site 3 (Florida): three applications of Lorsban 50W were made to tomatoes at a rate of 1.03 kg ai/ha and a spray volume of 562-1120 L/ha.

The study utilized 9 mixer/loaders (3/crop), 9 applicators (3/crop) and 10 re-entry scouts (5/crop, tomatoes and cauliflower only). Each participant served as a single replicate. Total application areas varied from 9.3 to 24.7 ha. The study considered each replicate (which consisted of several application cycles) to be complete after 4-5 hours had elapsed or when 40 acres (16 ha) had been treated. Due to heavy workloads, it was not possible to use professional workers at two test sites (cauliflower and tomato treatments). Instead, surrogate mixer/loaders, applicators and scouts (6 for each worker category) were trained to carry out the usual tasks. As surrogate applicators were not certified to drive the application rig, they were positioned in close proximity to the driver's cab for the duration of the replicate (either directly behind or adjacent to the tractor driver). Scouting activities were conducted approximately 24 hours after treatment for approximately 4 hours.

Each product was mixed in a spray tank and applied by open cab tractor-mounted boom (standard boom for cover crops and cauliflower, high clearance boom for tomato). Lorsban 4E was packaged in 2.5 gal (9.5 L) plastic jugs and Lorsban 50W in 5 lb (2.27 kg) bags. Water-soluble packaging was discussed as an alternative to these but was not used in the study in order to provide a worst case scenario.

All participants wore protective clothing as stipulated on the product labels. Applicators wore new coveralls (ie, long sleeves and pants), a new undershirt, a new pair of briefs and socks, chemical resistant boots and a “baseball” style hat. Mixer/loaders wore the same protective clothing as well as a half face respirator equipped with organic vapour cartridges and particulate filters (Lorsban 50W only), goggles (Lorsban 4E only) and nitrile gloves during loading operations. Field scouts were required to wear T-shirt and briefs, appropriate closed toe footwear, a baseball hat and coveralls with the sleeves cut off above the elbow. Sleeves were cut to simulate short sleeved shirt normally worn by re-entry staff in Arizona and Florida.

Passive dosimetry was used to measure potential respiratory and actual dermal exposure of all worker categories.

Biomonitoring was also conducted for each worker. Urinary TCP levels were used to estimate chlorpyrifos dose. Blood samples were also collected to estimate plasma and RBC ChE inhibition. To minimise biomonitoring interferences, exposure with chlorpyrifos products was restricted for up to seven days prior to the sample period until the last urine specimen was collected.

Leaf punch samples were collected for the estimation of dislodgeable foliar residues. Methodology and results of dislodgeable foliar residues are presented in the Post-application Exposure section (Section 4.3.1.1).

Data collection

Respiratory exposures were measured in the breathing zone of each participant using a sample pump. For mixer/loaders air monitoring pumps were turned on only during the performance of mixing and loading tasks. Mixer/loaders who were involved in clean-up operations wore a second air pump during the clean-up task to estimate the relative contribution of each task on the total respiratory exposure. Applicators’ air pumps were kept running for the entire duration of each replicate.

Air monitoring results were presented as mean time weighted average (TWA) exposures and estimated absorbed doses (calculated assuming a worker respiratory rate of ~25 L/min and 100% absorption). The authors estimated absorbed respiratory dose using a protection factor of 10% to allow for the respiratory protection worn by most of the Lorsban 50W mixer/loaders. These estimates are not presented here, as Australian agricultural workers are not required to wear respiratory protection.

The air monitoring samples for cauliflower mixer/loaders (Site 2) could not be analysed as they were above the GC detector range (which was not provided). The authors claim that diluting these samples was considered at a later date, but by this time the samples were not suitable for analysis.

Dermal contamination of exposed skin and areas covered by clothing (actual dermal exposure) was estimated using full body dosimetry techniques and hand washes. Mixer/loaders and applicators wore coveralls and a denim patch on hat (external dosimeters) and T-shirt/undershirt and briefs (internal dosimeters).

Field scouts wore coveralls (short sleeved) and sweatband on forearm (external dosimeters) and T-shirt/undershirt and briefs (internal dosimeters).

Hand washes (0.008% Emcol 4500 soap solution) were conducted for all participants before starting work, at usual break times (such as before smoking, eating or visiting the bathroom) and at the end of each monitoring period.

Total actual dermal exposures for mixer/loaders and applicators were estimated by adding the amount of chlorpyrifos penetrating coveralls (µg on torso, legs and arms x respective penetration factors) with hand contamination and an estimate of face/neck contamination (µg on patch x ratio of head to patch surface area ie, 1300 cm^2: 103.2 cm^2).

Total actual dermal exposures for scouts were estimated in a similar way except that the arm exposure component was estimated from sweatband contamination (µg on sweatband x arm area (2742 cm^2)/sweatband surface area (137 cm^2). A dermal absorption factor of 3% was used to calculate absorbed dose from total dermal exposures.

Penetration through coveralls (%) was estimated by dividing µg chlorpyrifos on T-shirt and briefs by µg chlorpyrifos on torso region of coverall and multiplying by 100.

Urine samples (complete) were collected from all participants at 12 hour intervals for 6 days commencing the day before treatment or re-entry. Samples were analysed for the metabolite TCP and the amount of chlorpyrifos absorbed was estimated. Two methods were used: one based on the urinary excretion factor of Gibaldi and Perrier (1992) and the other based on the compartment model of Nolan et al. (1984). The greater of the 2 estimates were converted to a dose/kg bw estimate. TCP background levels which were > 0.5 µg/kg/day were subtracted from the post-treatment estimates as they were believed to be due to prior chlorpyrifos exposure. Based on urinary creatinine excretion rates, some samples were considered incomplete, however losses were considered small and no correction was made for them.

Blood samples were also collected for the determination of plasma and erythrocyte cholinesterase activity, prior to exposure and the morning after treatment or re-entry.

Results

The results of the mixer/loader and applicator exposure are presented in Table 12, below.
The results of the field scout exposure and estimation of dislodgeable foliar residues are presented in the Post-application Exposure section (Section 4.3.1.1).

Table 12: Summary of exposure of mixer/loaders and applicators during boom application of EC and WP chlorpyrifos to vegetation, cauliflower and tomatoes

Site, crop and formulation type	Worker category	PPE	Total ai handled (kg)	Spray concentration (g ai/L)	Respiratory exposure			Dermal exposure			Sum of absorbed respiratory and dermal doses (µg/kg bw)	Absorbed chlorpyrifos based on urinary TCP (µg/kg bw)
					(µg/m^3)	absorbed dose[2] (µg)	absorbed dose[2] (µg/kg bw)	total dermal exposure (mg)	absorbed dose[3] (µg)	absorbed dose[3] (µg/kg bw)		
Site 1 vegetation EC	Applicator (open cab, standard boom)	new coveralls, undershirt, briefs and socks, chemical resistant shoes, baseball hat	48 (42-55)	14.2	10.7 (3.23-25.6)	73.7 (20.8-175)	0.861	1.23 (0.21-2.53)	36.9 (6.3-76.0)	0.431	1.3	1.9 (<0.4-4.1)
	Mixer/Loader (open mixing)	as for applicator, plus goggles and nitrile gloves			3.66 (1.11-3.58) [1]	4.1 (2.2-4.03)	0.0536	22 (0.208-62.7)	660 (6.24-1880)	8.63	8.68	7.8 (1.9-19.5)
Site 2 cauliflower WP	Applicator (open cab, standard boom)	new coveralls, undershirt, briefs and socks, chemical resistant shoes, baseball hat	19 (14-27)	3.39	10.6 (9.11-11.7)	67.3 (62.7-73.7)	0.926	1.84 (0.895-2.22)	36.8 (17.0-66.5)	0.506	1.4	2.0 (0.5-2.5)
	Mixer/Loader (open mixing)	as for applicator, plus half face respirator, goggles and nitrile gloves			samples over detector range			40 (8.42-68.5)	1218 (253-2060)	13.05	(no respiratory dose estimate)	12.0 (6.6-22.0)
Site 3 tomatoes WP	Applicator (open cab, high clearance boom)	new coveralls, undershirt, briefs and socks, chemical resistant shoes, baseball hat	11 (9-12)	1.18	25.4 (19.8-35.1)	175 (122-276)	2.13	2.44 (1.79-2.83)	73.1 (53.9-84.8)	0.888	3.0	2.8 (1.5-4.7)
	Mixer/Loader (open mixing)	as for applicator, plus half face respirator, goggles and nitrile gloves			2963 (1200-4370)	3670 (2130-4480)	49.3	13 (7.3-23.1)	377 (217-695)	5.06	10.0[4] 54.5[5]	11.4 (4.2-16.7)

All data are arithmetic means of 3 replicates - All dose estimates (µg/kg bw) are based on individual worker body weights (range 60-109 kg)
(1) two of these workers were also monitored during clean-up operations during which time airborne chlorpyrifos levels were ~1.33 µg/m^3 (below detection) and 4.05 µg/m^3
(2) assumes no respiratory protection (ie 100% transfer through respirator and 100% absorption of transferred dose) and respiratory rate of 1.5 m^3/h

(3) assumes 3% skin absorption
(4) these mixer/loaders wore respirators (assumes 10% transfer through respirator and 100% absorption) and is included for comparison with the monitoring results
(5) assumes no respiratory protection

Absorbed doses estimated by biomonitoring correlated well with exposure estimates based on passive dosimetry.

Mean penetrations of chlorpyrifos through the coveralls were 7.0% (1.7-18%) for applicators and 7.5% (1.7-44%) for mixer/loaders.

Blood cholinesterase levels from pre- and post- exposure samples showed depression (average 10%, range 5-14%) in 3/8 applicators and 4/8 mixer/loaders (results not presented), however correlation with absorbed doses was poor. The authors speculated that two of the affected applicators might have been exposed to another organophosphate present in the tank mix.

Discussion

The study design is suitable for regulatory purposes.

Both formulation types (EC and WP) are registered for use in Australia.

The crop types used in this study are relevant for the Australian use pattern. Exposure during application to bare ground may be relevant for the assessment of Australian workers during boom application to low crops (such as vegetables) and lawn/turf.

Study EC formulation was packaged in 2.5 gal (9.5 L) plastic jugs and WP formulation in 5 lb (2.27 kg) bags. Australian WP products are available in 500 and 250 g water-soluble packs and EC products available in 1, 2, 5 and 10 L containers. Mixing techniques (open mixing) used in the study are relevant for Australian workers. Australian mixer/loaders will be exposed to less WP chlorpyrifos than shown in the study, due to the differences in packaging types.

Application rates and total ai handled are comparable, however the spray volumes appear to be lower in the study.

The results from this study are suitable for use in the OHS risk assessment. The biomonitoring and dosimetry results are in good agreement and are both used in the risk assessment. The dosimetry data allow for risk to be determined for Australian workers who are not required to wear respiratory protection. Due to incomplete dosimetry data the biomonitoring data are also included.

Aerial application

No exposure studies were available for crop treatment by aerial methods. Dow provided three studies that measured respiratory exposure and/or area air concentrations during mosquito control by helicopter or fixed wing airplane. These are described below.

(1) Soule RD (1967) Environmental Survey: Human Exposure to Dursban During Field Applications in Lee County, Florida, A1A-387 TK-2-1091, The Dow Chemical Company, September 1967.

Two aerial applications were made to marshland/swampland for mosquito control. The first application (site 1) was carried out by aerial spraying, the second (site 2) by application of granular product using a helicopter. Area air samples within the treated area were taken at both sites (two samples at site 1, one sample at site 2). At site 2, the breathing zone air of one worker involved in signaling the pilot was also monitored. Air samples were collected using an air pump impinger filled with n-heptane.

The study parameters and results are summarised below.

Table 13: Summary of air sampling during aerial application of chlorpyrifos (Dursban) as spray or granule

Site number and application method		Application rate and area	kg ai handled	Sampling duration[(2)]	Area air samples (µg/m^3)	Breathing zone samples[(3)]	
						µg/m^3	µg/kg ai handled[(5)]
1	product[(1)] diluted with No. 2 diesel oil and spray applied by plane	0.028 kg/ha ~20 ha	0.56	15 min	< 4.4[(4)] < 5.4[(4)]	not measured	not measured
2	granular product applied by helicopter	0.028 kg/ha ~12 ha	0.336		< 4.4[(4)]	5.4	7.0

(1) formulation not provided
(2) the sampling began just before the application and ended 5 min after application
(3) man signaling swath location to helicopter pilot
(4) below Australian exposure standard for chlorpyrifos of 200 µg/m^3
(5) based on respiratory rate of 1.74 m^3/h

Area air samples, as well as a single breathing zone sample, were well below the NOHSC exposure standard for chlorpyrifos of 200 µg/m^3.

Discussion

Worker exposure during aerial operations occurs mainly during mixing and loading and to a lesser extent during flagging. Flagger exposure is mainly via the dermal route. By studying the respiratory exposure of a single flagger, the authors overlooked the most relevant exposure routes and worker categories.

Aerial application of granular product is not relevant for the current Australian use pattern. The performance questionnaires indicate this formulation is only available for home garden use or for use on sugarcane at planting (soil fumigation).

The results from site 1 also cannot be used in the risk assessment as the product type is not known, the study application rate is below the Australian rates for crop protection (~0.35-1.5 kg/ha), the replicate number is low and the product was used in conjunction with an oil diluent.

(2) The Dow Chemical Company (1967a) A Study of Air Samples in Areas of Ultra-Low Volume Application of Dursban M and an Estimation of Safety to Humans in Treated Areas, The Dow Chemical Company, Midland, Michigan, A1A TUMAN AM 9, November 1967.

This study investigates the use of chlorpyrifos for mosquito control.

Area air samples and deposition measurements were made during a single ULV application of Dursban to a rice field (130 ha) by helicopter. Application was at 0.028 kg Dursban/ha, spray volume 439 mL/ha.

Similar sampling was conducted during a single ULV application by fixed-wing aircraft (Piper Pawnee) using six repeated passes over a 229 m line on the grounds of a US gun club. Application was at 0.336 kg Dursban/ha (spray volume not specified) and was reported by the authors to be six times the rate necessary for mosquito control.

During helicopter application airborne chlorpyrifos concentrations were measured at <0.0022 mg/m^3 and spray deposition was observed up to 45 - 60 m from treated area. During aeroplane application airborne chlorpyrifos concentrations were measured at 0.0025 mg/m^3 and spray deposition was observed up to 25 - 50 m from treated area.

Discussion

The available Australian use pattern information suggests ULV application to be suitable only for use in field crops. The rate of application is expected to be 0.5 kg ai/ha for these crops, which is greater than the application rates used in this study. Due to low replicate numbers, poor study quality and lack of dermal exposure estimates, the results from this study cannot be used in the risk assessment of workers involved in crop protection.

(3) The Dow Chemical Company (1967b) A Study of Air Samples from the Breathing Zone of Personnel Mixing, Loading and Aerially Applying Oil Solutions Containing Dursban M and an Estimation of Safety to Such Personnel and Others on the Ground in Treated Areas, A1A-1341 TK-2-1766, The Dow Chemical Company, Midland, Michigan, December 1967.

Dursban insecticide (Dursban M) in No. 2 diesel oil was applied aerially at a rate of 2.3 and 4.6 g/ha and a spray volume of 292 mL/ha. Breathing zone samples were collected during preparation of the spray mixture, transfer of the mixture to the aircraft spray tanks, piloting the aircraft and flagging operations. A total of four samples were taken only.

Sample 1 was taken at the breathing zone of the pilot inside of the cockpit of a Piper Pawnee during application (rate 2.3 g/ha). One of the two spray tanks had a leak and the contents were transferred to the other, with the excess being dumped while the plane was in flight. This activity was believed to result in additional pilot exposure. The measured pilot exposure was 23.8 µg/m^3.

Sample 2 was taken at the breathing zone of a man mixing product with No. 2 diesel fuel and loading the mixture into the tank. The entire mixing/loading operation took 10 minutes. The measured mixer/loader exposure was 5.5 µg/m^3. This is equivalent to inhalation of 1.6 µg during the entire mixing loading operation based on a respiratory rate of 1.74 m^3/h.

Sample 3 was taken at the breathing zone of the pilot during a repeat application at 2.3 g/ha. The measured pilot exposure was 10.5 µg/m^3.

Sample 4 was taken at the breathing zone of two men sitting inside a Jeep during signaling activities. The Jeep was driven on a road. Both the driver and the companion were required to signal the pilot (one with a mirror, the other with flag). It is not stated whether this was conducted with the windows open or closed. The application rate was 4.6 g/ha. The measured flagger exposure was 3.9 µg/m^3.

Discussion

In most cases the study did not state the sampling times, treatment area or exposure times. Exposure estimates were presented as µg/m^3, however the concentration of chlorpyrifos in the product and the formulation type were not provided. In addition the replicate numbers (1 mixer/loader, 2 applicators, 1 flagger) are inadequate and the application rates are much lower than the Australian application rates for crop treatment. This study is not considered adequate for regulatory purposes and the results will not be used in the risk assessment of aerial crop treatment.

The authors estimated levels of safety based on extrapolation of a NOEL established in chronic dietary studies, which they claimed was equivalent to an inhalation NOEL of 100 µg chlorpyrifos/m^3. This approach is not considered appropriate.

<u>Handspray – Ornamentals</u>

Dow provided a number of studies which measured applicator exposure during handspray of ornamentals. A number of literature studies were also available. These are described below.

(1) Vaccaro JR (1977) Evaluation of Pesticide Applicators' Exposures to Airborne Chlorpyrifos during Ornamental Spraying Operations with Dursban, Chemscape, Division of Chem-Lawn Corporation, Kansas City, Missouri, August 30 1977, Dow Chemical USA, AIA-708TK-2-1755, October 1977.

Personal breathing zone samples (Poricil filled tubes) and wipe samples were taken from two workers applying Dursban to ornamentals (bushes and scrubs) on six separate occasions. Application was by high pressure spray forming a mist. The spray concentration was approximately 125 mL Durban/100 L (1 pint Dursban in 90-100 gallons) water. The application rate was not provided.

Each operator wore chemical resistant goggles, respirator (organic vapour) and disposable paper suit. Rubber boots were worn during some of the mixing operations.

The study reported airborne concentrations of chlorpyrifos of 0.3-60 µg/m^3 (arithmetic mean 12 µg/m^3, 75th percentile 4 µg/m^3) during application. The air concentrations increased as the day progressed.

Wipe testing was conducted on the applicator's truck, as well as on his arms, forehead and leather shoes. The wipe test results (µg/100 cm^2) are as follows:

forehead	1.1 (2 samples)
arm	9.3 (2 samples)
leather shoe	28.0
steering wheel	0.7 (2 samples)
car bumper after mist settled	170

Discussion

The spray concentration used in this study (125 mL/100 L) is similar to the Australian situation (100 mL/100L), however the application method, application rate, work rate, amount of pesticide handled and spray volume are not known.

Due to limited study details and dermal exposure data, this study is not used in the OHS risk assessment.

(2) Axe FD (1983) Evaluation of Applicator Exposure and Work-Environment Impact Following Treatment of a Greenhouse with Dursban 50W, Nakashima Nursery, Watsonville, California, Dow Chemical USA, A1A-254 TK-2-1757, August 1983.

Dursban 50W was applied to greenhouse roses at a rate of 1.12 kg/ha (final concentration of chlorpyrifos 0.6 g/L). The greenhouse was enclosed and ventilated (by means of louvered vents). The treatment area was 7161 m^2 (0.7161 ha).

Two subjects applied the spray via an underground piping system connected to a 3785 L agitated tank and pump system and fitted with a three-headed nozzle on the end of a long length of 3/8" pressure hose. The two subjects worked together, walking the length of each row until they met in the middle, spraying plants on each side on the way. The subjects wore PVC rain gear and a respirator with pesticide cartridge. The authors did not specify whether gloves were worn or not.

Personal breathing zone samples (1 for each subject) were collected during the time spent spraying (1.7 hours). Five area samples were collected from different sites within the greenhouse for a sampling time of 1.8 or 1.9 hours, starting 15 minutes after the spraying was completed. Both personal and area air samples were sampled using air tubes packed with Chromosorb 102 using a pump rate of 100 ml/min.

Personal breathing zone chlorpyrifos concentrations were 0.02 and 0.01 mg/m^3, (equivalent to 59.2 and 29.6 µg, respectively, at a respiratory rate of 1.74 m^3/h). Based on a total of 802 g ai handled by both subjects (401 g each), average applicator respiratory exposure is estimated at 0.110 mg/kg ai handled. The area air samples ranged from 0.01 to 0.02 mg/m^3. Area air samples were below the Australian exposure standard for chlorpyrifos of 0.2 mg/m^3.

Discussion

The study application rate was similar to the Australian rate indicated by the performance questionnaires. This study did not consider dermal exposure and is therefore not suitable for use in the OHS risk assessment.

(3) Stamper JH, Nigg HN, Mahon WD, Nielsen AP and Royer MD (1988) Pesticide Exposure to Greenhouse Foggers, Chemosphere, 17 (5), 1007-1023.

This study was conducted to evaluate the pesticide exposure of applicators to chlorpyrifos (Dursban 50% WP), fluvalinate or ethazol (sometimes in combination) to ornamentals in a Florida greenhouse. The chlorpyrifos results only are discussed here.

Study details

One male subject (3 replicates) applied the chlorpyrifos product as a drench spray using a fogging device which produced a misty spray from a single nozzle handgun. The applicator treated one Florida greenhouse containing chrysanthemums and African violets.

Timed exposure periods lasted an average of 30 min. The authors did not specify the tasks conducted during the exposure period. The greenhouse treated was described as enclosed and ventilated.

The subject wore a disposable coverall and hood, bibbed butyl apron, butyl gloves (mid forearm length), butyl boots (mid calf length), goggles and respirator (covering nose and mouth).

Data collection and analysis

Dermal exposure was assessed using pads placed inside and outside protective coveralls. External patches were placed on the middle of the back (slightly higher than shoulder blade level), on the chest (centre, just below the collar bone), on top of each shoulder, on each forearm (just below elbow, dorsal surface), each thigh (mid, ventral surface) and shins (just below the knee, ventral surface). Internal patches were positioned beneath the coverall just lower than the external patches at the following positions: chest, both forearms, both thighs and both shins. Outside patches were always exterior, however internal patches were sometimes protected by more than one layer, eg coverall and apron.

Total body surface area was estimated using the formula of Gehan and George (1970). Estimated total body accumulation rates (ETBAR), excluding hands but including head and neck, were estimated from the pad fluxes (compound on pad divided by pad area and exposure time) using USEPA (1985) body surface proportions. The ETBARs (mg/h) were normalised for spraying rates (kg ai/h) to give mg/kg ai handled. Fabric penetration percentages were estimated by dividing inside pad fluxes by outside pad fluxes and multiplying by 100.

Handwashes were collected from each replicate and analysed. Hand contamination estimates were normalised for spray rate (as above).

Personal air samples were collected from each replicate based on a 3 L/min intake by the personal air sampler fitted with a vapour filter (polyurethane foam filter plug). Air sample values were translated by the authors to mg/h via the 3 L/min factor. The authors normalised these values for spray rate (kg ai/h) but did not factor in the respiratory rate of the workers (they quote 17 L/min, here). Note, the results in Table 14 have been corrected for a respiratory rate of 29 L/min.

Results

The study results are summarised in Table 14. The study authors presented all data as arithmetic means ± standard errors.

Table 14: Summary of exposure estimates for workers[1] spraying chlorpyrifos to greenhouse bench plants

Data [2]	Spray rate (kg ai/h)	Outside ETBAR (mg/kg ai handled)	Total handwash (mg/kg ai handled)	Potential inhalation (mg/kg ai handled)[3]	Total chlorpyrifos dose[4] (mg/kg ai handled)		% penetration through PPE
					gloves	no gloves[5]	
arithmetic mean ± standard error	0.119 ± 0.008 [3]	5.8 ± 2.0 [3]	14 ± 13 [3]	0.59 ± 0.25 [3]	1.0	4.8	50.5[6] 11.7[7] 17.9[8] 7.6[9] [10]

75th percentile		7.2	21	0.75	1.4	7.1

(1) the subject wore a coverall, hood, gloves, apron, boots, goggles and respirator
(2) number of replicates in square parentheses
(3) air sampler values (collected at 3 L/min) corrected for respiratory rate of 29 L/min
(4) assuming 3% dermal absorption and 10% transmittance through one layer of clothing (ie. ETBAR x 0.03 x 0.1 + hand exposure x 0.03 + inhalation exposure x 100% transmittance)
(5) adjusted for 10% transmittance through gloves (default)
(6) through coverall plus apron onto chest; 2 replicates, SE = ± 43.7%
(7) through coverall onto forearm; 2 replicates, SE = ± 2.0%
(8) through coverall plus apron onto thighs; 2 replicates, SE = ± 2.1%
(9) through coverall plus boots onto shins; 2 replicates, SE = ± 4.9%
(10) due to inconsistencies in penetration factors, a default of 10% transmittance through one layer of clothing was used to estimate dermal dose

Right and left mean handwash data showed no statistically significant differences.

Total body accumulation rates, arithmetic mean normalized for spraying rates calculated from the residues on the sampling pads, was 5.8 mg/kg ai (milligrams deposited outside clothing per kilogram sprayed). Most of the exposure occurred to the legs.

Discussion

This study measured both respiratory and dermal exposure, however the replicate numbers (3) were low and the study details were reported poorly. The authors did not provide application rates and spray volumes, and did not provide full details of the tasks performed by each replicate (due to short exposure monitoring time task is assumed to be application only), the application method or detailed description of the greenhouse sprayed.

The study provided a spray rate of 0.119 kg ai/h (equivalent to 0.71 kg/6 h day) which is similar or greater than the amount of chlorpyrifos handled by Australian workers (0.4 or 0.1 kg per day, depending on equipment used). It should also be noted that the study monitoring time was short (30 min) and extrapolation to a full day may be an overestimate of the exposure.

The clothing penetration results were difficult to interpret. On the whole, penetration of chlorpyrifos was greatest through overalls worn in conjunction with an apron than overalls worn alone. In the absence of reliable clothing penetration factors, NOHSC used a default of 10% for the dermal exposure estimations.

Overall, the results from this study are considered adequate for inclusion in the OHS risk assessment. However, the study limitations are noted in considering the overall risks during hand spraying.

(4) Stamper JH, Nigg HN, Mahon WD, Nielsen AP and Royer MD (1989a) Pesticide Exposure to Greenhouse Handgunners, Archives of Environmental Contamination and Toxicology, 18, 515-529.

This study was conducted to evaluate the pesticide exposure of applicators of chlorpyrifos, fluvalinate, ethazol or dicofol (sometimes in combination) to ornamentals in a Florida greenhouse. The chlorpyrifos results only are discussed here.

Study details

Three study participants, one male (subject 1: 7 replicates) and 2 females (subject 2: 7 replicates and subject 3: 10 replicates), were monitored during the application of chlorpyrifos (Dursban 50% WP) to greenhouse chrysanthemums and African violets. For all applications, workers used a handgun with a 6-nozzle head attached by a long hose to a 227 L cylindrical spray tank. The wand was held about 15 cm from the nozzles.

Plants were located at bench height (0.7 m) and extended vertically another 0.3-1.0 m. Narrow aisles between the rows led to some applicator exposure from direct contact with foliage or benches. Two replicates were conducted in a greenhouse described as being enclosed and ventilated. The other applications were in a greenhouse described as open-sided with translucent plastic roof. Spray volumes and final spray concentrations were not provided.

Timed exposure periods for each replicate lasted an average of 30 min. The tasks conducted during the exposure period were not specified.

Data collection and analysis

Internal and external dermal patches were employed along with personal air monitoring and handwashes. The sampling and analytical methodology is described above in Stamper et al. (1988).

Results

The study results are summarised in Table 15.

The study authors presented all data as arithmetic means ± standard errors.

Right and left mean handwash data showed no statistically significant differences.

Total body accumulation rates, arithmetic mean normalized for spraying rates calculated from the residues on the sampling pads, was 269 mg/kg ai (milligrams deposited outside clothing per kilogram sprayed). Most of the exposure occurred to the legs.

Table 15: Summary of exposure estimates(1) for workers(2) spraying chlorpyrifos to greenhouse bench plants

Data	Spray rate (kg ai/h)	Outside ETBAR (mg/kg ai handled)	Total handwash (mg/kg ai handled)	Potential inhalation (mg/kg ai handled)(4)	Total chlorpyrifos dose(5) (mg/kg ai handled)		% penetration through PPE
					gloves	no gloves(6)	
Arithmetic mean ± standard error	0.091 ± 0.006 [23]	269 ± 56 [22] (3)	1.60 ± 1.30 [23]	0.77 ± 0.42 [23]	1.63	2.06	11.6(7) 5.5(8) 12.1(9) 0.5(10) 1.1(11) 3.7(12) 11 ± 5 [23] (13)
75th percentile		400	0.60	0.28	1.50	1.66	

(1) arithmeic means ± SE, number of replicates in square parentheses
(2) all subjects wore Tyvec coverall, hood, gloves (mid-forearm length), bibbed apron, boots (mid-calf length), goggles and respirator except for subject 3 who did not wear an apron for 2 of 10 replicates; gloves, boots and aprons were butyl rubber
(3) subject 3 acted as an assistant to subject 2 for one replicate and is not included here
(4) air sampler values (collected at 3 L/min) corrected for respiratory rate of 29 L/min
(5) assuming 3% dermal absorption and 10% transmittance through one layer of clothing (ie. ETBAR x 0.03 x 0.1 + hand exposure x 0.03 + inhalation exposure x 100% transmittance)
(6) adjusted for 10% transmittance through gloves
(7) through coverall onto chest; 2 replicates, SE = ± 43.7%
(8) through coverall plus apron onto chest; 22 replicates, SE = ± 2.6%
(9) through coverall onto forearms; 24 replicates, SE = ± 5.7%
(10) through coverall onto thighs; 2 replicates, SE = ± 0.3%
(11) through coverall plus apron onto thighs; 22 replicates, SE = ± 0.8%
(12) through coverall plus boots onto shins; 24 replicates, SE = ± 2.8%
(13) through coverall onto all body parts combined

Discussion

This study has similar limitations to the previous, although a larger number of subjects and replicates were employed. As indicated previously, extrapolation from a short exposure to a full day may result in overestimation. Spray rates were slightly lower in this study, but still greater than expected Australian use rates.

The clothing penetration results indicated an average penetration through the overalls (across all body parts) of 11 ± 5%. This value supports the use of 10% as a default in this report.

The data from this study are included in the OHS risk assessment. However, the study limitations are noted in considering the overall risks during hand spraying.

(5) Stamper JH, Nigg HN, Mahon WD, Nielsen AP and Royer MD (1989b) Pesticide Exposure to a Greenhouse Drencher, Bulletin of Environmental Contamination and Toxicology, 42 (2), 209-217.

This study is similar to the previous two (Stamper et al., 1988 and Stamper et al., 1989a).

Study details

One Florida greenhouse containing chrysanthemums and African violets was treated with chlorpyrifos (Dursban 50% WP), fluvalinate, ethazol and chlorothalonil, sometimes in combination. Two subjects (1 female: 1 replicate and 1 male: 8 replicates) applied the product as a drench spray using a single nozzle handgun equipped with an adjustable nozzle set to a low pressure for coarse spray. No description of the spray tank was provided.

Internal and external dermal patches were employed along with personal air monitoring, handwashes and tank mix sampling. The sampling and analytical methodology is described in Stamper et al. (1988) and summarised in study (3) above.

Most applications (7/9) were made in an open-sided greenhouse with translucent plastic roof. The others were in an enclosed, ventilated structure (female replicate and one of the male replicates). Timed exposure periods lasted an average of 40 min. The tasks performed during the exposure period were not specified.

Table 16: Summary of exposure estimates for workers spraying chlorpyrifos to greenhouse bench plants

Data	Spray rate (kg ai/h)	Outside ETBAR (mg/kg ai handled)	Total handwash (mg/kg ai handled)		Potential inhalation (mg/kg ai handled)(4)	Total chlorpyrifos dose(6) (mg/kg ai handled)		% penetration through PPE
			gloves	no gloves		gloves	no gloves	
arithmetic mean ± standard error(1)	0.306 ± 0.023 [8](2)	80 ± 27 [7](3)	-	7 ± 4 [8]	0.048 ± 0.011 [8]	-	0.498	5.4 (7) 11.1(8) 0.3(9)
75th percentile(2)		44 [8](3)	0.55[1]	3.6[8]	0.051 [8](5)	0.200	0.291	

Number of replicates in square brackets

(1) as provided in the study; does not include female subject; the male subject wore rubber boots and an apron (bib up for 1 replicate and down for 6 replicates) or Tyvek coveralls with hood and rubber boots (1 replicate) but no gloves or respirator

(2) includes female subject; female wore rubber boots, apron with bib up, rubber gloves and respirator

(3) authors did not estimate total body accumulation for one of the male replicates

(4) air sampler values (collected at 3 L/min) corrected for respiratory rate of 29 L/min

(5) no chlorpyrifos was detected in the air sample tube worn by the female

(6) assuming 3% dermal absorption and 10% transmittance through one layer of clothing (ie. ETBAR x 0.03 x 0.1 + hand exposure x 0.03 + inhalation exposure x 100% transmittance)

(7) through apron (bib up) onto chest; 1 replicate

(8) through apron onto thighs; 6 replicates, SE = ± 9%

(9) through boots onto shins; 8 replicates, SE = ± 0.1%

Right and left mean handwash data showed no significant differences.

Total body accumulation rates, arithmetic means normalized for spraying rates calculated from the residues on the sampling pads, was 44 mg/kg ai (milligrams deposited outside clothing per kilogram sprayed). Most of the exposure occurred to the legs.

Discussion

This study has similar limitations to the previous two studies. Again, extrapolation from a short exposure to a full day is expected to result in overestimation. Spray rates this time (equivalent to 1.8 kg ai/6 h day) were much higher than expected Australian rates (0.1 or 0.4 kg ai/d, depending on application method).

The data from this study are also included in the OHS risk assessment. However, the study limitations are noted in considering the overall risks during hand spraying.

(6) Nigg HN, Stamper JH, Easter E and DeJonge JO (1993) Protection afforded greenhouse pesticide applicators by coveralls: a field test, Archives of Environmental Contamination and Toxicology, 25 (4), 529-533.

This study was conducted to evaluate the pesticide exposure of applicators of chlorpyrifos, fluvalinate, or ethazol to ornamentals in a Florida greenhouse. The chlorpyrifos results only are discussed here.

The main aim of the study was to compare the permeabilities of different coverall fabrics. As such, only dermal exposure estimates were conducted and these did not include hand contamination. In addition, each replicate was conducted for a timed application period only, which is not representative of a typical application day.

Study details

Three applicators were monitored for a total of 20 replicates during the application of chlorpyrifos (Dursban WP and an unspecified EC formulation) to greenhouse chrysanthemums and African violets. Plants were located at bench height (0.7 m) and extended vertically another 0.3-1.0 m. Narrow aisles between the rows led to some applicator exposure from direct contact with foliage or benches. The greenhouse was described as enclosed and ventilated (ventilation was be temperature-activated exhaust fans). Spray volumes and final spray concentrations were not provided.

Timed exposure periods for each replicate lasted an average of 45 min. Tasks performed during the exposure period were not specified.

Data collection and analysis

Dermal exposure was assessed using pads placed inside and outside protective coveralls according to the monitoring procedure of Durham and Wolfe (1962). Coveralls were tailored to fit each applicator and were either spun-bonded, melt-blown, spun bonded synthetic disposable (SMS) or reusable treated twill (TT). External patches were placed on the chest (centre, just below the collar bone), each arm (just below elbow, facing outwards), each thigh (mid, facing frontward) and shins (mid, facing frontward). Internal patches were positioned beneath the coverall just lower than the external patches.

Estimated total body accumulation rates (ETBAR), excluding hands but including head and neck, were estimated from the pad fluxes (compound on pad divided by pad area and exposure time) using USEPA (1985) body surface proportions. Fabric penetration rates were estimated by dividing inside ETBAR by outside ETBAR.

Spray rates were calculated from actual tank mixture concentrations (collected pre- and post-application from the handgun), multiplied by the volume of spray applied and divided by the application time. These were provided as kg ai/h.

Results

Total body accumulation rates, arithmetic means normalized for spraying rates calculated from the residues on the sampling pads, was 320 mg/kg ai (milligrams deposited outside clothing per kilogram sprayed) for the five replicates applying a fine spray and 67 mg/kg ai for the 15 replicates applying a mist. Most of the exposure occurred to the legs.

The application methods and study results for chlorpyrifos are summarised below.

Table 17: Summary of application methods and exposure estimates for workers spraying chlorpyrifos to greenhouse bench plants

Application method	Spray rate (kg ai/h)	Outside ETBAR (mg/kg ai handled)	Percent penetration through coverall fabric	
			SMS(2)	TT(3)
Fine spray Handgun with 6-nozzle head attached by long hose to 227 L open cylindrical tank	0.1122 ± 0.0161 [5]	401 ± 167 [5 WP]	2.75 ± 1.38 [9](4)	18.64 ± 5.98 [10](4)
Mist Wand with single, adjustable nozzle connected by hose to 19 L enclosed tank	0.068 ± 0.0012 [14]	686 ± 160 [15: 8 WP, 5 EC]		

Fog single nozzle wand with 30 L enclosed tank	not provided	185 [1][(1)]		

All data are arithmetic means ± standard errors, number of replicates in square parentheses

(1) formulation not specified

(2) disposable polypropylene, spun-bonded, melt-blown, spun bonded synthetic

(3) reusable 35/65% cotton/polyester twill treated with water repellent finish

(4) authors did not specify which replicates were used for these estimations

Disposable coveralls, as defined in this study, afforded greater protection against chlorpyrifos exposure than cotton/polyester coveralls.

Discussion

Hand exposure is expected to contribute significantly to total exposure. As the study did not estimate hand or inhalation exposure the results cannot be used in the risk assessment.

The results obtained with cotton/polyester coveralls (18.64% penetration) suggest the 10% default used in this current review may be an underestimate. It is noted however that the greatest penetration estimates obtained in studies (3), (4) and (5) above, occurred when the amount of chlorpyrifos deposited on the clothing was lowest: 6 mg/kg ai in study (3), compared to 269 and 44 mg/kg ai in studies (4) and (5), respectively. It is also noted that the application duration is not representative of actual work situations. The penetration factors used in any of these studies are therefore of limited use in this review.

(7) Contardi JS, Gilbert JR, Lambesis DA, Murphy PG and Nolan RJ (1993) Evaluation of Chlorpyrifos Exposures during Mixing/Loading and Application of Empire 20 Insecticide to Ornamental Plants in Greenhouses, The Dow Chemical Company, HEH2.1-1-182(130), November 1993.

This study evaluated the exposure of mixer/loader/applicators during the treatment of greenhouse ornamentals with Empire 20 Insecticide (a microencapsulated concentrate containing 20% chlorpyrifos). The study was sponsored by DowElanco and conducted under GLP Standards in accordance with US EPA Pesticide Assessment Guidelines, Subdivision U (US EPA, 1987). The four study greenhouses were located in Ohio.

The study does not separate dermal exposure by the different tasks (ie, mixing/loading, application and clean-up). Therefore the results of dermal exposure cannot be extrapolated to other formulations for application only. In addition, the benefit of microencapsulated formulation for mixer/loader exposure cannot be gauged from this study. Respiratory exposure is measured during mixing/loading and during the combined tasks of mixing/loading and spraying, but no measurement is made during clean-up.

Study details

Sixteen experienced greenhouse workers (10 males and 6 females) were used in the study, with each participant corresponding to a separate replicate. The workers manually loaded Empire 20 Insecticide into a mix tank and applied the product to the greenhouse plants using hand held equipment. Fourteen of the participants were also involved in equipment clean-up at the end of the application.

The participants half-filled the spray tank with water from a hose and added the product by removing the product cap, puncturing the foil seal over the mouth of the bottle (454 g plastic bottle) and pouring the required amount into the tank using the graduated markings on the bottle. The remaining water was added into the tank and the spray was mixed using the hose pressure. Tank sizes varied from 1-200 gal (~3.8-757 L) and were either at a fixed location, on a portable cart or as a portable container.

Handguns or wands were used for application. Handguns predominated when spraying overhead plants, whereas wands predominated when spraying plants on floors or benches. Handguns were held in the applicators hands and spray released when a trigger or handle was depressed. Wands were 10-24 inches long and were usually continuous flow. The applicators usually held the nozzle or wand in one hand and guided the hose with the other, while walking slowly between the rows or benches treating one side of each row with each pass. Most spraying was done while walking backwards down each row to minimise contact with drift and wet leaves.

The concentration of chlorpyrifos in the final spray was similar for all replicates (either 0.96 or 1.2 g ai/L). The application rates ranged from 0.6-9.4 kg ai/ha (average 3.1 kg ai/ha) and the application volumes ranged from 668 to 6180 L/ha (average 2434 L/ha). The amount of chlorpyrifos handled during each monitoring period was estimated by the authors and appears in Table 18 and Table 19 as total ai sprayed (kg).

Clean-up activities consisted of filling the empty tank with water, flushing the hose/nozzle while spraying a small section of plants and then rolling up the hose.

Each replicate consisted of one or more mixing/loading/application cycle as well as the clean-up period (replicates 7 and 8 excluded). Replicate monitoring times ranged from 66 to 107 min.

Four different greenhouses (sites 1-4) were sprayed during the study. Most of these contained more than one species of plant, so it was usual practice to spray only selected sections of each greenhouse. Plants were located on floors/benches or overhead. They are treated separately in the results. Treatment areas ranged from 113-2325 m^2. Plant descriptions and application parameters for each replicate are provided in Table 18 and Table 19.

Data collection and analysis

Air sampling was conducted using air pumps fitted with glass fibre filters and chromosorb tubes. Two personal samples were taken from each worker, one during loading and one during loading plus application. Airbourne samples were also collected in the work areas just prior to application (T-1), just after application (T0) and at 4, 12 and 24 hours post-application (T4, T12 and T24, respectively). Pump flow rates were calibrated to 1 L/min for personal samples and 1.5 L/min for area samples.

Dermal exposure was determined using whole body dosimeters and handwashes. Workers applying chlorpyrifos to floor/bench plants wore cotton coveralls, rubber boots, nitrile gloves and goggles. Workers treating overhead plants wore cotton coveralls, rubber boots, nitrile gloves, goggles, neoprene rain jacket/pants, respirator, face shield.

Denim coveralls served as external or intermediate dosimeters (workers applying chlorpyrifos to overhead plants wore rain suits over their coveralls) and T-shirts and briefs served as internal dosimeters. Penetration factors (PF) were estimated by comparing coverall torso with T-shirt/brief contamination (ratio of chlorpyrifos on briefs and T-shirt to chlorpyrifos on torso of coveralls multiplied by 100). PF were used to estimate actual torso, arm and leg exposure.

Estimates of head and neck exposure were made using different dosimeters for each type of application. For overhead application, workers wore two headbands, one around the head and the other around the neck. For bench/floor applications workers wore a baseball cap with a denim patch attached to it.

Hand washes were collected from each worker at the conclusion of each treatment period (using a hand wash solution of 0.008% dioctyl sodium sulfosuccinate anionic surfactant). No breaks were taken by any of the workers during the exposure period.

Urinary TCP was used to estimate total absorbed chlorpyrifos dose. Total urine voided was collected at 12-hour intervals starting 24 hours before application and ending 4 days after the start of the study. The collection times for replicates 7-12 differed from the others due to their applications being conducted in the evening. All samples were also analysed for creatinine levels for the determination of sample completeness. The amount of chlorpyrifos absorbed was estimated using both the urinary excretion factor method and pharmacokinetic modelling described by Nolan et al. (1984).

Changes in plasma ChE were determined for each replicate. Blood samples were collected 48 and 24 hours pre-, as well as 24 hours post-application. The two pre-application samples served as a baseline mean. The post-application samples were presented as a percentage of their respective baseline means.

The study participants had been requested to avoid contact with chlorpyrifos for at least one week before the study commenced.

Table 18: Greenhouse plant application parameters and exposure estimates for workers treating floor/bench[1] plants

Replicate No.	Sprayer type; nozzle type	Plant orientation; types	Tank size (L)	PPE worn (in addition to cotton coveralls, rubber boots, nitrile gloves and goggles)	Total time of replicate[2] (min)	Total ai sprayed (kg)	Spray concentration (g ai /L)	Potential respiratory exposure[3] (µg/kg ai handled)			Dermal exposure (µg/replicate)				Total actual dermal exposure (µg/kg ai handled)	Total dose[10] based on passive dosimetry (µg/kg ai handled)	Absorbed chlorpyrifos based on urinary TCP[11]	
								ML	MLA	A[5]	Potential	Actual					(µg/replicate)	(µg/kg ai handled)
											Whole body[6]	Whole body[7]	Head and neck[9]	Hands				
1	hydraulic; handgun	bench; chrysanthemums	757	no additional PPE	66 [1]	0.354	0.96	0.410[4]	50.1	49.6	201790	1291	107	164	4412	182	105	297
4	hydraulic; wand	bench; chrysanthemums	757	neoprene pants	81 [3]	0.413	0.96	5.45	823	818	3600	108.4	70	1330	3652	933	114	276
5	Maruyama ; wand	bench; geraniums/mixed	23	no additional PPE	85 [3]	0.059	0.96	22.0	180	158	66340	66.3	9.5	11.6	1481	224	53	898
9	hydraulic; handgun	floor; various bedding plants	95	no additional PPE	80 [2]	0.236	1.2	20.3	103	82.2	24318	340	108	13.6	1956	162	105	445
10	manual; wand	bench; various	3.8	no additional PPE	90 [5]	0.027	1.2	103	244	140	20724	240[8]	19.1	5.1	9785	538	7	259
11	hydraulic; wand	bench; chrysanthemums/ mixed	190	no additional PPE	84 [1]	0.236	1.2	90.3	60.6	<0	23720	139	98	6.71	1033	92	75	318
12	backpack; wand	bench; chrysanthemums/ gloxinia	11	no additional PPE	78 [4]	0.295	1.2	9.08	11.2	2.07	696	8.1[8]	40.8	0.4[4]	167	16	42	142
13	Coldfogger; handgun	bench; chrysanthemums	45	no additional PPE	84 [2]	0.032	1.2	4.54[4]	960	955	1335	15.5[8]	27.7	1.0[4]	1381	1001	0[12]	-
14	backpack; wand	bench; chrysanthemums	11	no additional PPE	100 [4]	0.059	1.2	14.2	72.4	58.2	10380	50.9	25.2	7.02	1409	114	7	119
16	hydraulic; handgun	floor; various	189	no additional PPE	107 [1]	0.236	1.2	3.17	230	227	5079	97.0	85	58.9	1021	261	97	411
							75th percentile	21.2	237			190	92	36	2804	400		365
							arithmetic mean	27.2	273			236	59	159	2630	352		352

All data are corrected for spike recovery; TCP levels were normalised for creatinine exposure
ML: mixer/loader; MLA: mixer/loader/applicator; A: applicator
(1) plants grown on bench top, foliage usually 2-4 feet above the ground; plants grown on floor, foliage often less than 2 feet above the ground
(2) mean time of 16 replicates is 85 min (14 min loading, 60 min application, 6 min clean-up); number of MLA cycles in square brackets
(3) study data presented as µg/m^3 were adjusted for exposure time for each activity and respiratory rate of 1.74 m^3/h
(4) these samples were below the detection limit; estimates are based on ½ the detection limit
(5) MLA minus ML
(6) total of coverall torso, arms and legs
(7) potential whole body multiplied by penetration factor (ie, T-shirt/brief contamination divided by coverall torso contamination); the penetration factor used (1.16%) was an average of floor/bench replicates
(8) chlorpyrifos was non-detectable on T-shirt/briefs
(9) hat patch contaminations were adjusted for 1300 cm^2 head surface area and 260 cm^2 neck area
(10) total of actual whole body exposure, head and neck exposure and hand exposure (corrected for 3% dermal absorption) + potential M/L/A respiratory exposure (uncorrected: assumes 100% absorption)
(11) the values presented here are the greater of the urinary factor or kinetic modelling estimates of absorbed dose
(12) TCP levels less than pre-study day

Table 19: Greenhouse plant application parameters and exposure estimates for workers treating overhead[1] plants

Rep-licate No.	Sprayer type; nozzle type	Plant orientation; types	Tank size(L)	PPE worn[4] (in addition to cotton coveralls, rubber boots, nitrile gloves and goggles)	Total time of replicate[5] (min)	Total ai sprayed (kg)	Spray concentration (g ai /L)	Potential repiratory exposure[6] (µg/kg ai handled)			Dermal exposure (µg/replicate)				Total actual dermal exposure (µg/kg ai handled)	Total dose[13] based on passive dosimetry (µg/kg ai handled)	Absorbed chlorpyrifos based on urinary TCP[14]	
								ML	MLA	A[8]	Potential	Actual					(µg/replicate)	(µg/kg ai handled)
											Whole body[9]	Whole body[10]	Head and neck[12]	Hands				
2	hydraulic; wand	overhead; roses	757	neoprene rain jacket/pants, respirator, face shield	84 [1]	0.295	0.96	0.492[7]	219	218	8100	1823	21100	197	78373	2571	24	8
3	hydraulic; handgun	overhead; roses	757	neoprene rain jacket/pants, respirator, face shield	94 [1]	0.354	0.96	0.410[7]	254	253	15171	13002	63000	1110	217831	6789	356	1006
6	electrostatic; handgun	overhead; hanging baskets/mixed	19	neoprene rain jacket/pants, respirator, face shield	77 [1]	0.014	0.96	2764	74.3[7]	<0	65.2	31.9[11]	465	12.1	36357	1165	20	1429
7[2]	hydraulic; handgun	floor[3] and overhead; various bedding plants	757	neoprene rain jacket/pants, respirator, face shield	93 [1]	0.427	1.2	6.58	163	156	525	298	4710	42.9	11829	518	13	30
8[2]	hydraulic; handgun	overhead; various hanging plants	95	neoprene rain jacket/pants, respirator, face shield	77 [1]	0.114	1.2	90.4	891	801	656	202	790	73.0	9342	1171	140	1228
15	Coldfogger; handgun	overhead; hanging plants/ferns	45	neoprene rain jacket/pants, respirator, face shield	77 [2]	0.032	1.2	32.5	2691	2658	55[7]	26.9[11]	262	1.0[7]	9059	2963	8	250
							75th percentile	61.5	573			1061	12905	135	57365	2767		1117
							arithmetic mean	482	715			2564	15055	239	60465	2530		659

All data are corrected for spike recovery; TCP levels were normalised for creatinine exposure
ML: mixer/loader; MLA: mixer/loader/applicator; A: applicator
(1) roses and hanging baskets, foliage often extending to 6-8 feet above the ground
(2) these workers did not carry out clean-up activities at the end of the application
(3) plants grown on floor, foliage often less than 2 feet above the ground
(4) study suggests goggles were worn by all workers including those wearing a face shield; respirators were half-face type
(5) mean time of 16 replicates is 85 min (14 min loading, 60 min application, 6 min clean-up); number of MLA cycles in square brackets
(6) study data presented as µg/m^3 were adjusted for exposure time for each activity and respiratory rate of 1.74 m^3/h
(7) these samples were below the detection limit; estimates are based on ½ the detection limit
(8) MLA minus ML
(9) amount of chlorpyrifos deposited under rain suit onto coverall torso, arms and legs
(10) potential whole body multiplied by penetration factor (ie, T-shirt/brief contamination divided by coverall torso contamination); the penetration factor used (48.9%) was an average of overhead replicates
(11) chlorpyrifos was non-detectable on T-shirt/briefs
(12) headband contaminations were adjusted for 1300 cm^2 head surface area and 260 cm^2 neck area
(13) total of actual whole body exposure, head and neck exposure and hand exposure (corrected for 3% dermal absorption) + potential M/L/A respiratory exposure (uncorrected: assumes 100% absorption)
(14) the values presented here are the greater of the urinary factor or kinetic modelling estimates of absorbed dose

Results

Table 18 and Table 19 summarize the study results. Passive dosimetry data are provided here as actual contamination normalised for kg ai handled. The tabulated results assume no respiratory protection, one layer of protective clothing during floor/bench applications and two layers of protective clothing during overhead applications. The study authors also calculated chlorpyrifos dose based on passive dosimetry using 3% dermal penetration and the body weights of the individual participants (range 55-91 kg). These results are not presented here.

Exposure based on passive dosimetry was greater for overhead application than during floor/bench application even though additional PPE were worn.

Respiratory exposure was measured for mixer/loaders and mixer/loader/applicators. A comparison of these results suggests that application is the greater source of exposure when treating either high or low plants.

During floor/bench applications the distributions of dermal dose (actual) were 60% body (arms greater than torso or legs), 29% head and neck and 11% hands. For overhead applications 92% of the contamination was on the head or neck, 7% on the body (evenly distributed on all parts) and 1% on the hands.

Comparisons of coverall torso and T-shirt/briefs exposures showed a greater PF for the workers applying chlorpyrifos to overhead plants (48.9%) than to plants positioned on the floor/bench (1.16%).

The study authors reported a reasonable correlation between passive dosimetry and biomonitoring results. Assuming 3% dermal absorption and 100% respiratory absorption, the total absorbed chlorpyrifos dose (75th percentile) from combined respiratory and dermal routes of exposure was 400 and 2767 µg/kg ai handled, during floor/bench and overhead application, respectively. The respective doses based on urinary TCP were 365 and 1117 µg/kg ai handled.

The results of the blood ChE measurements and the area air monitoring are not included in the tables above. No significant changes were observed in plasma ChE during the study (all post-application levels were between 87 and 116% of the baseline mean). Air concentrations of chlorpyrifos are presented below. All airborne concentrations are well below the Australian exposure standard for chlorpyrifos of 0.2 mg/m^3.

Table 20: Greenhouse air concentrations after chlorpyrifos applications

Monitoring time	Air chlorpyrifos concentration (µg/m^3)	
	75th percentile	range
T-1*	0.250	0.054-0.880
T0*	4.10	0.102-9.32
T4*	3.31	0.311-6.72
T12**	1.65	0.29-2.52

T24***	3.38	0.49-9.47

* 16 replicates ** 6 replicates *** 10 replicates

Discussion

The study design and results are suitable for regulatory purposes.

The application rates and spray volumes used in the study are relevant for the Australian situation. Total amount of chlorpyrifos handled per day is also comparable.

Australian greenhouse workers will use EC or WP formulations. The study product however is a microencapsulated formulation, which is not available for use in crop protection and not considered in this review.

The study measured exposure using both biomonitoring and passive dosimetry methods. The exposure estimates derived from urinary TCP levels represent only the amount of ai absorbed by the worker, and are dependant on how quickly the ai is released from its encapsulated form and, in the case of inhalation, on whether the 'capsule' size is respirable or inspirable. Passive dosimetry however considers all the ai presented in the encapsulated form, not just the amount available on the 'capsule' surface or the amount released in the water after mixing. For this reason the passive dosimetry results are expected to be a better representation of exposure to EC or WP formulations. As the results derived by both methods were in reasonable agreement, both are used in the OHS risk assessment.

<u>Handspray – Lawn</u>

Dow provided a number of early studies which measured applicator exposure during lawn treatment. In general these studies are poorly described and involve inadequate replicate numbers as well as limited or no dermal exposure estimates.

Handspray application to lawn by Australian workers will be limited to spot spray only, therefore these studies are of limited relevance.

(1) Vaccaro JR (1976a) Time-Weighted Average (TWA) Exposures of Lawn Applicators to Airborne Chlorpyrifos during Dry Application with a Cyclone Spreader, Chem-Lawn Corporation; July 26, 1976, Houston, Texas, Dow Chemical USA, A1A-706 TK-2-1753, September 1976.

Dursban granules (particle distribution 99.7% ≥ 250 µm), containing 2300 ppm chlorpyrifos, was applied to lawn from a cyclone spreader (rates and areas not given). Two lawn applicators were monitored for airborne and skin exposures to chlorpyrifos during application. The average TWA (average of 3 exposures from one applicator and 2 from the other) was 1 x 10^{-3} mg/m^3 (1 µg/m^3).

Wipe testing showed surface contamination on the trucks, equipment and applicator's skin to be "very low". Skin wipes (forehead, left and right arms) were ≤ 0.8 µg/wipe (~100 cm^2). Equipment wipes ranged from 0.1 µg/wipe (driver's door) to 25.6 µg/wipe (pump at end of day).

Discussion

The granular chlorpyrifos products registered in Australia for use on grass are for home/garden use only, therefore they are not considered in this OHS review. The method of application used in this study may have some relevance for other crops, such as application to sunflowers by fertilizer spreader. However as the application rates are not provided in this study, the data collected is limited and the application equipment are different (cyclone versus fertilizer spreader), this study will not be considered in the risk assessment.

(2) Vaccaro JR (1976b) Evaluation of Pesticide Applicators' Exposures to Airborne Chlorpyrifos during Lawn Spraying Operations with Dursban, Chem-Lawn Corporation, Columbus, Ohio, August 16 & 17, 1976, Dow Chemical USA, AIA-707 TK-2-1754, November 1976.

Three lawn workers were monitored during wet application of Dursban. Duplicate air samples were collected at the breathing zone. Filter paper patches (47 mm diameter - 17.3 cm^2) were placed near the breathing zone (on lapels) and on legs (pinned to trouser at or below the knee). Wipe testing (~ area 100 cm^2) was conducted on the operator equipment. The exposure times and work rates were not provided in the study. The authors indicated that two of the four lapel patches were worn for approximately 1 hour, however the sampling duration was not provided for any other air, patch or wipe samples.

Airborne concentrations at the breathing zone ranged from 1.1-6.4 µg/m^3. Breathing zone patches ranged from 0.23-0.97 µg/patch, leg patches ranged from 18-135 µg/patch. Equipment wipes ranged from 0.22-3.8 µg/wipe.

Based on a respiratory rate of 29 L/min, 100% respiratory absorption and a 6 hour working day, the respiratory dose estimated from breathing zone concentrations equates to 11.5-66.8 µg/day or 0.00019-0.0011 mg/kg/day.

Based on the average body surface areas of Berkow (1931), cited in US EPA Subdivision U Guidelines (US EPA, 1987), the following dermal exposure estimates were calculated by NOHSC for a worker wearing one layer of clothing plus gloves. These values are not adjusted to a 6 hour working day as the exposure time is not known.

Table 21: Dermal exposure during spray application of chlorpyrifos to lawn

Exposure area	Chlorpyrifos in corresponding patch (mg/17.3 cm^2))	Potential exposure (mg/person)	Potential exposure (mg/kg/day)*	Dose ** (mg/kg/day)
Total body (21110 cm^2)	0.018-0.135 (leg)	24.2-181	0.40-3.02	0.0012-0.0091
Hands (820 cm^2)	0.018-0.135 (leg)			
Feet (1310 cm^2)	0.018-0.135 (leg)			
Head and neck (1300 cm^2)	0.00023-0.00097 (breathing zone)	0.017-0.073	0.00028-0.0012	0.0000008- 0.000004
			Total	0.0012-0.0091

* assuming worker wore patch all day (6 hour day); estimated for 60 kg person
** assuming 10% transmittance through one layer of clothing (or gloves or boots) and 3% dermal absorption

Discussion

This study is not used in the OHS risk assessment due to inadequacies in study details and data collection.

(3) Bohl RW (1981) Evaluation of Pesticide Applicators' Exposures to Airborne Chlorpyrifos during the Spraying of Residential Lawns with Solution Containing Dursban Insecticide, Dow Chemical USA, A1A-711 TK-2-1751, January 1981.

Personal breathing zone samples were taken from two workers applying Dursban to residential lawns concurrently with weedkiller and fertilizer. The spray rate was 1 ounce of chlorpyrifos per 1000 square feet of lawn (30.5 g ai/100 m^2). The spray concentration or volume was not provided. Air temperarature was 44-55°F during the sampling day. The number of lawns or area treated per day was not provided.

Average exposure for both workers, assuming an 8 h day, was calculated by the authors at 0.0008 mg/m^3. Total sampling time included travel time between the residential lawns where the spray was applied. Actual spraying time was less than half the sampling time, therefore the air concentrations during spraying could be much greater than the reported amount.

Based on a respiratory rate of 29 L/min, 100% respiratory absorption and worker body weight of 60 kg, NOHSC estimated a daily (8 hours) respiratory dose of 0.00018 mg/kg/day.

Discussion

This study is not used in the OHS risk assessment due to inadequacies in study details and data collection.

(4) Vaccaro JR (1984) Summary Report of the Evaluation of Exposures of Pesticide Applicators to Chlorpyrifos during Application of Dursban Insecticides to Turf, Dow Chemical USA, A1A-172 TK-2-1752, December 1984.

This study is a summary of seven applicator studies conducted over a period of five years. Six of these studies were conducted during lawn applications and one study during application to ornamentals (Vaccaro, 1977; discussed in a previous section). Three of the lawn applications are described below. The other three have been described separately in studies (1) to (3) above.

Several lawns were treated per study. All workers (2-9 per study) wore personal air monitors. External filter patches were attached to the worker's clothing at "various anatomical positions" for two of these studies. Wipe testing of equipment was also conducted in these two studies.

Airborne concentrations were reported as TWAs only. Average TWAs for each study are tabulated in Table 22.

Table 22: TWAs during spray application of chlorpyrifos to lawn

Study reference	No. of subjects	Average TWA ($\mu g/m^3$)	Absorbed chlorpyrifos (mg/kg/d)**
Vaccaro, 1975	2	9	0.0016
Vaccaro, 1979	8	10	0.0017
Vaccaro, 1980	9	2.8	0.00049

* based on a respiratory rate 29 L/min, 100% respiratory absorption, worker body weight 60 kg, application duration 6 hours

Equipment wipe testing showed chlorpyrifos residues of < 10 $\mu g/100\ cm^2$ area.

Most of the patch exposure was found below the thighs.

Discussion

This study is not used in the OHS risk assessment due to inadequacies in study details and data collection.

4.1.2 Pest control

Pre-construction termite control

As part of a separate submission, Dow have provided a pre-construction exposure study by Murphy et al. (1997a) and a risk assessment based on that study by Ellisor (1997). Upon the request of Dow these studies have been included in this review. The Dow exposure study is discussed below. The Dow risk assessment is discussed in Section 5.3.2.

Use pattern information included in this assessment is based on current Australian label rates and information available in previous NOHSC assessments of pre-construction termiticides.

Murphy PG, Beard KK, Chambers DM, Huff DW, Marino TA, Melichar M and Vaccaro JR (1997) Evaluation of Workers' Exposures to Chlorpyrifos during the Use of Dursban TC Termiticide Concentrate for Pre-Construction Termiticide Applications, The Dow Chemical Company, USA, December 1997.

This study was sponsored by Dow and followed a protocol according to Murphy et al. (1997b). The protocol was in accordance with the *Draft Guidance Document for the Conduct of Field Studies of Exposure to Pesticides in Use* (OECD, 1995) and the US EPA's *Occupational and Residential Exposure Test Guidelines* (US EPA, 1996).

The study was undertaken to measure the potential exposure of workers during two separate activities relating to pre-construction use of chlorpyrifos. They are (a) mixing/loading and application of the termiticide and (b) laying of the plastic membrane over the treated area. Typically a pest control operator is responsible for mixing/loading and applying, whilst a different worker (usually a construction worker) lays the plastic membrane.

The test sites were in Florida and Indiana, USA.

The study was conducted in accordance with good laboratory practice with appropriate quality assurance.

Study details

The test substance was Dursban TC Termiticide Concentrate, an emulsifiable concentrate registered in the US containing 43.2% chlorpyrifos.

The study was divided into two parts. The first monitored workers involved in mixing/loading and applying the termiticide. The second monitored workers involved in laying the plastic membrane after spray application (tarp pullers). The application stage was conducted by six workers treating 17 building sites in Florida (Orlando, Jacksonville or Gainesville). Application was conducted on 8 days from 18/4/96 to 19/3/97. The membrane laying stage was conducted in Indiana by a total of five workers on 2 days. Working in pairs, 4 workers covered 4 building sites at Fishers (23/7/97) and three workers covered four building sites at Carmell (2/8/97).

Mixer/loader/applicator

Experienced PCOs were used for this part of the study. Each PCO was responsible for loading the product into a mix tank (which was prefilled with water) and applying the mix to the building site by hand-held spray. A total of 17 replicates were monitored, each ranging from 3-4 hours, to represent a typical working day. Several application cycles were conducted over the course of the monitoring period, with some participants treating multiple sites (total of 6 participants with each performing up to 4 replicates). All participants carried out routine tasks (rolling of hoses etc) which were conducted at the end of each job cycle (mixing/loading or application) and at the end of each monitoring period.

Spray was prepared to contain 1% chlorpyrifos. In most cases (13 sites) the spray was prepared in ~750 L metal drop tank with water supplied from a larger tank on the truck. Trucks used for the other applications (five) were fitted with a single ~2,300 L tank. None of the applicator trucks had flow meters or pressure gauges.

Spray was applied using low pressure spray equipment fitted with hand-held hose-end sprayer or spray wand fitted with a shrouded rose nozzle. The industrial site was covered starting at the opposite end to where the truck was parked. Applicators typically held the wands at knee height sprayed in a lateral and backing motion.

The personal protective equipment worn during mixing/loading and application was a coverall buttoned to the neck and wrist (9 replicates wore Tyvek and 8 wore cotton), chemically resistant footwear (vinyl boots over new footwear, typically running shoes, with coveralls worn outside of boots), forearm length nitrile gloves and a hat. Underneath the protective clothing, workers wore a long sleeved shirt, pants, one-piece long cotton underwear and cotton socks. No respirator was worn. Where workers moved from one site to another during the same replicate, PPE was removed after treating one site and re-worn at the next site.

Tarp puller

Membrane laying was performed by a separate group of workers, known as tarp pullers. Working in pairs a total of five tarp pullers were monitored for the time needed to lay tarps over eight building sites (a total of 16 replicates). Approximately 1-3 hours after each building site had been sprayed by PCOs, two tarp pullers unfolded the membrane and placed it over the site. Cuts were made in the membrane for the service points. Treated pea gravel was placed over the membrane in some areas to weigh it down until the concrete was poured. Membrane seams were overlapped by “several feet”.

These workers wore a long sleeved shirt, long pants, one-piece long cotton underwear and cotton socks, leather boots and a hat. In addition, eight of the replicates wore forearm length nitrile gloves and chemical resistant boots over leather boots. The other eight replicates wore leather work boots but no gloves. Workers wore the same pair of leather boots throughout the study, however replicates wearing chemically resistant footwear were conducted first. No coverall or respirator was worn for any of the replicates.

Data collection and analysis

Sampling methods were the same for both applicator and tarp puller worker groups, therefore all workers are considered together in the following sections.

Dermal exposure

Shirts, pants, one-piece underwear, socks and denim patch (attached to hat) were collected at the end of each monitoring period for analysis. Hand washes were also conducted for each worker.

Shirts, pants and underwear were sectioned prior to analysis to reflect arm, leg and torso regions. Sectioning was used to estimate penetration through the workers outer clothing and to assess dermal exposure under various clothing scenarios, such as short sleeves and shorts. Total dermal exposure was estimated by adding the exposures to the different body regions. Levels of chlorpyrifos on socks and underwear were treated as actual dermal depositions.

Surface deposition on the denim hat patch was used to estimate exposure to the face, head and neck. Amount of chlorpyrifos on the 103 cm^2 patch was extrapolated to 1300 cm^2 (reference surface area of head and neck).

Handwashes were collected in dioctylsodium sulfoxinate solution (250 mL of ~0.008%) followed by a rinse in an equal volume of water. Due to time constraints, samples were collected at the end of the each monitoring period only.

Total dermal dose was calculated using two dermal absorption estimates, 1% and 3%. Only the results obtained using 3% dermal absorption are presented in this report.

Inhalation exposure

Each participant was monitored for inhalation exposure during the entire monitoring period excluding any normal breaks and lunch break. Personal breathing zone samples were collected using a personal air sampling pump attached to the lapel and fitted with a GN-4 mixed cellulose ester filter and glass absorber tube containing Chromosorb 102 solid sorbent. Pumps were calibrated to a rate of 1 L/min.

The authors estimated potential inhalation dose (PID) as µg/kg bw, based on a breathing rate of 1.5 m^3/h, 100% inhalation absorption and exposure time equal to the actual monitoring time. NOHSC have recalculated these values using a respiratory rate of 1.74 m^3/h (Durham and Wolfe, 1962).

Penetration factors

Clothing penetration factors were calculated for each replicate by dividing the amount of chlorpyrifos on the underwear by the amount of chlorpyrifos on the shirt/pants plus the underwear.

Tank samples

Tank samples were taken during the applicator part of the study. A sample was collected each time a batch of application spray was prepared (except for one replicate).

Quality assurance

Validated methodology was used to estimate both dermal and inhalational exposures. Air monitoring samples, handwashes and clothing dosimeters were analysed for chlorpyrifos residues using a gas chromatograph fitted with an electron capture detector.

Field samples and field spikes were corrected for method recoveries (conducted in the laboratory). The corrected field spike recoveries were used to adjust the corrected field samples. Method recoveries ranged from 89 to 116%. Field samples were not adjusted when field spike recoveries were > 100%.

Results

Mixer/loader/applicator

Applicator exposure is summarised in Table 24. Dermal exposure was similar for workers wearing tyvek and cotton coveralls, with the greatest exposure on arms (~29%) and hands (~25%). Respiratory exposure contributed ~40% to total dose (43% and 37% for workers wearing long and short sleeves, respectively), when no respirator was worn. When respiratory protection was factored in, the contribution was reduced to ~6% (both long or short sleeves).

Tarp puller

Tarp puller exposure is summarised in Table 25. Hand exposure was significantly different between workers working bare handed and those wearing gloves. For workers wearing gloves, dermal exposure was greatest on arms (~13%) followed by hands (~7%). When no gloves were worn, dermal exposure was greatest on the hands (~57%) followed by the arms (~11%). The contribution of respiratory exposure to total dose was ~52% for workers wearing gloves (54% and 49% for workers wearing long and short sleeves, respectively) and ~10% for workers working bare handed (11% and 9% for workers wearing long and short sleeves, respectively).

Clothing penetration

The clothing penetration results are summarised in Table 23. Penetration of chlorpyrifos was greatest through shirt sleeves than any other clothing region for both worker categories. Penetration averaged over all clothing regions was greater for mixer/loader/applicators (~26%) than for tarp pullers (~17%).

Table 23: Summary of clothing penetration for mixer/loader/applicators and tarp pullers during Pre-Construction treatment of building sites with 1% EC chlorpyrifos

Worker category		Penetration (%)* through shirt/pants onto underwear				
		Arms	Thighs	Calves	Torso	Combined
MLA	tyvek coveralls	40.8 ± 4.7	30.0 ± 4.0	19.7 ± 3.6	18.6 ± 1.9	24.8 ± 3.1
	cotton coveralls	37.3 ± 3.1	27.1 ± 5.1	20.4 ± 4.8	24.8 ± 4.1	28.0 ± 3.8
Tarp puller		37.0 ± 5.7	13.2 ± 3.9	8.66 ± 2.5	25.3 ± 3.8	17.8 ± 3.5

MLA mixer/loader/applicator
* arithmetic mean ± SE

Table 24: Summary of dermal and respiratory exposure of mixer/loader/applicators during Pre-Construction application of EC chlorpyrifos to building sites

Worker category	Replicate number and monitoring time (h:min)		Total ai handled (kg)[1]	Spray concentration (g ai/L)[2]	Potential respiratory exposure		Actual dermal exposure[4]						Total chlorpyrifos dose[7] (µg/replicate)			
							Long sleeve scenario			Short sleeve scenario						
					(µg/ m³)	(µg/replicate)[3]	Total[5] (µg/replicate)	Exposure as % of total		Total[6] (µg/replicate)	Exposure as % of total		*Long sleeve scenario*		*Short sleeve scenario*	
								Hands	Arms		Hands	Arms	No respirator	Respirator[8]	No respirator	Respirator[8]
MLA tyvek coveralls	1	5:32	43.5	23.7	5.4	52.0	3540	61	11	3820	57	17	158.2	111.4	166.6	119.8
	2	4:01	20.0	11.8	1.7	11.8	837	48	19	1200	34	44	36.9	26.3	47.8	37.2
	3	4:10	10.9	15.3	1.4	10.2	289	6	12	333	6	23	18.9	9.7	20.2	11.0
	4	3:07	14.1	15.5	2.4	13.0	169	8	10	235	6	35	18.1	6.4	20.1	8.4
	5	4:29	36.3	7.3	7.5	58.5	2140	1	31	2740	1	46	122.7	70.1	140.7	88.1
	6	5:00	29.0	11.0	3.7	32.2	3710	<1	68	5480	<1	78	143.5	114.5	196.6	167.6
	7	1:45	13.6	16.5	1.4	4.27	383	36	9	484	28	28	15.8	11.9	18.8	14.9
	8	4:24	16.3	9.8	2.2	16.8	417	54	5	455	50	13	29.3	14.2	30.5	15.4
	9*	4:15	25.4	10.7	4.7	34.8	3860	59	25	5120	44	44	150.6	119.3	188.4	157.1
	Arithmetic mean (± SE)				***[8]*	*28.7 ± 6.7*							*84.7 ± 22.7*	*59.0 ± 17.9*	*101.4 ± 27.9*	*75.6 ± 23.5*
					[9]	*26.0 ± 6.5*							*77.1 ± 20.2*	*53.8 ± 16.6*	*92.2 ± 26.2*	*68.8 ± 21.8*
	75th percentile				***[8]*	*34.8*							*143.5*	*111.4*	*166.7*	*119.8*
MLA cotton coveralls	10	4:13	21.8	10.3	4.9	36.0	651	30	6	739	26	17	55.5	23.1	58.2	25.8
	11	3:32	21.8	25.9	6.3	38.7	1620	13	3	1760	12	11	87.3	52.5	91.5	56.7
	12	5:05	15.4	13.6	3.0	26.6	3090	14	61	4590	9	74	119.3	95.4	164.3	140.4
	13	3:19	21.8	13.5	4.9	28.3	580	12	14	708	10	30	45.7	20.2	49.5	24.0
	14	4:26	14.5	20.2	7.1	54.8	1520	7	5	1630	7	11	100.4	51.1	103.7	54.4
	15	5:27	29.0	20.5	11	104.3	1800	14	11	2230	11	28	158.3	64.4	171.2	77.3
	16	3:38	NA	10.0	3.6	22.7	966	1	20	1300	<1	40	51.7	31.3	61.7	41.3
	17	3:58	14.5	8.6	8.5	58.7	1520	<1	12	1830	<1	27	104.3	51.5	113.6	60.8
	Arithmetic mean (± SE)					*46.3 ± 9.5*							*90.3 ± 13.7*	*48.7 ± 8.7*	*101.7 ± 16.5*	*60.1 ± 13.1*
	75th percentile					*54.8*							*104.3*	*52.5*	*113.6*	*60.8*
Arithmetic mean ± SE [17]			21.74 ± 2.26	14.4 ± 1.3		35.5 ± 6.0	1594 ± 306	~24	~28	2038 ± 418	~19	~43	83.3 ± 12.7	51.4 ± 9.4	96.7 ± 15.5	58.8 ± 12.5
75th percentile [16]**						45.4	1970			2485			122.7	70.1	164.3	88.1
[17]													133.1	67.3	165.5	82.7

MLA mixer/loader/applicator
[ ] number of replicates
* this is an additional replicate, added to the study to compensate for the low monitoring time of replicate 7
** results excluding replicate 7
(1) average area treated 464 m^2
(2) based on tank sample analyses
(3) assuming respiratory rate of 1.74 m^3/h (authors used 1.5 m^3/h instead)
(4) all workers wore long sleeved shirts; exposure on shirt sleeve was added to undergarment exposure to give exposure estimate for short sleeve scenario
(5) µg levels of chlorpyrifos on underwear + socks + hands + head/neck exposure estimate (µg on head patch x 1300 cm^2/103.2 cm^2)
(6) µg levels of chlorpyrifos on shirt arms + (5)
(7) dose via inhalation and dermal routes; assuming 100% respiratory absorption and 3% dermal absorption
(8) calculation based on default of 10% transmittance through respirator

Table 25: Summary of dermal and respiratory exposure of tarp pullers re-entering building sites after Pre-Construction application of EC chlorpyrifos

Worker category	Replicate number and monitoring time (min)		Re-entry interval (min)	Total ai applied (kg)(1)	Spray concentration (g ai/L)(2)	Potential respiratory exposure		Actual dermal exposure(4)						Total chlorpyrifos dose(7) (µg/replicate)	
								Long sleeve scenario			*Short sleeve scenario*				
						(µg/ m^3)	(µg/replicate)(3)	Total(5) (µg/replicate)	Exposure as % of total		Total(6) (µg/replicate)	Exposure as % of total		*Long sleeve scenario*	*Short sleeve scenario*
									Hands	Arms		Hands	Arms		
Tarp puller rubber boots and gloves	1	8	80	7.6	10.0	8.0	1.86	22.8	23	9*	35.7	15	42**	2.54	2.93
	2	8	80	7.6	10.0	10	2.32	51.2	4	10	70.3	3	35	3.86	4.43
	3	6	74	5.7	10.0	42	7.31	17.1	6*	11*	24.1	4*	37**	7.82	8.03
	4	6	74	5.7	10.0	12	2.09	40.1	4	16	70.5	2	52	3.29	4.21
	5	9	57	9.4	10.0	3.8	0.992	46.6	10	11	59.7	8	30	2.39	2.78
	6	9	57	9.4	10.0	4.8	1.25	176	1	19	188	1	24	6.53	6.89
	7	6	36	7.6	10.0	11	1.91	63.2	1	13	72.3	1	24	3.81	4.08
	8	6	36	7.6	10.0	5*	0.441	83.8	4	12	100	3	26	2.96	3.44
	Arithmetic mean (± SE)						*2.27 ± 0.75*		*~7*	*~13*		*~5*	*~34*	*4.15 ± 0.70*	*4.60 ± 0.67*
	75th percentile						*2.09*							*3.86*	*4.43*
Tarp puller (leather boots, no gloves)	9	6	130	5.7	10.0	11	1.91	41.3	31	13	54.2	24	33	3.15	3.54
	10	6	130	5.7	10.0	8.1	1.42	81.2	68	14	93.3	59	25	3.86	4.22
	11	5	111	5.7	10.0	17	2.47	110	24	10	123	21	19	5.77	6.16
	12	5	111	5.7	10.0	18	2.61	537	37	11	574	35	17	18.7	19.0
	13	9	58	3.8	10.0	2.4	0.626	1080	78	18	1110	76	21	33.0	33.9
	14	9	58	3.8	10.0	2.3	0.601	72.7	67	5	79.3	61	13	2.78	2.98
	15	6	196	3.8	10.0	0.74	0.129	248	74	12	804	23	73	7.57	24.2
	16	5	196	3.8	10.0	1.1	0.160	401	78	4	424	74	9	12.2	12.9
	Arithmetic mean (± SE)						*1.24 ± 0.35*		*~57*	*~11*		*~47*	*~26*	*10.9 ± 3.69*	*13.4 ± 4.03*
	75th percentile						*1.42*							*12.2*	*12.9*
Arithmetic mean ± SE									~59	~15		~26	~30	7.51 ± 2.01	8.98 ± 2.28
75th percentile														7.57	8.03

* sample not detected, this estimate based on half the detection limit (0.03 µg)
** includes underwear estimates at half the detection limit
(1) average area treated 100 m^2
(2) calculated from kg ai applied and L spray applied
(3) assuming respiratory rate of 1.74 m^3/h (authors used 1.5 m^3/h instead)
(4) all workers wore long sleeved shirts; exposure on shirt sleeve was added to undergarment exposure to give exposure estimate for short sleeve scenario (5) µg levels of chlorpyrifos on underwear + socks + hands + head/neck exposure estimate (µg on head patch x 1300 cm^2/103.2 cm^2)
(6) µg levels of chlorpyrifos on shirt arms + (6)
(7) dose via inhalation and dermal routes; assuming 100% respiratory absorption and 3% dermal absorption

Discussion

Product formulation

The test product (an emulsifiable concentrate containing 43.2% chlorpyrifos) is considered to be similar in formulation and concentration to Australian products used for pre-construction termiticide applications (EC containing 45% chlorpyrifos).

Application rate and spray concentration

During the applicator study, an average of 0.047 kg ai was applied per m^2 (replicate 16 excluded). According to the product label, Dursban Pre-Construction Termiticide will be applied at a concentration of 1% and a spray volume of 5 L/m^2 (horizontal barrier) or 100 L/m^3 (vertical barrier). This volume is equivalent to 0.05 kg ai/m^2 or 1 kg ai/m^3, which is similar to the study application rate. North of the Tropic of Capricorn, the product will be applied at 2%. In this case the equivalent application rate will be 0.1 kg ai/m^2 (horizontal barrier) or 2 kg ai/m^3 (vertical barrier). Therefore, in most cases, the study application rate is representative of the Australian use conditions and no adjustments will be made in the risk assessment.

Mixing/loading and application equipment

Australian workers are expected to use either open or closed mixing systems. The study uses an open system which is representative of the worst case scenario.

The Australian label states that hand spray should be conducted using a shrouded rose head shower nozzle held close to the ground. The study applicators used the same nozzle type (attached either to a hose or hand wand) held at knee height. The application equipment used in the study is therefore relevant for the Australian situation.

It was not possible to compare delivery pressures or flow rates. The label specifies a spray pressure of 170 kPa. The study applications were at low pressure, but no estimate was provided. Flow rates were claimed to range from ~30-45 L/min during the study. These are not provided on the label for a comparison to be made.

One notable limitation in this study, was that monitoring was conducted for combined mixer/loader and applicator tasks, thereby preventing the main source of exposure from being identified.

Work rate

NOHSC have been previously advised by Dow that three to five slabs would be treated in one working day with the area treated per house being approximately 130-150m^2 (ie, an average of 560 m^2 per day) and the average working day being 6 hours. Information provided in the performance questionnaires estimates one commercial site will be treated per 2 hours.

The study mixer/loader/applicators treated an average of 464 m^2 per day and worked an average of 4 hours and 8 min. Although these workers did not work an average day (6 hours), the areas treated are considered representative of the typical Australian work day and no adjustments for monitoring time are made in the risk assessment.

The tarp pullers covered an average of 100 m^2 per day. This may be an underestimate in some cases, however no adjustments are made here either.

<u>Worker categories</u>
Membrane laying may be conducted by either a PCO or a builder. The label states that "the PCO must be responsible for laying the moisture membrane". This suggests that there may be cases where the same worker will be involved in both mixing/loading/applying and tarp pulling. This scenario will be considered in the risk assessment.

<u>Personal protective equipment</u>
The label for Dursban Pre-Construction Termiticide states the following PPE requirements in the safety directions.

> When opening the container, preparing the spray, using the prepared spray, and laying the moisture membrane, wear chemical resistant overalls buttoned to the neck and wrist, a washable hat, chemical resistant footwear, elbow length PVC, neoprene or nitrile gloves, goggles and a half face respirator with combined dust and gas cartridge.

The risk assessment is based on workers wearing PPE similar to those specified in the above safety directions.

In the case of the study participants, tyvek coveralls were worn by nine of the workers, while eight wore cotton coveralls. None of the workers wore respirators. The authors claim that the tyvek coveralls, which are generally water resistant, should be sufficient to serve as chemically resistant coveralls when handling the dilute spray (1% chlorpyrifos). NOHSC has accepted this rationale, and has conducted the risk assessment on this basis. However, the risk assessment considers worker exposure with and without the use of respirators.

For tarp pullers, the risk assessment considers a worker wearing ordinary work clothing (as worn by the study participants) as this is more likely to be the case when construction workers are involved (worst case scenario).

<u>Conclusion</u>
Overall, this study is suitable for the risk assessment of Australian PCOs and tarp pullers involved in pre-construction chlorpyrifos treatments.

<u>Post-construction termite control</u>

Table 26 summarises the exposure data available for post-construction application of chlorpyrifos for termite control.

Table 26: Summary of exposure of pest control operators during post-construction application of chlorpyrifos for termite control

Reference Formulation; application rate	Study details	Airborne concentrations (mg/m^3)	Respiratory exposure		Actual dermal exposure based on passive dosimetry	ChE depression (%) and other findings/comments	Suitable for OHS risk assessment
			Breathing zone samples (mg/m^3)	Exposure estimates			
Vaccaro (1975) Rate not provided	Two PCOs applied chlorpyrifos and xylene to various public buildings (theater, hotel, motel, funeral home, Country Club, rectory, bakery). Each worker treated a number of buildings on the same day for a total treatment time of 4 or 5 hours.	not measured	0.0064	0.051 mg/replicate[(1)]	not measured	ChE depression not measured	No - unknown application rate
Axe (1979) 1%	Post-construction termiticide application to 4 US houses (1 applicator per house). Application methods included rodding, trenching, drip nozzle and spray.	<0.001-0.003 (living quarters); 0.04 (crawl space after 18 hours)	<0.0006-0.51	maximum 1.55 mg/treatment[(2)]	not measured	Application times ranged from 1.2-2.2 hours to treat house and 0.63-0.67 hours to treat garage	Yes - suitable for estimation of respiratory risk only
Vaccaro and Bohl (1979) 1%	Post-construction termiticide application. Liquid under pressure was shot into drill holes and trenches. Four applicators treated 5 US houses (3 crawl space and 2 basement type). The number of workers treating each house was not provided.	0.0003-0.002 (living quarters); 0.001-0.04 (crawl space); <0.004-0.03 (basement)	0.0004-0.08	maximum 0.25 mg/applicator[(3)]	not measured	Serum ChE levels were unaffected by treatment. RBC ChE levels showed an increase in all subjects (the authors offered no explanation for this)	Yes - suitable for estimation of respiratory risk only
Vatne (1979a) 1% final spray	Nine US houses treated with chlorpyrifos for control of subterranean termites using slab drilling, trenching and drip nozzle application techniques.	0.015 ± 0.011 [4] (crawl space); 0.007 ± 0.004 [3] (basement); 0.0013 ± 0.0003 [8] (living quarters)[(4)]	not measured		not measured	Study not reliable due to conflicting results in text and tables	No - no estimates available for worker exposure
Vatne (1979b) 2% final spray	One US house treated with chlorpyrifos (26.88 kg ai) for control of subterranean termites by trenching.	0.181 (crawl space)	not measured		not measured	One garage/apartment was also treated (9.84 kg ai by lab drilling) but no measurements were made during application	No - no estimates available for worker exposure

Vaccaro (1981) 1% final spray	Post-construction termiticide application to crawl space of 4 US houses (2 subjects treating 3 or 1 house each). Application was by band spray around the inside perimeter of the crawl space.	0.002-0.010 (living quarters)	0.05-0.37	72-412 µg/kg ai handled (5)	not calculated	Wipe testing after application was conducted. Most samples were below 1 µg/wipe	Yes - suitable for estimation of respiratory risk only

All data presented as means ± SE, number of replicates in square brackets [ ], 75th percentile in curved brackets { }
(1) breathing zone concentrations adjusted for sampling time (mean 4.5 hours) and respiratory rate (1.74 m^3/h)
(2) based on actual application times and a respiratory rate of 29 L/min
(3) based on a maximum monitoring time of 1.8 hours (estimated from sample volumes and pump flow rates provided in study) and a respiratory rate of 1.74 m^3/h
(4) area concentrations are based on results presented in study tables; area samples claimed to be taken near breathing zone height where possible
(5) breathing zone concentrations were used to estimate respiratory exposure (mg/applicator) based on sampling time and a respiratory rate of 1.74 m^3/h; these values were then corrected for amount of chlorpyrifos applied per house to give µg/kg ai (as 2 applicators worked together to treat 1 of the houses, the exposure of these workers was corrected for ½ the amount of chlorpyrifos applied)

Table 26: Summary of exposure of pest control operators during post-construction application of chlorpyrifos for termite control (continued)

Reference Formulation; application rate	Study details	Airborne concentrations (mg/m^3)	Respiratory exposure		Actual dermal exposure based on passive dosimetry	ChE depression (%) and other findings/comments	Suitable for OHS risk assessment
			Breathing zone samples (mg/m^3)	Exposure estimates			
Bohl (1985)	Review of open literature and Internal Dow reports Main findings of relevant studies (excluding studies assessed in other parts of this report) are summarised below						
Rate not provided	Hayes et al. (1980) PCO treatment US houses with OP mixture including chlorpyrifos (limited study details provided)	not measured	not measured	0.10 mg/replicate[(1)]	not measured	ChE depression not measured	No - low or unknown application rate
0.2-0.5% (0.6-14.5 L of spray)	Heath and Spittler (no date) PCO treatment of 15 residential and commercial buildings	not measured	0.019 ± 0.009 [15]	58 ± 29 [15] {44} mg/replicate[(2)] 2281 ± 738 [15] {2937}µg/kg ai[(2)]	Potential skin contact was detected with surface tests, with hands being the major target; residues on chest, back and legs were reported as ng/cm^2 only and were not presented as whole body exposure estimates		
Ballard (1986) 1%	Data collected from a total of 68 houses (crawlspace, plenum, slab and crawlspace types). Area air samples collected pre-, during, and post-treatment. Applications were 1.7-9.5 kg chlorpyrifos for 16 of the houses. Application methods not provided.	<0.0001-0.015	not measured		not measured	ChE depression not measured	No - no estimates available for worker exposure
Vaccaro et al. (1987) 0.6-1.2%	PCOs treated 32 US houses (plenum, crawlspace, basement and slab construction types) by trenching, injection and/or surface band. Applications were 1.2-7.0 kg chlorpyrifos per house.	≤ 0.010 (living areas and basements)	not measured		not measured	ChE depression not measured	No - no estimates available for worker exposure
Kawakita (1987) Rate not provided	Homes (number not provided) treated with termiticide by 7 applicators by injection and spraying. Patch tests; personal air monitoring; plasma ChE	1.26 (maximum crawl space concentration)	0.027-0.25	not calculated	0.16-1.43 mg/treatment (2 layers of clothing)[(3)]	No change in plasma ChE Breathing zone samples were vapour only (no filters used to trap aerosols)	No - unknown application rate
Ishikura H (1988) 1% EC formulation	Three US Air Force base houses in Japan were treated by 2 operators using slab drilling and spraying (attic only) and a total of ~ 61 kg ai per house). Area air monitoring was conducted at 0, 24 and 48 h. Personal air monitoring at 0 h (attic only). Dermal patches were collected during both activities	not measured	0.17 (during spraying only)[(4)]	3230 µg/kg ai (19 through mask)[(5)]	0.012 mg/kg ai (0.72 mg/treatment)[(6)] (during floor injection and attic spraying)	ChE depression not measured	Yes - both respiratory and dermal exposure measured (noted that hand and head exposure not included)

Jitsunari et al. (1989) 1% emulsion	Eight subjects (6 PCOs and 2 salespeople) monitored monthly during termite control season and off-season. PCOs wore overalls, hood, rubber gloves, rubber boots and respiratory protection.	not measured	not measured	not measured (urinary TCP correlated with duration of work)	Plasma ChE showed reciprocal relationship with duration of work (~80% reduction in ChE when exposed for 110 h/month)	No - no estimates available for worker exposure

All data presented as means ± SE, number of replicates in square brackets [ ], 75th percentile in curved brackets {}
(1) estimated from 8 hour TWA (mean of 17) and respiratory rate of 1.74 m^3/h
(2) estimated from individual breathing zone concentrations based on respiratory rate of 1.74 m^3/h
(3) measured on patches under cotton coverall plus either tyvek polylaminated coverall or nylon tafta coverall; head, hand and foot patches positioned under nylon head cover, chemical goggles, respirator, polyurethane gloves and rubber boots
(4) based on only one measurement
(5) based on breathing zone concentration through mask of 0.001 mg/m^3, exposure time 20 min and respiratory rate of 29 L/min
(6) assuming that 10% chlorpyrifos passes through one layer of protective clothing; exposure to hands and head/neck not measured

Table 26: Summary of exposure of pest control operators during post-construction application of chlorpyrifos for termite control (continued)

Reference Formulation; application rate	Study details	Airborne concentrations (mg/m^3)	Respiratory exposure		Actual dermal exposure based on passive dosimetry	ChE depression (%) and other findings/comments	Suitable for OHS risk assessment
			Breathing zone samples	Exposure estimates			
Ishikura (1989) 1% ME formulation	One Japanese house (crawlspace type) was treated with a chlorpyrifos suspension by power sprayer by 2 operators. Area air monitoring at 0-1, 1-2 and 24 h	0.0198 (under house) 0.0024 (mean of 6 areas inside house)	not measured		1.54 mg/treatment[(1)]	ChE depression not measured	Yes - suitable for estimation of exposure to body only (no hand or head estimates)
Asakawa et al. (1989) 1% oil and 1% emulsion	Two Japanese houses were treated for termites. Each home was treated by 2 applicators for a total of 3 applications. Study in Japanese (abstract in English). Not known how dermal exposure is calculated. Application methods not known.	0.03 (inside house) 1.41 (in crawl space)	not provided	0.147 ± 0.033 [4] mg/replicate (inside house) 1.67 ± 0.58 [2] mg/replicate (in crawl space)	2.12 and 35.84 mg each for the 2 applicators [(2)]	Authors measured chlorpyrifos in the plasma and erythrocytes of the workers after application, while pre- work samples were below detection. Plasma ChE levels in 7 workers tested both before the termite control season and during the busy season showed a mean reduction of ~ 50%	Yes - both respiratory and dermal exposure measured (dermal estimates exclude hands and neck)
Fenske and Elkner (1990) 0.71%	Chlorpyrifos was applied to 4 US houses by sub-slab and soil injection. Three of the houses were treated in the crawl space also. Two applicators were needed to treat each house. Dermal exposure was estimated from external and internal patches plus handwashes; most workers did not wear gloves; dermal estimates represent exposure through one layer of clothing although some workers did not wear coveralls.	not measured	not provided	{66}µg/kg ai[(3)]	{7.2} mg/kg ai (actual exposure)[(3) (4)]	Total dose (respiratory + dermal) = 0.282 mg/kg ai without respirator and 0.223 mg/kg ai with respirator [(5)]. Workers dealing with accidental spills experienced the highest dermal exposure. Over 50% of the actual dermal exposure found beneath the clothing on upper and lower legs. Hand exposure contributed 7% to total actual dermal exposure, head and neck 7.5%, forearms 34%, upper legs 38% and lower legs 13%. Dermal dose was not estimated from urinary TCP, however TCP levels in 24-48 hour urine samples correlated well with estimates of total absorbed dose based on passive dosimetry	Yes - both respiratory and dermal exposure measured

Leidy et al. (1991) 1% emulsion; 4.4-9.2 kg ai per house	Chlorpyrifos was applied to 16 US houses with varying construction and soil types. All applications were conducted according to the label instructions for the specific construction type.	0.0467 ± 0.00213 [5] (crawl) 0.0171 ± 0.0110 [5] (crawl-slab)	0.0718 [11] mg/m^3 (6)	0.134 ± 0.064 mg/kg ai (6)	not measured	Treatment time for each house ranged from 96 to 365 min. The authors identified 5 replicates as being overestimates of respiratory exposure due to splashback, these have been omitted from the calculations	Yes - suitable for estimation of respiratory risk only

All data presented as means ± SE, number of replicates in square brackets [ ], 75th percentile in curved brackets {}
(1) estimated from contamination on sections of long cotton undergarments (hands and head excluded from calculations)
(2) external patches showed total contamination of 'whole protective outfit' of 7.82 and 78.58 mg for the respective applicants, with a mean penetration of 40% to the internal pads
(3) as 2 applicators worked in each house, the respiratory dose (µg) and dermal dose (µg) reported in the study for each worker was divided by
½ the amount of chlorpyrifos handled per house
(4) dermal dose (reported as 0.216 mg/kg ai) was converted by NOHSC to actual dermal exposure by dividing by the absorption factor of 0.03
(5) actual dermal exposure x 0.03 + potential respiratory exposure x 1.0
(6) respiratory exposure (µg/replicate) was estimated for 11 replicates from µg chlorpyrifos on sample plug corrected for pump flow rate, treatment time and heavy work respiratory rate (60 L/min); mean µg/replicate for each construction type was then divided by mean kg ai handled/replicate to give µg/kg ai handled

Three of the studies presented in this table were located in the literature (Asakawa et al., 1989; Fenske and Elkner, 1990; Leidy et al., 1991). All of the other studies were provided by Dow as part of the Data Call-in.

Summary of study methods and results

Respiratory exposure

Most studies reported potential respiratory exposure, based on chlorpyrifos concentrations in each subject's breathing zone. Actual respiratory exposure was also measured in one study (Ishikura, 1988), by quantifying the amount of chlorpyrifos trapped on the inside of the mask.

Dermal exposure

Dermal exposure estimates were estimated in five of the studies only. Methods used included patches or full-length underwear as dosimeters, positioned under either one or two layers of clothing. One of these studies (Kawakita (1987) did not provide details on application rate or concentration. Three of the remaining four studies (Ishikura, 1988; Ishikura, 1989; and Asakawa, 1989) did not measure hand or head and neck exposure.

Airborne concentrations

Airborne concentrations in crawl spaces were reported to reach levels greater than the NOHSC exposure standard for chlorpyrifos of 0.2 mg/m^3 during application (Kawakita, 1987: 1.26 mg/m^3 (application rate not known); Asakawa et al., 1989: 1.41 mg/m^3). All airborne concentrations inside dwellings and in basements, where measured, were below the exposure standard.

ChE effects

Significant inhibition of plasma ChE was observed in workers exposed regularly (50% reduction, Asakawa et al., 1989) or during the busy part of the termite control season (80% reduction, Jitsunari et al., 1989). Isolated exposures did not show any significant changes in plasma ChE (Vaccaro and Bohl, 1979; Kawakita, 1987; Asakawa et al., 1989).

Discussion

Application parameters

Australian workers will treat up to three premises per day (average 130-150 m^2 each) at a rate of 100 or 200 g ai/10 L. Horizontal barriers will be applied at a spray volume of 5 L/m^2. Workers will therefore handle 21 kg ai per day if they treat three average homes (140 m^2) at the lowest application rate. The application rates where not specified in all studies, however the final ai concentration used by Australian workers is similar to those used in the studies.

Mixing/loading and application methods

Information on mixing and loading methods was not available in many of the studies. Where indicated, study workers used open mixing techniques. No packaging information was provided in the studies. Australian workers will use open mixing techniques using 1, 2, 5 and 20 L drums/containers.

Based on performance questionnaire information, Australian application methods will include hand held pneumatic sprayers or bucket/watering cans, soil injection using rodding equipment with high ion pressure, hand lance with low pressure high volume sprayer (rose head nozzle), and under slab reticulation systems.

Study application methods covered a range of methods such as rodding, slab drilling, injection, trenching, drip nozzle and surface band spray. All these application methods have been grouped together in Table 26, as the methods were not always provided in the studies and where more than one method was used, there was no breakdown of exposure estimates to reflect the different tasks. Reticulation systems were not used in any of the studies.

Personal protective equipment

The PPE worn by the study participants was not always provided. Worker clothing ranged from no overalls (own clothing only) to tyvek or nylon overalls worn in addition to cotton overalls. Respiratory protection and gloves were not always used.

Australian PCOs are required to observe the following safety directions:

> When opening the container, preparing the spray and using the prepared spray, wear chemical resistant overalls buttoned to the neck and wrist, a washable hat, chemical resistant footwear, elbow length PVC, neoprene or nitrile gloves, goggles and a half face respirator with combined dust and gas cartridge.

The risk assessment is based on workers wearing PPE similar to those specified in the above safety directions. It is not possible to extrapolate dermal exposures from workers using cotton overalls to workers using chemically resistant overalls, therefore no adjustments are made in the risk assessment. Respiratory exposure is estimated for workers wearing respiratory protection.

Conclusion

Studies that did not provide adequate information on application parameters were not included in the risk assessment. Studies that did not measure worker exposure were also excluded. The remaining studies were also incomplete, but were included as they give some indication of exposure, either respiratory, dermal or both.

The suitability of each study is indicated in the last column of Table 26.

Industrial/domestic - General pest control

Dow provided two worker studies conducted during general pest control. These are summarised in Table 27.

Table 27: Summary of exposure of pest control operators during application of chlorpyrifos for general household pests

Source	Formulation/ ai concentration	Study details	Results (respiratory dose, ChE depression and other findings/comments)
Eliason et al. (1969)	0.5% emulsion	Five applicators applied Dursban to homes over a 9 day period. Application was by orchard-type spray gun. Chlorpyrifos usage averaged 0.55 kg per site.	Plasma ChE reduced by 52-82%
	0.25% suspension and 0.5% emulsion	Four applicators applied Dursban over 5 days using suspension and emulsion preparations (totaling 1.7 and 2.7 kg chlorpyrifos, respectively, ie ~2.2 kg per worker).	No significant changes in plasma ChE
	0.5% suspension or emulsion	Seven applicators applied Dursban to homes over a 9 day period. Application was by pistol-type spray gun.	Depressed plasma ChE (up to 91%) were seen for 5 workers after application of 2.1-6.7 kg, no significant changes seen in 2 workers applying up to 2.2 kg; no decrease in RBC ChE in any worker; no clinical manifestations of OP poisoning by any of the workers
Meihle (1981)	0.25 and 0.5% (~24 mL spray/m^3)	One applicator applied chlorpyrifos to 3 Dow houses by broadcast spray for flea control. Floor wipe testing and area air monitoring was conducted from 1-96 hours post-application.	Respiratory dose was equivalent to 0.00025 mg/replicate while applying 0.25%[(1)] spray and 0.00047 mg/replicate for 0.5% spray[(2)] Broadcast applications took 6.8-9.7 min each

(1) chlorpyrifos measured in tubes (0.011 mg/m^3) adjusted for sampling time (7.8 min) and respiratory rate (1.74 m^3/h), adjusted for respiratory protection (x 0.1)
(2) chlorpyrifos measured in tubes (0.024 mg/m^3) adjusted for sampling time (6.8 min) and respiratory rate (1.74 m^3/h), adjusted for respiratory protection (x 0.1)

Discussion

Australian PCOs treating industrial or domestic sites for general household pests (such as ants, cockroaches, spiders etc), will apply chlorpyrifos at a final concentration of 0.5% by spot spray. These workers are expected to use a knapsack for this type of application. For the control of fleas the same concentration will be used however the area to be treated will be greater and may require the use of vehicle-mounted equipment.

The study workers used similar final chlorpyrifos concentrations (0.25 and 0.5%) to Australian workers, however they did not estimate total worker exposure. Australian PCOs will apply chlorpyrifos at 5 g ai/m^2 (50 g ai/10 L, 1 L/m^2). This equates to approximately 2.1 kg when treating 3 sites of 140 m^2 each, which is similar to the amount of chlorpyrifos handled by the study participants in Eliason et al. (1969).

Significant and marked inhibition in plasma ChE levels were seen in a number of subjects after repeated treatments (over 9 days) of residential sites using 0.5% chlorpyrifos (Eliason et al., 1969). This information cannot be fully assessed, as the study did not provide details of PPE worn by the subjects, actual work practices (such as mixing/loading methods) or actual duration of application.

The study by Meihle (1981) provided a single estimate of respiratory exposure for a worker applying 0.5% chlorpyrifos for the control of fleas. The inhalation dose was determined to be equivalent to 0.00047 mg/application (0.0078 μg/kg for a 60 kg worker treating one site whilst wearing respiratory protection). It should be noted, however, that the study participant used a smaller application volume than anticipated by Australian workers (24 mL compared to 1 L) and that Australian workers are not required to wear respiratory protection during general pest control. Due to the low replicate number and the differences in application volumes, this study will not be considered in the risk assessment.

Mosquito control

The principal registrant, Dow, provided a number of studies that measure chlorpyrifos exposure during mosquito control.

Chlorpyrifos use for mosquito control is expected to be low in Australia. Situations covered by label information include vegetation, polluted water as well as swamps and waterways. Label information recommends application by spray. Survey information provided by the chemical industry suggests that council workers will use a fogging apparatus for the control of mosquitoes in swamps and waterways and vegetation will be treated by knapsack or rega pressure sprayers. No label or survey information was available regarding the use of aerial application methods.

The following table summarises the findings for all possible application methods.

Table 28: Summary of exposure[(1)] of pest control operators during application of chlorpyrifos for mosquito control

Application method	Source	Formulation/ chlorpyrifos concentration/ application rate	Study details	Airborne concentrations (mg/m^3)	Respiratory exposure		ChE depression (%) and other findings/comments
					Breathing zone samples (mg/m^3)	Exposure estimates	
Aerial application	Soule (1967)	0.028 kg/ha; spray and granules	Marshland mosquito control: aerial application (spray) and helicopter application (granules)	plane: <0.0054 helicopter: <0.0044	0.0054 (helicopter flagger)	7.0 µg/kg ai handled (helicopter flagger)	no biomonitoring conducted
	The Dow Chemical Company (1967a)	helicopter: 0.028 kg Dursban/ha, spray volume 439 mL/ha	Aerial mosquito control; ULV application of Dursban to a rice field (130 ha) by helicopter	<0.0022	not measured		spray deposition was observed up to 45 - 60 m from treated area
		fixed-wing aircraft: 0.336 kg Dursban/ha	Aerial mosquito control: application by fixed-wing aircraft (Piper Pawnee) using 6 repeated passes over a 229 m line on the grounds of a US gun club	0.0025	not measured		spray deposition was observed up to 25 - 50 m from treated area
	The Dow Chemical Company (1967b)	2.3 g/ha (pilot and mixer/loader exposure) 4.6 g/ha (flagger exposure)	Aerial spray application for mosquito control	not measured	0.0238 (pilot: with tank leak) 0.0105 (pilot: no tank leak) 0.0055 (mixing/ loading) 0.0039 (flagger)	0.00003[(2)] mg/kg/d (mixing/ loading)	no biomonitoring conducted
	Kilian et al. (1967) in The Dow Chemical Company (1968)	fixed wing aircraft: 0.23 kg/ha	ULV spray (15.2% chlorpyrifos) applied by aerial application	not measured	not measured		no changes in either plasma or RBC ChE
Fogging	Soule and Wolf (1967) in The Dow Chemical Company (1968)	2% fog	Thermally generated fog Mullets, rats and chicks exposed to the fog	0.0175-0.0230 (stationary locations) 0.0053 (inside truck cab)	not measured		no changes in ChE levels in exposed experimental animals

* full summary in Section 4.1.1 (Aerial application studies)
(1) no dermal exposure data were available in any of the submitted studies

(2) estimated from breathing zone concentration based on respiratory rate of 1.74 m^3/h, 10 min total exposure duration per day and 60 kg body weight

Table 28: Summary of exposure[1] of pest control operators during application of chlorpyrifos for mosquito control (continued)

Application method	Reference	Formulation/chlorpyrifos concentration/application rate	Study details	Airborne concentrations (mg/m^3)	Respiratory exposure		ChE depression (%) and other findings/comments
					Breathing zone samples (mg/m^3)	Exposure estimates	
Fogging (continued)	Ludwig et al. (1970)	Dowco 179 in xylene (63% concentrate) diluted in diesel oil and applied by thermal fog in 3 separate tests					
		1.12% Dowco 179 (0.029 kg Dowco 179/ha)	Test 1. Thirteen subjects positioned 15 m from the fogger path were subjected to 2-5 passes of the fogger. I subject ran behind the fogger at a distance of 4.6 m for 2 min.	not measured	not provided	0.004 mg/replicate (4.6 m behind fogger for 2 min)	chlorpyrifos drift (amount collected on air tubes) was 10 fold greater at 15 m than at 30 m no changes in plasma or RBC ChE levels
		1.12% Dowco 179	Test 2. Three subjects positioned 6 m from the fogger for 3-8 min.	not measured	0.969	not calculated	no changes in plasma or RBC ChE levels
		4.48% Dowco 179	Test 3. Three subjects positioned 3.7 m from the fogger for 1-4 min.	not measured	97	not calculated	slight depression of plasma ChE activity in subjects exposed for 2 and 4 min. dermal exposure was not calculated, however deposition on shoulder filter paper patches was 10 times greater in test 3 than in test 2 subjects
	Pennington and Edwards (1971) cited in DHAC (1998)	M-2995 (61.5% chlorpyrifos, 34.5% xylene)	Delivered at 3.8 L/h for 5 min using ULV cold aerosol fog generator. Four subjects stood 8 m away wearing plastic coveralls (2 with hands and head exposed; 2 with hands, head and arms exposed)	not measured	108000 (108 mg/L)	not calculated	no changes in plasma or RBC ChE at 24 h experimental animals (rabbits) exposed during the study showed 33% reduction in plasma ChE and 12% reduction in RBC ChE at 24 h, recovering by 72 h
Handspray	The Dow Chemical Company (1968)	Review of exposure during mosquito control Main findings of relevant studies (excluding studies assessed in other parts of this report) are summarised below					
		0.25 suspension and 0.5% emulsion	Kenaga (1967). Spray emulsion and suspension was applied in residential areas; application volumes and pressures were greater than label rates; workers were not required to wear PPE	not measured	not measured		"varying degrees of depression" in plasma ChE when applied at high volumes (~10 x label rate); no change in RBC ChE
		0.5%	Shoof (1968). Seven applicators each applied 3.8-9.9 kg ai over 11 days, outdoors to urban block areas	not measured	not measured		reduction in plasma ChE: 41-91% (4 subjects day 10), 7-15% (2 subjects day 10), 51% (1 subjest day 14); no changes in RBC ChE

		various	Kilian et al. (1967). Four workers were exposed during the following activities: (1%) granular Dursban applied to ground by machine strapped to back; 2% in diesel oil applied by handgun attached to truck mounted generator for a total of 2 min; and manual handling of concentrated Dursban product (66% in xylene)	not measured	not measured	no changes in either plasma or RBC ChE
		0.112 kg/ha	US Department of Interior (1968)	0.0039-0.0077	not measured	experimental animals exposed during the study showed no changes in ChE levels

(1) no dermal exposure data were available in any of the submitted studies

Discussion

Airborne chlorpyrifos concentrations during all methods of mosquito control were below the Australian exposure standard for chlorpyrifos of 0.2 mg/m^3.

Changes in plasma ChE were demonstrated in a number of studies during handspray and fogging, however most of the affected workers did not wear PPE and the application rates or concentrations were greater than Australian rates (0.015-0.06 kg ai/ha for land application).

In most cases respiratory exposure during mixing/loading, application or flagging could not be estimated from breathing zone concentrations, as the exposure duration or amount of product handled were not provided. The only exceptions were mixing/loading for aerial application (The Dow Chemical Company, 1967a: 0.00003 mg/kg/d (10 min)) and flagging during helicopter application (Soule, 1967: 0.007 mg/kg ai handled). As aerial application for mosquito control is an unlikely method for Australian workers, these two studies will not be considered in the risk assessment.

Overall, the submitted studies are not suitable for the risk assessment, as they did not provide adequate study details or dermal exposure estimates.

4.1.3 Other uses

4.2 Predicted end use exposure

The UK Predictive Operator Exposure Model (POEM) is a descriptive model based on databases of operator exposure field studies. POEM provides surrogate exposure values, which are derived from the levels determined in several field studies for each of several different scenarios. Exposure calculations are divided into two parts; contamination from handling the concentrated product and contamination during actual application of the dilute spray. The model assumes that the level and distribution of potential dermal contamination are mainly dependent on the handling techniques used during preparing the pesticide product for use, the type of application equipment employed and the work practices of the individual operator.

In this model, exposure during mixing/loading, is assumed to be confined to the hands only, and no respiratory exposure is assumed to occur during mixing/loading. Dermal (hands, trunk and legs) and inhalation exposure is assumed during spray application.

In using POEM, it is necessary to make assumptions in order to estimate the actual exposure from potential exposure. These assumptions may be based on laboratory or field data, but in the absence of data conservative estimates have to be made.

The use of exposure values derived from predictive models (such as POEM), involve the use of conservative assumptions for unknowns and a range of values for a particular method of spraying. Such modelling is internationally accepted as the first step in a tiered risk assessment (Tier 1).

POEM was used to estimate mixer/loader and applicator exposure to EC and WP formulations of chlorpyrifos for a number of end use situations. These estimates are provided in Attachment 1. The end use parameters, resultant exposure estimates and risk assessment for each end use scenario are presented and discussed in Section 5.3 (Risk from End Use Exposure).

The following parameters are common for all POEM estimates.

NOEL	0.03 mg/kg/d (oral, human)
Dermal absorption	3%
Inhalation absorption	100% (default value)
Average body weight	60 kg

The information available from the applicants states that WP formulations will be packaged in 500 and 250 g water-soluble packs (except for seed treatment products), while EC formulation will be packed in 500 mL, 1 L, 5 L or 10 L containers (neck size unspecified). The POEM estimates in this report are based on 250 g water-soluble packs for WP products and 5 L containers with either wide or standard necks for EC products. EC pack sizes of 5 L is chosen for most POEM estimates, as it is the most common pack size available.

Details of the following are provided in Section 5.3 (Risk from End Use Exposure).

Model type
Concentration of active ingredient
Spray volume
Work rate
Container size
Hand contamination
Application time

4.3 Post-application exposure

4.3.1 Crop protection

Re-entry exposure may occur when workers enter treated crops to check, irrigate, thin or harvest the crop. Crop checks (scouting) may be required any time after treatment. The time that workers need to perform these tasks will depend on the type of crop and activity. Harvest time will be limited by the withholding period for each crop. Harvesting may be manual or mechanical.

Fruit has a withholding period of at least 7 days and will generally be harvested manually. Leafy vegetables and legume vegetables have no withholding period and may also be harvested manually. Broadacre crops have a withholding period of at least 2 days but are usually harvested mechanically.

There are no label re-entry/re-handling statements for chlorpyrifos products registered for crop protection.

4.3.1.1 Measured re-entry exposure data and studies on dislodgeable foliar residues

Orchards

Dow provided the following re-entry study conducted after treatment of citrus.

Honeycutt RC and Day EW Jr (1993) Worker Re-entry Exposure to Chlorpyrifos in Citrus Treated with Lorsban 4E Insecticide, DowElanco (USA), GH-C 3183, December 1993.

This study investigates re-entry exposure of citrus pickers and pruners after application of Lorsban 4E Insecticide to orange and lemon groves. The applications made for this study were part of a larger citrus worker exposure study (Honeycutt and Day, 1994).

This study was conducted to meet the re-registration data requirements of the US EPA. It was conducted in accordance with US EPA Re-entry Protection Guidelines, Subdivision K (US EPA, 1991), with some minor deviations. These are not expected to alter the interpretation of the results.

Study details

Three citrus groves (approximately 4-6 ha) were treated with Lorsban 4E Insecticide using an airblast sprayer at a rate of 6.72 kg ai/ha. Full details of worker numbers, PPE worn, work practices, etc are provided in Table 29.

Data collection and analysis

Worker exposure

The average estimated total chlorpyrifos dose (μg/kg BW) for pruners and pickers was estimated using passive dosimetry and biomonitoring. Dermal exposure was estimated using outer (denim coveralls) and inner (T-shirt and briefs) dosimeters, denim head patches pinned to hat (for estimation of head and neck exposure) and handwashes. Clothing penetration factors were estimated by comparing coverall torso with T-shirt/brief contamination.

Respiratory exposure was estimated using personal air monitoring pumps attached at the worker breathing zone and fitted with Chromosorb 102 air sampling tubes and GN-4 filter cassettes.

Urinary TCP was used to estimate total absorbed chlorpyrifos dose. Total urine voided was collected at 12-hour intervals starting 24 hours before re-entry and ending 4 days after re-entry. All samples were also analysed for creatinine levels for the determination of sample completeness. The amount of chlorpyrifos absorbed was estimated using both the urinary excretion factor method and pharmacokinetic modelling described by Nolan et al. (1984).

Blood samples were collected from each worker for the estimation of plasma and RBC ChE. Pre-exposure samples were collected at 10-5 and 4-2 days prior to re-entry. Post-exposure samples were collected 1 day after re-entry.

Foliar residues

Leaf punch disc samples were collected from each site for the estimation of dislodgeable residues and dissipation rates. Re-entry transfer factors were also calculated.

Results

Worker exposure

The study results are summarised in Table 29. The authors calculated absorbed chlorpyrifos dose (µg/kg BW) from passive dosimetry using a dermal penetration factor of 0.03 and a body weight of 70 kg. These results are not presented here.

The results showed good correlation between passive dosimetry and biomonitoring data.

The greatest exposure was experienced by workers pruning trees 2 days after chlorpyrifos treatment. Workers that pruned trees in wet weather had higher levels of exposure than those working under dry conditions.

Orange pickers, working 43 days post-treatment showed the least exposure. These workers wore an additional layer of clothing between their external and internal dosimeters, however the reduction in chlorpyrifos exposure was not reflected in the clothing penetration factor.

For all workers, the distribution of chlorpyrifos was greatest on the torso than on legs and arms.

Glove contamination was presented for pickers only. The average contamination was 5114 µg (75th percentile 5207 µg), when corrected for a field spike recovery of 9.7%. This result shows a protection factor of approximately 100-fold for gloved hands.

Blood cholinesterase results have not been presented, as there were no significant changes in either plasma or RBC ChE activity following exposure.

Table 29: Summary of exposure[1] of re-entry workers after chlorpyrifos treatment to citrus groves

Site number, work category and tasks	PPE worn	Re-entry time (days post-application)	Product application rate (kg ai/ha)	Area worked (ha)	Total time of re-entry (h)	Potential respiratory exposure		Potential body exposure[4] (µg/person)	Actual dermal exposure (µg/person)				Absorbed chlorpyrifos based on urinary TCP (µg/person)[7]
						mg/m^3 [2]	µg/person[3]		Body[5]	Hands[6]	Head and neck	Total	
Site #2 5 orange pickers; stood on ladder and picked oranges from outside the tree to inside, placing fruit into large canvas bag over shoulder and pouring the fruit into large wooden crates on ground when bag was full	intermediate clothing (pants and short sleeved shirt), new socks and new tennis shoes; T-shirt and briefs, coverall, baseball cap, thick soft work gloves, canvas gauntlets on each arm	43	6.70	0.8 (30 trees)	5.8 (includes 10 min break)	1.45 {1.72}	15.6 {18.4}	494 {502}	24.2 {24.6}	53 {54}	34.5 {35.3}	112 {111}	53 {61}
Site #5 5 orange pruners; cut branches working from inside to outside (worked in wet weather)	new socks and new tennis shoes; T-shirt and briefs, coverall, baseball cap, thick canvas work gloves, canvas gauntlets on each arm	2	6.70	0.5 (10 trees)	6-6.6	8.27 {8.70}	98.3 {103.3}	15987 {16088}	799 {804}	12.9 {14.7}	1831 {2084}	2649 {2816}	447 {491}
Site #6 5 lemon pruners; pruned from outside the tree towards center to prevent contact with thorns	new socks and new tennis shoes; T-shirt and briefs, coverall, baseball cap, thick canvas work gloves, canvas gauntlets on each arm	2	6.23	0.5 (10 trees)	6.2	4.64 {4.95}	61.2 {65.3}	5281 {5446}	650 {670}	32.7 {26.2}	262 {273}	935 {984}	224 {220}

(1) exposure estimates are given as arithmetic means of 5 replicates, data in { } are 75th percentile
(2) µg/person of cassette and air tube (corrected for spike recovery) ÷ total air volume (m^3)
(3) mg/m^3 adjusted for actual monitoring time and respiratory rate of 1.74 m^3/h

(4) excludes hands
(5) based on average penetration factors: 4.9% for pickers, 5.0 and 12.3% for orange and lemon pruners respectively (study authors used an average penetration factor of 7.4% for all workers)
(6) study measured actual hand exposure using handwashes
(6) the values presented here are the greater of the urinary factor or kinetic modelling estimates of absorbed dose

Foliar residues

Leaf punch samples were collected from three separate treated zones of each citrus grove, as well as from a designated control area in each grove. Duplicate samples were taken from each zone, each consisting of 50 leaf discs.

Table 30: Dislodgeable residues of chlorpyrifos on citrus leaf surfaces

Site no.	Dislodgeable residues (µg/cm^2) Days after application									
	0	1	2	4	5	7	14	21	35	43
#2 Orange	1.46	0.212	ns	0.096	0.079	0.074	0.024	0.006	0.006	0.003
#5 Orange	1.82	0.547	0.157	ns	0.007	0.004	ns	ns	0.002	ns
#6 Lemon	1.48	0.367	0.082	ns	0.013	0.005	ns	0.004	ns	ns

ns - no sample

The authors estimated transfer factors from dislodgeable residues on re-entry days. The transfer factors are shown in Table 31.

Table 31: Transfer factors for citrus re-entry workers

Crop and work task	Re-entry time (days)	Actual dermal exposure(1) (µg/person)	Dislodgeable residues (µg/cm^2)	Transfer factor(2) (cm^2/h)
Orange pickers	43	111	0.003	6201
Orange pruners (wet weather)	2	2816	0.157	2812
Lemon pruners	2	935	0.082	1896

(1) based on 75th percentile values
(2) calculated based on total actual dermal exposure (ie dermal transfer factor) and 6 hours of work

Discussion

The study design is appropriate for regulatory purposes. An adequate number of replicates were used, with each replicate performed by a different worker.

The participants wore similar clothing and gloves to those expected for Australian workers during picking/pruning operations. The scouted areas however, were treated at a much higher application rate (over 6 kg ai/ha) than the maximum Australian rate for orchards (1 kg ai/ha). The resultant residue and exposure estimates are expected to be a overestimates of Australian residues and worker exposure.

The transfer factors estimated in this study are used with caution to gauge the exposure of workers at other re-entry times, for which an estimate of dislodgeable residues is known.

Dislodgeable foliar residues (DFR) are based on residues from two-sided leaf surface areas. The transfer factor (TF) is used to indicate the "residue transfer index" as a function of "field work activity". It by no means indicates total transfer of DFR of the contacted surfaces, nor the actual surface contacted by the workers. It is established that only a fraction of DFR of the contacted surface will be transferred to a harvester's skin (Maddy et al., 1989, cited in Thongsinthusak et al., 1993). Therefore, considering all of the above, exposure estimates using DFR and TF are likely to be overestimates.

Corn fields

Dow provided a number of re-entry studies conducted after treatment of corn by centre-pivot irrigation.

(1) Bohl RW and Parsons TW (1983) Potential Exposure of Field Scouts to Chlorpyrifos during Time Spent in Cornfields Treated with Lorsban 4E, Bartlett, Nebraska, August 2-3, 1982, Dow Chemical USA, A1A-720 HEH3.5-5-27(5), March 1983.

This study investigates re-entry exposure of field scouts entering cornfields after treatment with Lorsban 4E (an emulsifiable concentrate containing 40.7% chlorpyrifos) by centre pivot irrigation.

This study was conducted in support of market development by The Dow Chemical Company. The study claims to be conducted following standard quality control procedures, however it appears that field spikes may not have been employed for the dermal patch samples.

Study details

Lorsban 4E was applied by centre pivot irrigation at a rate of 1.12 kg ai/ha in Sun Oil. Airborne exposure and potential skin contamination was measured for six post-spray time zones ranging from 2-48 hours, with duplicate sampling conducted at 24 and 48 hours.

Three Dow Chemical USA employees, instructed in "typical scouting work", served as surrogate scouts. These workers wore socks, shoes, pants (length not specified), and short sleeved shirt. The type and extent of undergarments worn were not specified. The scouting activities also were not specified.

Data collection and analysis

Airborne chlorpyrifos was sampled at the breathing zone of each scout using air pumps attached to glass adsorber tubes containing chemically bonded Carbowax 400 on Poracil F packing. Two area samples (positioned approximately 30 m away from the scout) were also collected at each re-entry zone/time.

Body exposure (excluding hands) was estimated using gauze patches (3 x 3 inch) pinned to the worker's clothing at the following positions: upper centre of the back, upper centre of the chest, right and left shoulder, upper midpoint of each forearm, front of each thigh and front of each ankle. A contact exposure rate (CER) µg/h was then estimated based on the standard body surface areas of Durham and Wolfe (1962). Hand exposure was estimated using cotton glove liners.

Air and dermal samples were collected for approximately 20 min.

Results

The study results are presented in Table 32. The authors estimated total chlorpyrifos dose for a 6 hour work period and a 70 kg person, assuming 100% inhalational absorption, no absorption through clothed areas, and a range of absorption rates (3-9%) for the unprotected body areas. This approach does not consider penetration of chlorpyrifos through clothing and is therefore not presented here. Instead NOHSC estimates of dose consider penetration through clothing and are based on a 60 kg worker.

Table 32: Inhalation and dermal exposure(1) of field scouts re-entering corn fields

Re-entry times (h)	Airborne chlorpyrifos concentration (mg/m^3)		Respiratory exposure(3) (µg/h)	Potential body exposure (µg/h)	Potential hand exposure (µg/h)	Total dose by all routes	
	Breathing zone	Area				(µg/d)(4)	mg/kg/d(5)
2	0.0118 [3]	0.0081 [2]	21	5115 [3]	483 [3]	318	0.0053
4	0.0192 [3]	0.0112 [2]	33	886 [3]	189 [3]	233	0.0039
8	0.0035 [2]	0.0133 [2] (2)	61	344 [2]	123 [2]	380	0.0063
12	0.0063 [4](2)	0.0030 [2]	11	310 [2]	264 [2]	82	0.0014
24	0.0038 [2] (2) 0.0033 [3] (2)	0.0089 [2] (2) 0.0036 [2] (2)	63	158 [2]	132 [2]	386	0.0064
48	0.0041 [3] (2) 0.0063 [3] (2)	0.0051 [3] (2) 0.0038 [2] (2)	90	227 [3]	72 [3]	549	0.0092

(1) arithmetic mean; number of replicates in [ ]
(2) includes samples below detection limit (0.004 µg/sample)
(3) assumes a respiratory rate of 1.74 m^3/h
(4) assumes 100% respiratory absorption, 50% of body covered by clothing (rough estimate), 10% default transfer through clothing and gloves, 3% dermal absorption and 6 h working day
(5) based on (4), assumes 60 kg body weight

Discussion

Due to the following reasons, the results are used in the risk assessment with caution:

Chlorpyrifos will be applied to field crops at application rates not exceeding 0.75 kg ai/ha. The study application rate is higher (1.12 kg ai/ha).

The number of replicates was low.

The study did not describe the scouting activities and the subjects were not experienced agricultural workers.

The study did not measure head and neck exposure.

The study application method is not used for chlorpyrifos products in Australia.

The sampling period was very short (20 min).

(2) Brady UE, Tippins R, Perry J, Young JR and Wauchope RD (1991) Chlorpyrifos Exposure of Workers Entering Sweet Corn after Chemigation, Bull. Environ. Contam. Toxicol., 46, 343-350.

Study details

Chlorpyrifos in peanut oil was applied to a corn field by chemigation at weekly intervals beginning 9 days after planting for a total of four applications. The application rates and volumes were: 0.56 kg chlorpyrifos/ha, 1.82 kg peanut oil/ha, spray volume 25,374 L/ha.

Re-entry workers (three) entered the field 4 and 48 hours after each treatment for an exposure period of approximately 30 min.

Leaf samples were collected at each re-entry time and dislodgeable residues were assessed by the leaf wash method of Iwata et al. (1977).

Dermal and respiratory exposure was estimated using the sampling techniques of Durham and Wolfe (1962) and Davis (1980), with modified sampling media attached externally to the worker's protective clothing (patches located on hat, shoulder, forearm, mid chest, front of thigh and ankle). For dermal exposure, polyurethane foam was used instead of alpha-cellulose pads. For respiratory exposure, two stacked polyurethane foam pads were placed over the commercial filters on each side of the face mask respirator. Gloves (type not specified) were used to estimate hand exposure.

Area chlorpyrifos samples were collected within and outside the spray radius. Glass funnels and collection tubes were positioned in the designated treatment areas while foam pads where positioned outside.

Results

Area samples showed the spray distribution to be greater (30% greater) near the pivot and near the spray perimeter than at the mid-boom sites.

The dermal exposure results were presented as µg/100 cm^2/hr on each separate body area tested (including the hands), however total exposure based on body surface area was not calculated. The results, however, show an increase in exposure with later treatment dates, ie with increasing foliage height. The results also showed exposure at 4 hours post-treatment to be approximately 2 times the exposure at 48 hours.

Respiratory exposure was presented as µg/100 cm^2 for each of the polyurethane pads, and were not converted to worker exposure or to an airborne chlorpyrifos concentration. The results however were able to show that exposure was greater at 4 than at 48 hours (all 48 hour samples were below the detection limit), and that pad residues increased with foliar height.

The authors claimed to correlate worker exposure with foliar residues at the same re-entry times (4 and 48 hours) however the foliar residue results were not presented.

Discussion

Estimates of worker exposure could not be determined from the data (dermal and respiratory) in the manner that they were presented. Additionally, the method of application (centre pivot irrigation) is not relevant for Australian chlorpyrifos products.

This study is not considered in the risk assessment.

(3) Two literature studies were available evaluating re-entry workers after corn chemigation. They are described separately below.

Kamble ST, Byers ME, Witkowski JF, Ogg CL and Echtenkamp GW (1992) Field Worker Exposure to Selected Insecticides Applied to Corn Via Center-Pivot Irrigation, Journal of Economic Entomology, 85 (3), 974-980.

This study investigates re-entry exposure of field workers entering cornfields after treatment with chlorpyrifos (with and without crop oil), carbaryl, and permethrin by centre pivot irrigation. The chlorpyrifos results only are discussed here.

Study details

Field workers were monitored for dermal and respiratory exposure to Lorsban 4EC at re-entry intervals of 2, 4, 8, 24, and 48 h after application. The number of workers, number of replicates and work practices are summarised in Table 33.

Lorsban with or without crop oil was applied to R3 stage corn through an overhead center-pivot irrigation system. Applications were made on two separate days, in 1987 and 1988. The corn density was ~ 64000 plants/ha with a line spacing of 76 cm. The application rate was

1.12 kg ai/ha and the application volume was 0.64 cm of irrigation water (approximately 80000 L/ha). The crop oil application rate was 0.45 L/ha.

Dermal exposure was measured using 18 dermal patches on the outside of a Tyvek coverall (located on the shoulders, forearms, thighs, ankles, chest and back), eight of these were covered with a 50:50 cotton-polyester swatch and were used to estimate dose through the protective clothing. The authors estimated percent penetration by dividing the amount of chlorpyrifos on the gauze patch by the contamination on the swatch plus gauze patch and multiplying by 100. Gauze patch contamination was converted to dermal exposure estimates for separate body parts using the body surface areas of Dubois and Dubois (1916).

Total (potential) hand exposure was determined by measuring the amount of chlorpyrifos on cotton gloves worn over protective PVC gloves.

Respiratory exposure was determined using portable air samplers equipped with polyurethane foam plugs to trap ambient insecticide residues. Air samplers were calibrated to an airflow rate of 2 L/min. Sample extracts were converted to respiratory exposure estimates based on a respiratory rate of 1740 L/h.

Field spikes were employed to check sample (gauze pad) stabilities. A field recovery value of 94% was provided in the study, but it is not known if the field samples were corrected for this amount.

Results

The authors provided averaged data for each day of application. Percentage of toxic dose and margins of safety were also calculated by the authors, but these are not included here.

Table 33: Summary of exposure estimates[(1)] for scouts re-entering corn treated with chlorpyrifos via a center pivot irrigation system

Re-entry time (h)	1987			1988					
	Chlorpyrifos			Chlorpyrifos			Chlorpyrifos with crop oil		
	Exposure (μg/h)		Total dose (mg/kg/d)[(3)]	Exposure (μg/h)		Total dose (mg/kg/d)[(3)]	Exposure (μg/h)		Total dose (mg/kg/d)[(3)]
	Total actual dermal[(2)] (% hand contamin-ation)	Respir-atory		Total actual dermal[(2)] (% hand contamin-ation)	Respir-atory		Total actual dermal[(2)] (% hand contamin-ation)	Respir-atory	
2	143.5 ± 94.1 (68)	25.7 ± 17.3	0.0030	185.7 ± 127.4 (64)	42.4 ± 25.1	0.0048	178.7 ± 91.4 (55)	50.4 ± 9.6	0.0056
4	60.8 ± 55.2 (62)	10.9 ± 12.3	0.0013	132.9 ± 65.8 (60)	16.2 ± 12.5	0.0020	137.8 ± 66.1 (54)	17.2 ± 4.2	0.0021

8	26.3 ± 26.3 (53)	3.5 ± 9.1	0.00043	56.1 ± 44.7 (75)	6.1 ± 3.6	0.00078	45.6 ± 23.7 (75)	0.9 ± 1.9	0.00023
24	13.4 ± 12.9 (74)	nd	0.000040 *	25.4 ± 19.5 (93)	0.1 ± 0.1	0.00086	13.4 ± 5.2 (96)	nd	0.000040 *
48	7.9 ± 8.0 (78)	nd	0.000024 *	14.0 ± 5.3 (90)	nd	0.000042 *	10.1 ± 4.9 (100)	nd	0.000030 *

Scouts checked for insect activity on at least 10 plants on each of 5 separate areas within their plot (the entire re-entry exercise took approximately 30 min)
(1) arithmetic mean of 3 replicates ± standard error (3 different workers)
(2) corrected for measured clothing penetration (actual dermal exposure); hand exposure represents potential dermal exposure
(3) assuming 60 kg worker, 100% dermal absorption, 3% dermal absorption and 6 hour work day
nd - below detection limit, 0.005 ng/µl
* based on dermal exposure only

Highest dermal and respiratory exposures were found at the 2 h re-entry interval. Exposures decreased as the re-entry interval increased. Dermal exposure was primarily confined to the hands. Residues detected by air samplers ranged from 0 to 0.03 µg/L.

The authors reported a range in mean chlorpyrifos penetrations through cotton-polyester swatches of 16.5 to 26.2%. The highest penetration (34.1%) was observed when chlorpyrifos was applied with oil, however the presence of crop oil had no bearing on worker exposure.

Discussion

This study design and methodology are suitable for regulatory purposes, however the data are used with caution for the following reason:

The number of replicates was low (3 per re-entry time).

The study application rate (1.12 kg ai/ha) is slightly higher than the Australian rate in field crops (maximum 0.75 kg ai/ha).

The application method used in the study results in uneven distribution of chemical on the crop, and is not used with Australian chlorpyrifos products.

<u>Low crops – cauliflower and tomatoes</u>

Shurdut BA, Murphy PG, Nolan RJ and McNett DA (1993) Lorsban 4E and 50W Insecticides: Assessment of Chlorpyrifos Exposures to Applicators, Mixer/Loaders, and Re-entry Personnel During and Following Application to Low Crops, DowElanco (USA), HEH2.1-1-182(118/124), September 1993.

Dow provided a study which measured exposure of mixer/loaders, applicators and re-entry scouts during and following treatment of low crops with chlorpyrifos. The re-entry exposure and foliar residue results are presented here.

Study details

Full study details and methodology for re-entry workers are provided in Section 4.1.1).

Dermal contamination of exposed skin and areas covered by clothing (actual dermal exposure) was estimated using full body dosimetry techniques and hand washes.

Field scouts wore coveralls (short sleeved) and sweatband on forearm (external dosimeters) and T-shirt/undershirt and briefs (internal dosimeters).

Hand washes (0.008% Emcol 4500 soap solution) were conducted for all participants before starting work, at usual break times (such as before smoking, eating or visiting the bathroom) and at the end of each monitoring period.

Dislodgeable foliar residues were estimated from leaf punch samples collected during the day prior to treatment (T-1), on the treatment day (T0) and on 8 days over the following 30 day period (T+1, T+2, T+3, T+5, T+7, T+14, T+21 and T+30).

Results

The re-entry exposure results are summarised in Table 34.

Absorbed doses estimated by biomonitoring correlated well with exposure estimates based on passive dosimetry.

Mean penetrations of chlorpyrifos through the coveralls was 8.9% (3.8-16%) for scouts.

Blood cholinesterase levels from pre- and post- exposure samples showed depression in four of ten subjects (average 9%, range 2-17%), however correlation with absorbed doses was poor.

Residue dissipation was shown to be biphasic, with rapid decay occurring over the first 3-4 days followed by a slower degradation rate. Dislodgeable residue $t_{1/2}$s ranged from 3.0-3.9 days. The mean transfer coefficients estimated from worker exposure and foliar residue data at 24 hours post-application were 729 cm^2/h for cauliflower and 670 cm^2/h for tomatoes. Data used to estimate the transfer coefficients are shown in Table 34.

Discussion

This study is suitable for regulatory purposes. The number of replicates (5) are adequate and the study application rate (~1 kg ai/ha) is representative of the Australian rates for similar crops (1 kg ai/ha for cauliflower and tomato).

Table 34: Summary of exposure of field scouts and estimation of transfer coefficients 24 hours after chlorpyrifos treatment of cauliflower and tomatoes

Site, crop and formulatio ntype	PPE	Duration of scouting activities (h)	% ai in spray	Respiratory exposure[(1)]			Dermal exposure[(1)]			Sum of absorbed respiratory and dermal doses (µg/kg bw)	Absorbed dose based on urinary TCP (µg/kg bw)	Estimation of transfer coefficient		
				(µg/m^3)	absorbed dose[(2)] (µg)	absorbed dose[(2)] (µg/kg bw)	total actual exposure (mg)	absorbed dose[(3)] (µg)	absorbed dose[(3)] (µg/kg bw)			Dermal exposure rate (µg/h)[(5)]	Dislodge-able foliar residues at 24 hours (µg/cm^2)[(4)]	Transfer coefficient (cm^2/h)[(6)]
Site 2 cauliflower WP	coveralls with sleeves cut off above elbow, T-shirt, briefs, closed footwear, baseball hat	3.98	~ 0.3%	5.05 (0.944-17.5)	30.0 (5.62-104)	0.358	2.23 (0.65-4.86)	67.3 (19.8-146)	0.802	1.16	0.76 (<0.5-1.4)	560	0.769	729
Site 3 tomatoes WP		4.03	~ 0.1%	3.32 (2.9-3.7)	20.1 (17.6-22.5)	0.270	0.95 (0.78-1.43)	29.0 (23.3-45.7)	0.389	0.659	2.2 (<0.3-3.4)	234	0.349[(7)]	670

All dose estimates (µg/kg bw) are based on individual worker body weights (range 60-109 kg)

(1) arithmetic mean of 5 replicates

(2) assumes no respiratory protection (100% respiratory absorption) and respiratory rate of 1.5 m^3/h

(3) assumes 3% skin absorption

(4) arithmetic mean of 6 leaf samples

(5) estimated by dividing total dermal exposure (µg) by duration of exposure (h)

(6) estimated by dividing dermal exposure rate (µg/h) by dislodgeable foliar residues (µg/cm^2)

(7) this estimate was obtained from another tomato plot due to the scouted plot not giving interpretable dissipation results (dislodgeable foliar residues at the scouted plot were 0.258 mg/cm2 however the dissipation curve was not typical)

Cotton

Dow submitted the following literature study as part of the data call-in.

Buck NA, Estesen BJ and Ware GW (1980) Dislodgeable Insecticide Residues on Cotton Foliage: Fenvalarate, Permethrin, Sulprofos, Chlorpyrifos, Methyl Parathion, EPN, Oxamyl, and Profenofos, Bulletin of Environmental Contamination and Toxicology, 24, 383-288. (A1A-217 TK-2-1363).

This study investigated the disappearance rates of a number of pesticides, their metabolites and pesticide mixtures from cotton leaves. The part of the study that involved chlorpyrifos is discussed here.

Lorsban 4EC was applied by manually drawn ground rig at a rate of 1.1 kg ai/ha and an application volume of 122 L/ha. The test plot was four treated rows with 102 cm spacing, 30.5 m long. The average plant height on the treatment day was 48 cm.

Leaf punch samples were collected 0, 24, 48, 72 and 96 hours after treatment. Triplicate samples (each consisting of 100 leaf punches from the top, middle and bottom portions of the plants) were collected from all treated rows.

The chlorpyrifos dislodgeable residue results are tabulated in Table 35.

Table 35: Dislodgeable leaf residues following chlorpyrifos (Lorsban 4EC) treatment of cotton

Sample time (h)	Chlorpyrifos residues (μg/cm^2)
0	3.64
24	0.13
48	0.071
72	0.055
96	0.034

Discussion

The study application rate (1.1 kg ai/ha) is comparable to the Australian rate for chlorpyrifos on cotton (up to 1 kg ai/ha).

These results show a rapid decline of residues on cotton foliage following chlorpyrifos application, with a degradation t½ of < 1 day.

Transfer factors have not been determined in this crop group. The risk assessment will consider a default transfer factor to roughly gauge exposure for cotton scouts.

4.3.2 Pest control

Re-entry exposure may occur after pest treatment of existing buildings or buildings under construction. Occupational exposure will be limited to construction workers re-entering treated areas or office workers re-entering treated work sites.

Products used for pre-construction termite control carry the following re-entry/re-handling statement:

> **Suspended floors:** allow treated areas to completely dry (normally 3-4 hours) and ventilate buildings before re-occupying
> **Concrete slabs:** cover immediately after treatment with a moisture membrane

Products used for post-construction termite control and general pest control carry the following re-entry/re-handling statement:

> **Re-entry to treated areas:** allow treated areas to completely dry (normally 3-4 hours) and ventilate buildings before re-occupying

4.3.2.1 Studies on chlorpyrifos residues

<u>Offices</u>

The following study was available in the literature.

Currie KL, McDonald EC, Chung LTK and Higgs AR (1990) Concentrations of Diazinon, Chlorpyrifos, and Bendiocarb after Application in Offices, American Industrial Hygiene Association Journal, 51 (1), 23-27.

This study examined airborne and surface contamination of diazinon, chlorpyrifos and bendiocarb at intervals up to 10 days after broadcast spray application. The chlorpyrifos results only are discussed here.

Chlorpyrifos (0.5%) was applied to the carpeted floors of three offices by a pesticide applicator using a B and G compressed air sprayer (tank capacity 3.79 L) with an adjustable nozzle. The nozzle tip was kept 30 cm from the floor surface while using a flat fan spray and a coarse spray. Each room was slowly traversed, back and forth, along its length and then its width. The application rate was approximately 0.03 L/m^2. The application time was approximately 3-5 min/office.

Offices were kept shut and unventilated during the exposure and sampling period.

Air samples were pumped through glass-fibre filters to Chromosorb 102 filled tubes. Pump positions were ~ 1 m above floor level.

Surface deposition was estimated using aluminium pie plates positioned at various heights, as well as surface wipes of furniture and aluminium foil placed on the floor.

Results

The maximum air chlorpyrifos concentration was measured 4 h after application.

The presence of office furniture appeared to impact significantly on the air concentration of chlorpyrifos, with air concentration being greater and persisting for longer in unfurnished rooms. In all reported cases, airborne chlorpyrifos concentrations were well below the NOHSC exposure standard for the chemical (TWA 0.2 mg/m^3).

In general, surface contamination was greater at 24 and 48 hours than just after application. The contamination levels, however, were very low.

The results are tabulated in Table 36.

Discussion

This study is relevant for Australian workers who may enter offices after they have been treated for general pests. The study measured only surface contamination and airborne air concentrations and did not consider worker exposure. It is therefore of limited use. In addition the application rate used for the study application was much lower than the expected rate for indoor general pest control in Australia (0.03 L/m^2 in the study compared to 1 L/m^2 according to Australian label information, both applying a 0.5% solution).

Table 36: Summary of office contamination after chlorpyrifos application

Time after spraying (h)	Airborne chlorpyrifos (µg/m^3)[(1)]			Surface contamination (ng/cm^2) [(2)]								
				Aluminium plates [(1)]						Furniture and Floor		
	Office 4 unfurnished	Office 5 unfurnished	Office 6 furnished	Office 4 unfurnished		Office 5 unfurnished		Office 6 furnished		Office 4 unfurnished	Office 5 unfurnished	Office 6 furnished
				0.6 m	1.5-2.1 m	0.6 m	1.5-2.1 m	0.6 m	1.5-2.1 m			
-1	0	0	0	not measured						not measured		
0	6	6	10									
1-2	not measured			0.78	0.36	0.24	0.20	0.75 [2]	1.14 [3]	< 0.3	< 0.3	3.3 [3]
2	18.5	11	3	not measured						not measured		
4	27	14	2									
6	ns	ns	2									
8	ns	ns	2									
24	20	15	2	4.86	2.55 [2]	1.32	2.2 [2]	0.49 [3]	0.47 [3]	4.3	4.4	3.0 [3]
48	11	13	0.5	not measured						5.9	4.2	ns

144	5	5	0.5
240	ns	ns	0.5

ns - not sampled
(1) estimated from study graph results
(2) arithmetic means are provided where more than one data point reported, number of data points in [ ]

5. OCCUPATIONAL RISK ASSESSMENT

The occupational risk assessment takes into consideration the hazard of the chemical as determined by toxicology testing (Section 2), its use pattern in Australia (Section 3) and worker exposure for each exposure scenario (Section 4).

Australian workers may be exposed to chlorpyrifos during product handling, product application (mainly spray) and during clean-up activities.

The potential routes of occupational exposure to chlorpyrifos will be dermal and inhalation. Inhalation exposure may occur to product dust (WP or granular formulations) and/or spray mist (EC, WP or ULV formulations). Exposure to active constituent vapour is not likely to be significant as the vapour pressure of chlorpyrifos is low (2.5 x 10^{-3} Pa). Workers may however inhale vapour when using liquid formulations which contain hydrocarbon solvents.

5.1 Acute toxic potential

The main hazards associated with acute exposure to chlorpyrifos are moderate oral and dermal toxicity. Skin irritation and sensitisation are not a concern, however eye irritation (moderate) may result.

The acute RfD for chlorpyrifos in humans is 0.01 mg/kg/d, based on the NOEL and including a 10-fold safety factor (Section 1.1.1). Assuming 60 kg body weight and 3% dermal absorption, the RfD is equivalent to skin contamination with 20 mg chlorpyrifos, 0.04 mL of 500 EC formulation (0.04 g of 500WP formulation), or greater volumes of the less concentrated formulations. During spray application the most concentrated spray will result during bandspray at sowing (3.75% ai) or during ULV application (30% ai). In this case the RfD will be equivalent to contamination with 0.53 mL of spray or 0.067 mL of undiluted ULV formulation.

The acute RfD level indicates a potential for unacceptable exposure during end use.

5.2 Repeat dose toxic potential

The most sensitive indicator of toxicity in humans and animals is the inhibition of plasma ChE.

A human NOEL of 0.03 mg/kg/d, established in a short-term repeated dose study, is used to assess the risk to workers repeatedly exposed to chlorpyrifos. Assuming 60 kg body weight and 3% dermal absorption, this is equivalent to skin contamination with 60 mg chlorpyrifos, 0.12 mL of 500EC formulation, 0.12 g of 500WP formulation, 1.6 mL of the most concentrated spray (3.75% ai), or 0.20 mL of the ULV formulation (30% ai). This calculation does not include a safety factor.

The theoretical calculations indicate a potential for unacceptable exposure during end use.

5.3 Risk from end use exposure

In order to adequately determine the risk associated with chlorpyrifos, Margins of Exposure (MOE) were calculated by comparing the most appropriate NOEL with exposure data obtained from measured exposure studies and predicted modelling.

Worker exposure data derived earlier from labels, NRA advice and performance questionnaires (Section 3.2), were standardised for the Australian use pattern. Predictive modelling was used where no suitable worker exposure data were available, or where some scenarios (such as different formulations or packaging types) were not covered by particular studies. The conservative nature of POEM generated data is considered when interpreting model results. A qualitative risk assessment was conducted when neither measured or predicted exposure data were available.

The most appropriate NOEL was 0.03 mg/kg/d, based on plasma ChE inhibition observed over 20 days in a human study. This NOEL was compared with the standardised exposure estimates or the predicted exposure estimates to give MOE for each Australian use scenario. As a human NOEL was used, MOE of approximately 10 or more were considered to be acceptable, consistent with the safety factor selected for establishing the Acceptable Daily Intake (ADI). It is recognized that in cases where the use of chlorpyrifos is infrequent, the above NOEL may be conservative and result in an overestimation of risk.

The following assumptions were made in calculating MOE for end users of chlorpyrifos products.

workers wear PPE consistent with product labels;

10% penetration (default) through cotton overalls or equivalent clothing, consistent with Shurdut et al. (1993) and Stamper et al. (1989a);

10% penetration (default) of liquid products through PVC (or other chemically resistant) gloves, consistent with Thongsinthusak et al. (1993) and POEM default parameters;

1% penetration (default) of dry products through PVC (or other chemically resistant) gloves, consistent with POEM default parameters;

10% penetration (default) through respirator, based on 10% through half face respirator, Thongsinthusak et al. (1993);

3% dermal absorption, as discussed in Section 2.1.2;

100% respiratory absorption, consistent with Thongsinthusak et al. (1993);

an average body weight of 60 kg, consistent with the World Health Organisation;

an average respiratory rate of 29 L per minute, based on Durham and Wolfe (1962); and

average body surface areas based on Berkow (1931), cited in US EPA Subdivision U Guidelines (US EPA, 1987), ie total body area 21,110 cm^2, hands 820 cm^2, feet 1310 cm^2, head/neck/face 1300 cm^2; and

human oral NOEL of 0.03 mg/kg/d.

5.3.1 Crop protection

<u>Airblast application</u>

Margins of exposure were estimated for workers applying EC and WP formulations by airblast. Table 37 summarises the MOE determined based on worker exposure data, while Table 38 summarises the results obtained using the Predictive Operator Exposure Model (POEM).

Both measured and predicted estimates are standardised for Australian application and work rates (total ai handled 15 kg ai/d). The use pattern parameters chosen for these estimates are based on the airblast scenario with the greatest exposure potential (ie, pome and stone fruit). Most study estimates are for workers in open cabs. No adjustments are made for the differences in PPE worn by the study participants. POEM estimates assume workers are in open cabs wearing coveralls and gloves but no respiratory protection.

Table 37: Mixer/loader/applicator risk during airblast application based on measured exposure

Source Crop Formulat-ion	Worker category: equipment type, number of tests	Study conditions and results			Standardised results***	
		PPE	Mean total absorbed chlorpyrifos based on urinary TCP (mg/kg/d)**	Total ai handled (kg)	Mean total absorbed chlorpyrifos based on urinary TCP (mg/kg/d)**	MOE
Bohl et al. (1985) Orchards (tree type not specified) 50% WP	Mixer/loader/applicator: low pressure (40+ psi), open/covered cab, one directional sprayer, 1 test (2 half day applications)	own clothing, cotton gloves, half face respirator*	0.057	4.08	0.21	<1

	Mixer/loader/applicator: high pressure, open cab, two directional sprayer, 2 tests	own clothing, half face respirator*	0.372	7.38	0.76	<1
	Mixer/loader/applicator: high pressure, closed cab (vent windows open), two directional sprayer, 1 test	own clothing	0.036	4.54	0.119	<1 (no respirator)
	Mixer/loader/applicator: high pressure, closed cab, two directional sprayer, 1 test	own clothing, half face respirator*	0.0175	4.54	0.058	<1
Honeycutt and Day (1994) Oranges, lemons 40.7% EC	Mixer/loader: open mixing, 15 tests	T-shirt and briefs, short sleeved shirt, long pants, coveralls, chemical resistant gloves, boots, helmet, respirator	0.00945 (567 µg/d)	33.6	0.00422	7.1
	Applicator: open cab airblast sprayer (nozzle pressure 100-200 psi), 15 tests		0.01115 (669 µg/d)		0.00513	5.8
	Clean-up worker: hose down of equipment, 16 tests		0.00134 (80.5 µg/d)		0.000598	50
	Total		0.0219		0.00978	3.1

* respirator worn only during mixing/loading
** day here is the test working day which ranged from ~6-8 hours in the Bohl et al. (1985) study
*** standardised for 15 kg ai handled per day (1 kg ai/ha, 15 ha/d)

Table 38: Mixer/loader/applicator risk during airblast application based on POEM estimates

Formu-lation	Estimate No. (Pack type)	Applica-tion rate, spray volume	Mixer/loader		Applicator		Mixer/loader/ Applicator	
			Absorbed dose(1) (mg/kg bw/d)	MOE	Absorbed dose(2) (mg/kg bw/d)	MOE	Absorbed dose(2) (mg/kg bw/d)	MOE
50% WP	Estimate 1 (250 g water-soluble pack)	1 kg ai/ha, 2000 L/ha	Nil exposure expected		0.024	1.3	0.024	1.3
50% EC	Estimate 2 (5 L pack, standard container)		0.030	1	0.024	1.3	0.054	<1
	Estimate 3 (5 L pack, wide neck)		0.002	15	0.023	1.3	0.025	1.2

POEM model used is V-500 (without cab) for all estimates; all estimates are for workers wearing one layer of clothing and gloves
(1) only dermal exposure considered during mixing/loading
(2) dermal and inhalation exposure considered during application (inhalation exposure contributed ~13% to absorbed dose)

The results of the Bohl et al. study in Table 37 show unacceptable risk (MOE <1) for mixer/loader/applicators. These workers handled a WP formulation using open mixing techniques and wore no hand protection for the duration of the study. Most of these workers also worked in open cabs. The mixer/loader/applicator that worked in a completely enclosed cab experienced the lowest exposure, however the MOE for this worker was still unacceptable.

The MOE estimated from Honeycutt and Day (1994) show marginally acceptable risk (MOE = 7.1) for mixer/loaders handling EC formulation using open mixing techniques and PPE (respirator) in excess of label requirements. Applicators in open cabs showed unacceptable risk (MOE 5.8) while clean-up workers were adequately protected (MOE 50). Due to the high exposure during mixing/loading and application, workers performing combined tasks will also experience unacceptable risk.

For airblast applications, exposure modelling was used to estimate exposure scenarios where measured data were not available, for example WP formulations in water-soluble packaging and non-standard containers for liquids. The resulting POEM estimates show that exposure during mixing/loading is largely dependent on the types of formulations handled and the container size and type. The use of WP formulation in water-soluble packs is expected to result in nil exposure. The use of EC formulations in wide neck containers resulted in acceptable risk (MOE = 15), whereas standard EC containers resulted in unacceptable risk (MOE = 1).

The POEM estimates show the risk for applicators using open cabs is unacceptable (MOE = 1.3), with potential inhalation exposure contributing significantly to this risk (~13% of total dose).

Discussion

The risk assessment based on exposure data is in agreement with POEM estimates. Both showed unacceptable risk for mixer/loaders/applicators (MOE $\leq$ 3) during open mixing/loading and airblast application in open cabs.

Australian workers are expected to treat orchards or vines 1-8 times a season (most often 2-4 times), therefore the NOEL, which is based on 20-day repeat exposure, is conservative. The skin absorption value used in the POEM estimates (3%) is also conservative.

It is noted that the workers in Bohl et al. (1985) wore no gloves, therefore the exposure and risk is overestimated for this study. It is also noted that the workers in Honeycutt and Day (1994) wore respiratory protection, which is not a safety direction requirement for Australian workers. However this difference is not expected to influence the overall assessment as inhalation exposure contributes little to total exposure in this study.

Taking into consideration all the above points, the overall assessment indicates that worker exposure should be minimised.

Oscillating boom

No relevant worker exposure data exist for agricultural workers applying chlorpyrifos by oscillating boom. Exposure modelling is not available for this application method.

Discussion

The use of oscillating booms in citrus is expected to be infrequent with most trees requiring 2-4 applications per season. Therefore the NOEL used in the risk assessment (based on 20-day repeat exposure) is conservative and will overestimate risk.

The application rate for this method is lower than airblast application. The spray volumes are usually very high (at least 1000 L/ha but often as high as 5000 L/ha) resulting in higher dilutions of spray. It is established that applicator exposure is higher with oscillating boom than with airblast, however the vehicles are usually equipped with closed cabs. The overall risk to workers during application by oscillating boom is expected to be similar to airblast application.

Workers will handle similar total amounts of chlorpyrifos for oscillating boom as for airblast applications, however only EC formulations are available for this end use.

The precautions or restrictions, which are associated with airblast application, should also be observed for application by this method.

Boom application

Margins of exposure were estimated for workers applying EC and WP formulations by boom. Table 39 summarises the MOE based on worker exposure data, while Table 40 summarises the results obtained using POEM.

Measured exposure estimates are standardised for Australian application and work rates for broadacre crops, the major end use situation by boom spray. Study estimates are for workers in open cabs. No adjustments are made for the differences in PPE worn by the study participants.

POEM was used to estimate exposure for scenarios where measured data were not available, namely WP formulations in water-soluble packaging and liquids in non-standard containers. Modelling was conducted for use in lawn and turf (Estimates 5, 7 and 9), as this is the scenario expected to result in the greatest exposure to workers. However as lawn and turf is a relatively minor use, modelling was also conducted for broadacre crops (Estimates 4, 6 and 8), which is the scenario with the next greatest exposure potential. All estimates were conducted for vehicles with closed cabs and assume PPE worn by workers is consistent with Australian labels (workers wear coveralls and gloves, but no respiratory protection).

Table 39: Summary of risk to mixer/loaders and applicators during application of EC and WP chlorpyrifos to vegetation, cauliflower and tomatoes by boom, based on measured exposure

Source Crop Formulat-ion type	Worker category (number of subjects); Equipment type; PPE	Total ai handled (kg)	Absorbed chlorpyrifos* (µg/kg/d)	MOE**

			Based on passive dosimetry	Based on urinary TCP	
Shurdut et al. (1993) Vegetation EC	Applicator (3); Open cab, standard boom; Coveralls, undershirt, briefs and socks, chemical resistant shoes, baseball hat	48	0.61	0.89	49 [34] no gloves, no respirator
	Mixer/loader (3) Open mixing As for applicator, plus goggles and nitrile gloves		4.1	3.7	7 [8] gloves, no respirator
Cauliflower WP	Applicator (3); Open cab, standard boom; New coveralls, undershirt, briefs and socks, chemical resistant shoes, baseball hat	19	1.7	2.0	18[13] no gloves, no respirator
	Mixer/loader (3); Open mixing; As for applicator, plus half face respirator, goggles and nitrile gloves		(no respiratory dose estimated)	14.2	[2.1] (dermal dose only) gloves
Tomatoes WP	Applicator (3); Open cab, high clearance boom; New coveralls, undershirt, briefs and socks, chemical resistant shoes, baseball hat	11	6.1	5.7	5[5] no gloves, no respirator
	Mixer/loader (3); Open mixing; As for applicator, plus half face respirator, goggles and nitrile gloves		111.5 ***	23.3	[1.3] gloves, respirator <1 gloves, no respirator

* standardised for 22.5 kg ai handled per day (based on use parameters for cereal, pasture, forage crops and sugarcane: 0.45 kg ai/ha, 50 ha/d)
** based on NOEL of 0.03 mg/kg/day; values without brackets based on passive dosimetry, values in square brackets based on biomonitoring results
*** assumes no respiratory protection

Table 40: Mixer/loader/applicator risk during boom application based on POEM estimates

Formulation Pack type	Estimate No. *Situation*	Application rate, spray volume	Mixer/loader		Applicator		Mixer/loader/ Applicator	
			Absorbed dose(1) (mg/kg bw/d)	MOE	Absorbed dose(2) (mg/kg bw/d)	MOE	Absorbed dose(2) (mg/kg bw/d)	MOE
50% WP 250 g water-soluble pack	Estimate 4 *Broadacre*	0.45 kg ai/ha, 1000 L/ha	Nil exposure expected		0.001	30	0.002	30
	Estimate 5 *Turf*	2 kg ai/ha, 400 L/ha	Nil exposure expected		0.007	4.3	0.007	4.3
50% EC 5 L standard container	Estimate 6 *Broadacre*	0.45 kg ai/ha, 1000 L/ha	0.045	<1	0.001	30	0.047	<1

	Estimate 7 *Turf*	2 kg ai/ha, 400 L/ha	0.080	<1	0.007	4.3	0.087	<1
50% EC 5 L wide neck	Estimate 8 *Broadacre*	0.45 kg ai/ha, 1000 L/ha	0.002	15	0.001	30	0.004	7.5
	Estimate 9 *Turf*	2 kg ai/ha, 400 L/ha	0.004	7.5	0.007	4.3	0.011	2.7

POEM model used is Vehicle Mounted (with cab) Hydraulic Nozzles (V-Nozzles) for all estimates; all estimates are for workers wearing one layer of clothing and gloves
(1) only dermal exposure considered during mixing/loading
(2) dermal and inhalation exposure considered during application (inhalation exposure contributed up to 40% of absorbed dose)

Margins of exposure estimated from exposure data collected during application of chlorpyrifos to broadacre crops by boom (Table 41) show the following results (biomonitoring results discussed only):

unacceptable risk (MOE 2.1 and 1.3; gloves, overalls plus respirator) for mixer/loaders open mixing wettable powders packed in 2.27 kg bags, with potential inhalation exposure contributing significantly to total absorbed dose (~60%);

marginally acceptable risk (MOE 8; gloves, overalls but no respirator) for mixer/loaders open mixing EC formulation packed in 9.5 L plastic jugs (neck size not known); and

acceptable risk (MOE 34, 13 and 5; overalls but no gloves or respirator, open cab) for applicators in standard boom but unacceptable for higher clearance boom.

The POEM estimates for workers wearing PPE in accordance with label instructions (gloves, overalls but no respirator) showed the following:

acceptable risk for mixer/loaders using WP in water-soluble packaging;

acceptable risk for mixer/loaders using EC in wide neck container using lower rate (MOE = 15), marginally acceptable for higher rate (MOE = 7.5);

unacceptable risk (MOE <1) for mixer/loaders using EC in standard container;

acceptable risk (MOE = 30) for applicators in closed cabs using lower application rate, but unacceptable (MOE = 4.3) for applicators using higher rate; and

for both application rates, potential inhalation exposure of applicators contributed significantly to total absorbed dose (~40%).

The POEM estimates show a greater risk for lawn and turf treatment than for broadacre crops, although smaller areas are treated. This is a reflection of the higher application rate and lower spray volume used for lawn treatment.

Discussion

Workers will treat crops five times and amenity turf up to two times per season, therefore the NOEL (based on 20-day repeat exposure) used in the risk assessment is expected to be an overestimate for boom applications. As a result, marginal MOE (values close to 10) will be accepted for workers treating crops or amenity turf by boom.

The POEM estimates for turf were estimated for a work rate of 20 ha/d. The total extent of most amenity turf, such as bowling greens and golf courses, is expected to be smaller, therefore this is considered to be the worst case scenario. In normal use situations the treatment of amenity turf by boom application is expected to result in acceptable risk provided exposure is kept to a minimum during mixing and loading and application is conducted in closed cabs.

The overall assessment indicates adequate protection will be afforded to workers involved in boom applications provided closed cabs are used and exposure is minimised during mixing and loading.

<u>Aerial application</u>

No relevant worker exposure data were provided for Australian agricultural workers applying chlorpyrifos by aerial equipment.

Worker exposure during aerial spraying may occur during mixing and/or loading operations, during equipment clean-up, or in the event of spills or spray tank leaks. Exposure during application will be limited to spray mist, which may enter the cockpit. This is expected to be unlikely as pilots generally fly against the direction of the spray mist and are in closed cabins.

Aerial spraying by farmers is unlikely. Trained aerial spray operators carry out most aerial spraying. These workers will apply either EC (normal dilution) or ULV (undiluted) formulations of chlorpyrifos. Due to the regular nature of their work, they may handle larger quantities of chlorpyrifos than other workers involved in ground based spraying.

Flagger exposure is not expected to be significant as most aircraft are fitted with Geographic Positioning Systems (GPS). Flaggers will only be used in situations when GPS cannot be used, such as spraying at night. Additionally, flaggers are required to adhere to best practice guidelines, eg those developed by the Aerial Agricultural Association of Australia (AAAA) in order to minimise exposure to spray drift.

For aerial applications chlorpyrifos is applied at a rate of 0.5 kg ai/ha covering an area of approximately 1200 ha. EC formulations are applied at a spray volume of $\geq$ 10 L (final spray concentration up to 5%), ULV formulations are applied undiluted (30 or 50%).

There is no mixer/loader exposure associated with ULV application as the product is transferred directly using closed transfer techniques (from 20 or 200 L drums) and no mixing is required.

Mixer/loader exposure to EC products will also be low. Closed transfer from large drums (200 L) is the preferred method of loading the product into the airplane spray tank. Mixing is conducted mechanically by adding water directly into the tank.

In some cases smaller packages may be opened and loaded manually. A POEM estimate (Estimate 10) was conducted for mixer/loaders transferring product from 10 L wide neck containers, which are known to result in lower hand contamination than standard designs. Mixer/loaders are actually expected to handle containers of 20 L or greater, however 10 L is the largest pack size covered by the model for wide neck containers. The neck size of the containers was not provided. The estimate is based on the widest neck (63 mm) and is therefore considered the best case scenario for manual mixer/loading.

Modelling showed an absorbed dose of 0.150 mg/kg/d (MOE <1) for this situation. Therefore, the risk associated with manual loading is unacceptable irrespective of container design.

Isolated incidents of accidental spills can result in significant exposure due to the large quantity of concentrate handled as well as the relatively high concentrations of chlorpyrifos in the final spray. Workers are therefore required to wear PPE (coveralls and gloves) during mixing/loading operations.

Discussion

Open mixing and loading methods will result in unacceptable risk for workers using either EC or ULV formulations.

The risk to mixer/loaders using closed systems, as currently used by many Australian operators, is acceptable.

Although aerial spray crew operate regularly and may be involved in applying chlorpyrifos repeatedly, these workers are adequately trained. Applicator exposure is not expected to pose unacceptable risk.

Flaggers will be adequately protected provided they follow best practice guidelines.

<u>Handspray</u>

Handspray will be used primarily for berry fruit and vegetables. These crops will be grown in the field or in greenhouses. Product formulations which will be used include wettable powders (25 or 50%) and emulsifiable concentrates (50%).

Measured exposure data were available for indoor treatment of ornamentals using WP or ME chlorpyrifos formulations. Use on ornamentals is indicated by the performance questionnaires, but is not included on any labels. The results from the ornamentals studies will therefore be used as a general indication of exposure during treatment of other horticultural crops housed in greenhouses. Study participants used a range of tank sizes for their applications ranging from ~3.8-757 L (although the details were not provided for all studies). The results from these studies are standardised for the Australian work rate for workers using vehicle mounted spray tanks (1 ha/d at 0.4 kg ai/ha, equivalent to 0.4 kg ai handled/d) as most or all of the study participants did not use knapsacks. The parameters chosen represent the worst case exposure scenario for handspray. The risk estimates based on greenhouse studies are summarised in Table 41.

Table 41: Mixer/loader/applicator risk during greenhouse applications of WP and ME formulations based on measured exposure

Source Crop *Formulation type*	Worker category (number of subjects); Equipment type; PPE	Total ai handled (kg) and replicate duration	Absorbed chlorpyrifos (mg/kg/d)* **		MOE***		
					Respir-ator + gloves	No respirator	
			Based on passive dosimetry	Based on urinary TCP		Gloves	No gloves
Stamper et al. (1988) Chrysanthe mums and African violets *WP*	Applicator (1 subject, 3 replicates; Single nozzle handgun, fogging device (misty spray); Coverall, hood, gloves, apron, boots, goggles and respirator	0.06 (0.119 kg ai/h for ~30 min)	0.00935 (gloves) 0.047 (no gloves)	-	-	3.2	<1
Stamper et al. (1989a) Chrysanthe mums and African violets *WP*	Applicator (3 subjects, total of 24 replicates); Handgun with 6-nozzle head; Coverall, hood, gloves, apron, boots, goggles and respirator	0.05 (0.091 kg ai/h for ~30 min)	0.01 (gloves) 0.0111 (no gloves)	-	-	3	2.7
Stamper et al. (1989b) Chrysanthe mums and African violets *WP*	Applicator (2 subjects, 1 replicate for one subject and 8 for other); Single nozzle handgun, drench spray (coarse spray); Apron (or coverall) and boots; gloves and respirator also worn for one replicate	0.2 (0.306 kg ai/h for ~40 min)	0.0014 (gloves) 0.0019 (no gloves)	-	-	22	15
Contardi et al. (1993) Bench/floor plants (various) *ME*	MLA (10 replicates, one subject per replicate); Wand or handgun; Cotton coveralls, rubber boots, nitrile gloves and goggles	0.195 ****	0.0027	0.0024	-	11 [12]	-

Overhead plants (various) *ME*	MLA (6 replicates, one subject per replicate); Wand or handgun; Cotton coveralls, rubber boots, nitrile gloves, goggles, neoprene rain jacket/pants, respirator, face shield	0.206 ****	0.018 (water-proof clothing)	0.0074 (water-proof clothing + respirator)	[4.0] (water-proof clothing)	1.6 (water-proof clothing)	-

All data are 75th percentile doses unless indicated otherwise, in order to compare with POEM results
MLA – mixer/loader/applicator
* total chlorpyrifos dose (mg/kg ai handled) x kg ai handled ÷ 60 kg person; based on one layer of clothing + gloves, unless otherwise specified
** standardised for 0.4 kg ai handled/d (work rate of 1 ha/d using 0.4 kg ai/ha)
*** based on NOEL of 0.03 mg/kg/day; values without brackets based on passive dosimetry, values in square brackets based on biomonitoring results
**** total ai sprayed for individual replicates averaged to give this value

No exposure data were available to assess the risk to mixer/loader/applicators using EC formulations in greenhouses and POEM has no suitable model for indoor applications. In order to gauge exposure during mixing and loading (which may not necessarily be conducted in the greenhouse) POEM hand contamination factors are used (Table 42).

Table 42: Mixer/loader risk during greenhouse applications of EC formulation based on POEM hand contamination factors

Packaging type	Number of operations*	POEM contamination estimate** (mL/operation)	Absorbed dose*** (mg/kg/d)	MOE
5 L standard container	7	0.2	0.035	<1
5 L wide neck	7	0.01	0.00175	17

* number of spray tank fills assuming vehicle mounted spray tanks are 250 L and workers handle 0.4 kg ai/d or 1600 L of spray
** for liquid products
*** number of operations per day x contamination estimate (mL) x 500 mg/mL(concentration of ai in product) ÷ 60 kg body weight, x 0.1 (transfer through gloves) x 0.03 (skin absorption)

POEM was suitable for the estimation of exposure to workers during applications to crops in the field using knapsacks. No measured data were available for this scenario. The work rate for workers using knapsacks is expected to be 0.25 ha/d, equivalent to 0.1 kg ai handled/d. Margins of exposure based on POEM estimates of exposure are summarised in Table 43.

Table 43: Mixer/loader/applicator risk based on POEM estimates of exposure during knapsack applications to fields

Formu-lation	Estimate No. (Pack type)	Application rate, spray volume, application time	Mixer/loader		Applicator		Mixer/loader/ Applicator	
			Absorbed dose(1) (mg/kg bw/d)	MOE	Absorbed dose(2) (mg/kg bw/d)	MOE	Absorbed dose(2) (mg/kg bw/d)	MOE

50% WP	Estimate 11 (250 g water-soluble pack)	0.4 kg ai/ha, 1600 L/ha (POEM maximum of 400 L spray per day by backpack) 3 h (application time expected to be short by this method)	Nil exposure expected		0.003	10	0.003	10
50% EC	Estimate 12 (5 L, wide neck)		0.007	4	0.003	10	0.010	3
	Estimate 13 (5 L, standard container)		0.135	<1	0.003	10	0.138	<1

POEM model used is Hand Held Outdoors Hydraulic Nozzles (H-Nozzles); estimate is for workers wearing one layer of clothing and gloves
(1) only dermal exposure considered during mixing/loading
(2) dermal and inhalation exposure considered during application (inhalation exposure contributed 8% of absorbed dose)

Indoor handspray

Study data (Stamper et al. studies in Table 41) showed unacceptable to acceptable risk (MOE 3.2-22) for gloved workers (without respirators) applying spray by handgun to greenhouse ornamentals. These estimates are not considered to account for workers mixing and loading. No exposure is anticipated during the mixing and loading of WP formulations in water-soluble packaging. Therefore the results from these studies can be used as a measure of Australian mixer/loader/applicator exposure during handgun application of WP products in greenhouses. The limitations of the Stamper et al. studies, namely short exposure monitoring times, low replicate numbers and repeated monitoring of subjects, are noted.

Based on the Stamper et al. study results, the risk to Australian greenhouse workers applying WP formulations packed in water-soluble packs is likely to be acceptable provided full PPE is worn. No respirator is recommended on the product labels, however the contribution of inhaled exposure to total absorbed dose is small.

Based on POEM contamination factors (Table 42), exposure of workers mixing/loading EC formulations into vehicle mounted spray tanks is expected to be unacceptable (MOE <1) with standard packaging using open mixing techniques. Open mixing of EC formulations in wide neck containers is expected to be acceptable (MOE = 17). Applicator risk is independent of formulation type. Given that the application rate is identical for both WP and EC formulations, the risk to applicators is considered acceptable provided all PPE are worn.

Study workers applying ME formulation to greenhouse plants (Contardi et al. study in Table 41) showed acceptable risk (MOE = 12, based on biomonitoring) for workers treating floor or bench plants but unacceptable risk (MOE = 1.6, based on passive dosimetry) for workers treating overhead plants, even when additional waterproof clothing was worn. Risk to workers treating overhead plants was reduced when a respirator was worn but was still unacceptable (MOE of 4, based on biomonitoring).

ME formulations are not available for crop protection in Australia, therefore the results from Contardi et al. (1993) are not directly relevant for Australian situations. Extrapolation of exposure estimates obtained for studies using ME formulations to WP and EC formulations are made with caution.

Noting that:

(i) mixer/loader exposure to WP formulations packed in water-soluble packs is expected to be comparable or less than exposure during open mixing with ME,

(ii) potential dermal exposure to EC products may be comparable to ME (given that both are liquids) however the amount of ai available for penetration through clothing and absorption is expected to be greater for EC than ME,

(iii) the potential exposure of applicators may be similar for EC and ME formulations, but again the amount available for penetration and absorption is expected to be greater for EC than ME, and

(iv) the amount of ai available in each case is not quantifiable for ME formulations as it is dependant on a several factors (including encapsulation material),

it is reasonable to assume that estimates of risk obtained for passive dosimetry and biological monitoring for ME formulations will underestimate the risk for EC formulations. The degree of protection afforded by water-soluble packs for WP formulations will offset to some extent the risk to mixer/loader/applicators. However this benefit cannot be quantified for this study given that combined mixer/loader/applicator exposures were measured.

Based on the Contardi et al. study results, the risk to Australian greenhouse workers using WP formulation for handspray of floor or bench plants, is considered acceptable. Handspray of overhead plants may result in unacceptable risk. As handspray of greenhouse ornamental plants is an off label use for chlorpyrifos, the concern for workers treating overhead plants may not be relevant for Australian workers.

Outdoor handspray

POEM estimates (Table 43) show the risks to workers during knapsack application to outdoor crops. The results show acceptable MOE (10) for mixer/loader/applicators with WP formulations in water-soluble packaging. EC formulations in wide neck containers were safer than standard containers, however both resulted in unacceptable risk (MOE 3 and <1).

Mixing/loading for knapsack applications is expected to result in greater worker exposure than mixing/loading for use with vehicle mounted spray tanks, due to the number of times that the tanks will need to be refilled. The number of operations required for knapsack spraying using a total of 400 L spray is 27 (Estimates 12 and 13). For vehicle mounted handspray, a total of 1600 L will be applied using 7 filling operations (assuming the spray tank is of 250 L capacity). Based on the relative number of mixing/loading operations using vehicle mounted equipment compared to knapsack, the risk to mixer/loaders is expected to be acceptable (MOE = 17) for wide neck containers and unacceptable (MOE <1) for standard containers. The risk to mixer/loaders using WP in water-soluble packs will again be negligible.

Applicator exposure using vehicle mounted equipment is expected to be similar to knapsack use. Although the volume applied will be greater (4 times), the spray concentration is the same and the overall spray time is not expected to differ significantly due to the equipment being able to deliver greater amounts of spray.

Discussion

Considering the range of crops treated by handspray, applications are expected to range from a small number of applications per season to frequent applications (such as every 3 weeks). In all cases exposure will be intermittent, therefore the NOEL used in this risk assessment (based on a 20-d repeat dose exposure) is expected to overestimate the risk to workers.

Given the intermittent use of the products, the overall risk assessment concludes that:

> WP formulations can be used safely for indoor or outdoor handspray of low level plants provided water-soluble packaging is used;
>
> EC formulations can be used safely for indoor or outdoor handspray of low level plants provided exposure is minimised during mixing/loading;
>
> EC formulations in standard containers are not safe to use for any type of handspray application; and
>
> high level applications will result in unacceptable risk irrespective of formulation.

<u>Basal application</u>

Basal application is specified on labels for EC and WP formulations. Workers may be exposed to either EC or WP formulations during mixing/loading and application. The level of exposure will depend on the formulation used and the method of basal application.

No relevant worker exposure data were submitted. The risk assessment is based on modelling data wherever appropriate.

Spray application

WP or EC chlorpyrifos product will be mixed with water or yeast hydrolysate and applied by coarse spray or drench, as a strip (band) or patch, low on tree and/or surrounding soil. Based on survey information, workers using this method are not expected use large amounts of chlorpyrifos as the total treatment area will be small. For example, a worker treating 100 m^2

of soil will handle a maximum of 0.1 kg ai (maximum application rate 10 kg ai/ha), equivalent to 200 g WP or 200 mL EC (for 50% products). The final ai concentration in spray will not exceed 1%.

Workers mixing/loading WP formulations will drop water-soluble packs directly into the spray tank and should therefore not be exposed to significant amounts of chlorpyrifos by either the dermal or inhalation routes.

The dermal exposure of workers mixing/loading EC formulations can be estimated using POEM (Table 44).

Table 44: Mixer/loader/applicator risk based on POEM estimates of exposure during basal spray application

Formu-lation	Estimate No. (Pack type) Application rate, spray volume Work rate (total spray applied)	Mixer/loader		Applicator		Mixer/loader/ Applicator	
		Absorbed dose[1] (mg/kg bw/d)	MOE	Absorbed dose[2] (mg/kg bw/d)	MOE	Absorbed dose[2] (mg/kg bw/d)	MOE
50% EC	Estimate 14 (5 L, standard container) 10 kg ai/ha, 1000 L/ha 0.01 ha/d (total spray 10 L)	0.005	6	0.009	3	0.014	2

POEM model used is Hand Held Outdoors Hydraulic Nozzles (H-Nozzles); estimate is for workers wearing one layer of clothing and gloves
(1) only dermal exposure considered during mixing/loading
(2) dermal and inhalation exposure considered during application (inhalation exposure contributed ~10% of absorbed dose)

Modelling data show mixer/loader risk to be marginal (MOE = 6) when standard 5 L containers are used and product is applied according to the above parameters.

Applicator exposure cannot be accurately quantified. Survey information suggests that handguns attached to vehicle mounted spray tanks (100 L) will be used. It is anticipated that knapsacks may also be used. POEM exposure estimates for applicators using knapsacks are used as a rough guide (Table 44). The modelling data suggest that applicator exposure may be significant at the maximum application rate, even though only small volumes of spray are applied (10 L). However exposure estimates obtained using POEM are expected to overestimate applicator exposure, as the spray will be applied at a lower level than usual foliar applications, resulting in less dermal contamination.

Trunk injection

Survey information suggests that some applications will be made to the interior of the tree trunks by first drilling and then pouring or injecting a mixture of product and water into the holes. Worker exposure and risk during trunk injection could not be quantified. The risk to workers using this method are expected to be no greater than by spray, provided equal amounts of product are used by both methods.

Incorporation with sand

This method is used only on bananas. WP formulations will be mixed with sand before application to the ground around the tree. The product label (50% WP) specifies the application of 500 g of a formulation in 4 kg sand, before application to each tree base (30 g per tree). Workers may inhale dust during both mixing operations as well as during the manual spreading of the product and sand mixture.

Mixer/loaders will open 250 g water-soluble packs and measure out required quantity of product, add it to the sand and mix it together. Based on POEM hand contamination estimates for solid formulations, workers mixing two packs of product with 4 kg of sand mixture (enough to treat 133 trees) will be contaminated dermally with 0.2 g of product during mixing operations (based on POEM contamination estimate 0.1 g for large packs). This level of contamination is equivalent to an absorbed dermal dose of 0.0005 mg/kg/d (0.1 g ai adjusted for 3% dermal absorption, 60 kg body weight and 1% penetration through gloves). The MOE for this task is 60.

This result alone indicates that the risk workers applying chlorpyrifos by this method will be acceptable. However, it should be noted that the above estimate does not account for differences in mixing techniques required for preparation of a dry mixture compared to a liquid (POEM contamination is based on spray preparation). For example workers pouring dry product into water are expected to be exposed to much less dust than workers adding the same dry product to sand and dry mixing the ingredients. Additionally the POEM contamination estimate does not account for inhalation exposure during the mixing/loading operation and only accounts for hand contamination by the dermal route.

Applicators will manually distribute the sand mixture around the base of each tree. There are no suitable models available to estimate applicator exposure. The risk to workers applying WP product with sand cannot be quantified.

Discussion

Application to bananas is expected to occur once per season (post-harvest), while application to other crops may be frequent (as often as every 7 days). In most cases however the amount of product handled will be small.

As an alternative to using sand on banana trees, the WP product label states that the product may be applied as a spray. Survey information suggests that EC formulation will be used instead of WP and applications will be by spray.

The risk to mixer/loaders preparing spray using WP formulations in water-soluble packs will be acceptable, as the packaging type will minimise exposure.

Workers opening water-soluble packs may be exposed to significant amounts of powder by both the dermal and inhalation routes. No data are available to estimate potential inhalation exposure during mixing and loading operations. Estimations of dermal exposure based on POEM hand contamination values are believed to be underestimated when the product is mixed with dry ingredients.

The risk to mixer/loaders preparing spray using EC formulations will depend on packaging design. Products packaged in standard containers may result in acceptable risk when small areas are treated, final ai concentrations are low or applications are infrequent. For scenarios with greater exposure potentials, EC products packaged in standard containers may result in unacceptable risk to mixer/loaders.

The risk to applicators applying spray could not be quantified. Using POEM exposure estimates as a guide, application using hand equipment may be acceptable when small areas are treated, final ai concentrations are low or applications are infrequent.

The risk to workers applying WP formulation as a dry mixture cannot be quantified. Application using this method will be infrequent (once per season in bananas), however exposure may be significant by both dermal and inhalation routes. Where workers have an option to apply WP product as either a dry mixture or spray, the spray method should be used to minimise exposure.

Seed treatment

No relevant worker exposure data were submitted and there are no modelling methods appropriate for estimation of total exposure by this method.

Seed treatment will be conducted at sowing only. Cereal seed will be treated at a rate of 40-200 g ai/100 kg seed and sowed at a minimum rate of 95 kg seed/ha. Assuming an average area of 30 ha will be sown, workers will handle 1.1 to 5.7 kg ai (4.4-22.8 kg WP formulation or 2.2-11.4 L EC formulation). Other seeds will be treated at a higher rate but the sowing rate is not provided.

As seed treatment and sowing is likely to occur as one operation, this activity is more likely to be conducted by individual farmers. The frequency of use should therefore be low.

Solid formulations

Solid formulations are marketed specifically for use as seed treatments.

Workers will use 25% wettable powder available as a primary pack of 1 kg containing 2 x 500 g measure packs. Powder product will be sprinkled over seed in a seed box on the planter and manually stirred. No premixing will occur. Survey information suggests that most end users will mix the seed dressing in this way, however some will use seed dressing equipment.

Exposure during mixing will occur when packages are opened and product added to the seed box as well as during the manual mixing of the product and the seed.

Based on POEM contamination estimates for solid formulations (0.01 g/operation contamination for small packs and 0.1 g for large packs), workers handling the maximum amount of product for cereal treatment (11.4 kg, requiring 23 x 500 g packs) will be contaminated with 2.3 g of product (or 1.15 g ai). This level is equivalent to an absorbed dermal dose of 0.00575 mg/kg/d (1.15 kg ai adjusted for 1% transfer through gloves (based on POEM default for solid formulations), 3% dermal absorption and 60 kg body weight). This estimated dose will result in unacceptable risk (MOE = 5). The POEM contamination estimates account for the tasks of opening and pouring only and consider only hand contamination. Dermal exposure to other parts of the body may be significant during these tasks, while inhalation exposure can also be significant. Exposure during manual mixing with seed will result in further dermal and inhalation exposure. The overall risk to mixer/loaders may be unacceptable.

The seed box feeds directly into the planter, therefore there is no exposure associated with transfer.

Exposure to workers during application should not be a concern, as this task is automated and the seeds are covered by soil immediately after sowing/planting.

Liquid formulations

Workers will use 50% emulsifiable concentrate available in a range of pack sizes. Liquid product will be mixed with seed using seed dressing equipment. After treatment, the seed will be sown using calibrated application equipment.

Exposure during mixing will occur when containers are opened and product poured into the seed treatment machinery. Seed treatment machinery has an inlet port for the seed, an inlet port for the chemical product, and an outlet port for collecting the treated seed. Once the product has entered the machinery there is little potential for worker exposure.

For liquid formulations, as a worst case, workers may handle 11.4 L of product during cereal treatment. Based on POEM contamination estimates for liquid formulations (POEM instructions stipulate 0.2 mL contamination for standard 5 L containers and 0.01 mL for wide neck 5 L containers), workers mixing 3 x 5 L containers will be contaminated with 0.6 mL or 0.03 mL of product when using packaging of non-specific or wide neck design, respectively. These values assume similar contamination will occur for workers pouring from product containers to seed dressing equipment, as occurs when mixing and loading spray solutions (POEM situation).

Absorbed dermal doses (based on the above exposure estimates, 10% transfer through gloves, 3% dermal absorption and 60 kg body weight) are 0.015 and 0.00075 mg/kg/d for standard and wide neck containers, respectively. Workers mixing product from standard containers will be exposed to unacceptable levels of chlorpyrifos (MOE = 2), whereas the risk to mixer/loaders using wide neck containers will be acceptable (MOE = 40).

Minimal exposure is expected during the transfer of treated seed to application equipment, and during the planting itself, as the product is not volatile and once incorporated with the seed will have limited opportunity to come in contact with the worker.

Discussion

Worker risk during seed treatment will be limited to mixing and loading operations only. The risk assessment showed the risk during mixing and loading to be:

> unacceptable during open mixing of WP formulations or EC formulations in standard containers; and
>
> acceptable during open mixing of EC formulations in wide neck containers.
>
> Although seed treatments will be infrequent (only once at sowing), and the MOE (based on 20-day repeat exposure data) may be considered conservative, this is off-set to some extent by the incomplete nature of the exposure estimates (estimates do not include exposure on all body parts and by all routes).

<u>Soil baits</u>

Crop protection using soil baits is not expected to be a major use of chlorpyrifos.

Workers will mix liquid formulations of chlorpyrifos (50% EC) with bran, wheat or sorghum and apply the bait by aerial application, fertiliser spreader or by hand. Solid formulations are not registered for this end use.

Exposure may occur when workers add the product to grain, during mixing operations, when the mix is loaded (into the airplane or fertiliser spreader) or during application (ground application only).

Information on mixing techniques was not available. Liquid formulation will be added to dry grain. Depending on the amount required, workers are expected to either mix the ingredients manually, or use mechanical methods, such as an auger.

Workers mixing product for use by fertiliser spreader or by hand are expected to handle small amounts of product. Areas treated aerially will be larger and will therefore result in greater mixer/loader exposure. Based on an application rate of 100 g ai/ha, and maximum work rates by other methods (30-50 ha/d for ground applications and 1200 ha/d for aerial), workers may handle up to 10 L of product for application by fertiliser spreader or 240 L of product for aerial applications.

The risk to mixer/loaders preparing bait for ground applications is expected to be less than during mixing/loading of EC for seed treatment. Fertiliser spreaders are generally loaded manually. Exposure during all loading operations should be low given the final proportions of chlorpyrifos in the bait mix. Given the large quantities handled by workers mixing and loading for aerial applications, the risk to these workers may be substantial. However, most aerial mixer/loaders are expected to use closed loading systems.

Applications will be once or twice a season, the first being usually at planting. During the first application, fertiliser spreaders may be located behind planters. Workers are not required to handle bait during application therefore the risk during bait application is acceptable.

The risk to pilots applying bait is expected to be low, as there is limited opportunity for bait to come in contact with these workers.

In some cases bait application will be by hand. This method will be used to treat small areas only. As most of the product will be incorporated in the mix, these workers should be adequately protected under normal use situations.

It is not known whether flaggers are used in aerial bait applications.

Discussion

Use in soil baits is not expected to be a major use of chlorpyrifos.

Fertiliser spreaders will be used for small areas and aerial application for large areas. An industry survey suggests that hand spreading may also be conducted.

The exposure and risk to workers during soil bait preparation and application cannot be adequately quantified.

For ground applications the risk during mixing is expected to be comparable with open-pour mixing for other application methods, except that smaller volumes of product will be handled. The risk during loading should be acceptable as the final concentration of ai in the bait is low and the mixture loaded is a solid, such that exposure during splashing etc will not occur. Exposure to dust should also be low given the formulation is a liquid and the final end use form of the product is a bait. There is no significant exposure anticipated during application, as the method is mechanical.

For aerial applications, manual mixing operations are not likely to be used given the large amounts of product handled. With the use of closed loading systems, the risk to loaders should be acceptable. No exposure is anticipated for aerial applicators.

The risk to workers treating smaller areas by hand is expected to be acceptable based on the low volume of product handled and the proportion of chlorpyrifos present in the final mixture.

Bandspray at sowing

No relevant worker studies were available for this end use.

Bandspray at sowing will be conducted using EC and ULV formulations. EC formulations (containing 50% ai) will be packaged in a variety of containers ranging from 1 L to 20 L. The one ULV formulation (containing 30% ai) will be available in bulk containers.

The risk to workers mixing and loading EC formulations was estimated using POEM (Table 45).

Table 45: Mixer/loader risk during bandspray application based on POEM estimates

Formulation	Estimate No. (Pack type)	Application rate, work rate	Mixer/loader	
			Absorbed dose[1] (mg/kg bw/d)	MOE
50% EC	Estimate 15 (5 L, standard container)	0.75 kg ai/ha, 30 ha/d	0.045	<1
	Estimate 16 (5 L, wide neck)		0.002	15

POEM model used is Vehicle Mounted (with Cab) Hydraulic Nozzles (V-Nozzles), mixing/loading section only; estimate is for workers wearing one layer of clothing and gloves
(1) only dermal exposure considered during mixing/loading

Based on POEM, mixing and loading EC formulation in standard containers will result in unacceptable risk (MOE < 1), while wide neck containers will afford workers adequate protection (MOE of 15).

The risk to workers mixing and loading ULV formulation cannot be quantified, however as closed transfer systems will be employed, the risk is expected to be minimal.

The risk during application cannot be estimated quantitatively, for either EC or ULV product application. Bandspray will be conducted low to the ground and covered immediately by soil. The products are non-volatile and there is little opportunity for exposure to spray drift. The overall risk to applicators should be acceptable.

Discussion

The risk to workers mixing/loading and applying chlorpyrifos products by bandspray will be mainly dependant on the product packaging. The majority of exposure will occur during mixing and loading.

Product packaging which affords acceptable levels of worker protection are wide neck containers or bulk containers.

Gravity feed at sowing

There are no relevant worker studies available for this application method.

This method of application will be solely used on sugarcane. Either granular product (containing 14% ai) or EC product (containing 50% ai) will be loaded into a drum on the tractor planter and gravity fed onto the plant sett during sowing. Once applied the product will be immediately covered by soil.

The majority of the exposure associated with this end use will occur during the transfer of product directly from the original packaging to the application equipment.

Solid formulation

Workers handling solid formulation will be potentially exposed by the dermal and inhalation routes. Dusting should be minimal due to the granular form of the product, therefore inhalation exposure should not be significant. As chlorpyrifos is formulated as a slow release granule, dermal exposure should also be low as most of the active ingredient will be bound to the other product ingredients.

Modelling is not appropriate for this formulation type, however POEM hand contamination estimates are used as a rough guide. Chlorpyrifos formulated as a slow release granule is available in large (20 kg on label) multi-walled paper valve sacks. Information supplied on performance questionnaires states that the work rate for granule application will be either 4 or 10 ha/d depending on whether a Trash or Billet planter is used, respectively. At a minimum application rate of 21 kg product/ha, respective amounts of product handled are 84 kg/d for Trash planting and 210 kg/d for Billet planting.

Based on a hand contamination estimate of 0.1 g product per operation (POEM estimate for solid formulations in 1 kg containers), operators using 20 kg packs with a Billet planter, will require 11 operations, resulting in exposure to 1.1 g of product (0.154 g of ai). This is equivalent to a dermal dose of 0.00077 mg/kg/d and MOE of 39 (based on 1% transfer through gloves, 3% absorption through skin and 60 kg body weight). This estimate assumes that all ai present in the granules will be available for transfer through gloves, therefore this value is expected to be an overestimate.

Applicator exposure is not expected to be significant due to the mechanised application method.

Liquid formulation

Workers applying EC formulation will cover about 12 ha/d (2 ha/h provided on the performance questionnaires) using a minimum of 1.5 L product/ha, equivalent to 9 kg ai handled/d.

Workers handling liquid formulation may be dermally exposed during the transfer from the product containers. Workers using 5 L containers will require four or five operations to treat 12 ha at label rates. Previous POEM estimates (Estimates 2 and 3) have shown that mixer/loaders requiring similar number of operations (6) from similar container types, will be inadequately protected when using standard containers but adequately protected with wide neck containers.

Applicator exposure is not expected to be significant due to the mechanised application method.

Discussion

The overall assessment suggests that application of chlorpyrifos by gravity feed will be safe for workers applying granular product or EC formulation in wide neck containers.

The use of standard containers may result in unsafe levels of exposure.

Bell injection and irrigation

These methods are not label uses and are therefore not considered in this review.

5.3.2 Pest control

Pre-construction termite control

The risk assessment of workers involved in pre-construction termite control is based on the results of the worker exposure study of Murphy et al. (1997).

The risk assessment is summarised in Table 46.

Table 46: Margins of exposure (MOE) for mixer/loader/applicators and tarp pullers during pre-construction treatment of building sites with 1% chlorpyrifos

Worker category			Total chlorpyrifos dose (mg/kg/d)(1)				MOE			
			Long sleeve scenario		*Short sleeve scenario*		*Long sleeve scenario*		*Short sleeve scenario*	
			AM	75th P	AM	75th P	AM	75th P	AM	75th P
MLA	No respirator	Tyvek(3)	0.00141	0.00239	0.00169	0.00278	21	13	18	11
		Cotton	0.00151	0.00174	0.00170	0.00189	20	17	18	16
	Respirator(2)	Tyvek(3)	0.00098	0.00186	0.00126	0.00200	31	16	24	15

		Cotton	0.00081	0.00088	0.00100	0.00101	37	34	30	30
Tarp puller	Rubber boots and gloves		0.000069	0.000064	0.000077	0.000074	430	470	390	405
	Leather boots, no gloves		0.00018	0.00020	0.00022	0.00022	170	150	130	140

AM – arithmetic mean
75th P – 75th percentile values
MLA – mixer/loader/applicator
(1) total chlorpyrifos dose µg/replicate (equivalent to µg/d) ÷ 60 kg ÷ 1000 µg/mg (all replicates included)
(2) no subjects wore respirator; calculation based on default of 10% transmittance through respirator
(3) excluding replicate 7

Australian PCOs are expected to wear a respirator and chemically resistant coveralls. Underneath the coveralls, either long sleeve or short sleeve shirts may be worn depending on the climatic conditions. For all workers (mixer/loader/applicators and tarp pullers) the margins of exposure did not differ noticeably between estimates based on long or short sleeves.

Mixer/loader/applicator risk

At an application rate of 1% the MOE for mixer/loader/applicators are acceptable for all clothing scenarios using either arithmetic means or 75th percentile values. In regions north of the Tropic of Capricorn, where the application rate is 2%, the MOE are expected to be lower. However, based on the margins obtained for workers wearing respiratory protection, workers in these locations should be adequately protected provided they comply with the label safety directions. Use of closed mixing systems is expected to further reduce exposure, however as the exposure estimates were not separated for the mixing/loading and application tasks, the relative contributions of these tasks on the overall exposure cannot be measured.

Tarp puller risk

The MOE for tarp pullers are acceptable for all scenarios under the conditions of this study. According to the safety directions, tarp pullers are also required to wear chemically resistant coveralls gloves and respirator. The wearing of such equipment is expected to further reduce exposure.

Combined risk

In some cases PCOs will carry out both application and membrane laying activities with potential for exposure during both these activities. In the worst case, workers may absorb 0.003 mg/kg/d (greatest applicator dose 0.00278 mg/kg/d plus greatest tarp puller dose 0.00022 mg/kg/d) with a corresponding MOE of 10. Given that this is the worst possible scenario and PCOs are expected to keep some of their PPE on for the tarp pulling activity, the margins of exposure are expected to be greater under such conditions.

Dow risk assessment

Dow provided two risk assessments based on the above study. The first was an assessment of the applicator part of the exposure study (Ellisor, 1997) while the other concerned the tarp pullers (Ellisor, 1998). Both risk assessments are claimed by Dow to be conducted by an independent private consultant (Mid-American Occupational Health).

NOHSC have reviewed these assessments and are satisfied with the methodology and accuracy of the results. The final MOE values that are provided in these reports are different to those provided in NOHSCs risk assessment due to differences in some risk assessment parameters/assumptions. However, the overall conclusions are not affected. Table 47 details the different parameters/assumptions used in the Dow and NOHSC risk assessments as well as the main outcomes.

Table 47: Comparison of Dow and NOHSC risk assessment parameters/assumptions and outcomes

Parameters/assumptions used		***Dow***	***NOHSC***
Dermal absorption		1% and 3%	3%*
Inhalation absorption		100%	100%
Respiratory rate		1.5 m^3/h	1.74 m^3/h*
Worker body weight		96 kg (applicator)** 82 kg (tarp puller)**	60 kg (NOHSC default)
NOEL (human)		0.1 and 0.03 mg/kg/d	0.03 mg/kg/d *
Respirator worn by applicators		✗	✗ and ✓
Clothing worn by applicators***		L sl/L pt under tyvek coverall S sl/L pt under tyvek coverall S sl/S pt under tyvek coverall L sl/L pt under cotton coverall S sl/L pt under cotton coverall S sl/S pt under cotton coverall no coverall	L sl/L pt under tyvek coverall S sl/L pt under tyvek coverall L sl/L pt under cotton coverall S sl/L pt under cotton coverall
Clothing worn by tarp pullers***		L sl/L pt, gloves S sl/L pt, gloves S sl/S pt, gloves L sl/L pt, no gloves S sl/L pt, no gloves S sl/S pt, no gloves	L sl/L pt, gloves S sl/L pt, gloves L sl/L pt, no gloves S sl/L pt, no gloves
Applicator replicate = typical day		✓	✓
Tarp puller replicate = typical day		✓	✓
Tarp puller replicate x 3 = typical day		✓	✗
Acceptable MOE		10	10
Results****			
Exposure values given as		arithmetic means	arithmetic means and 75th percentiles
MOE – Applicator, L sl/L pt***, no respirator, 3% dermal absorption, NOEL 0.03 mg/kg/d, based on arithmetic means	tyvek coverall	37	21
	cotton coverall	34	20
MOE – Tarp puller, 3% dermal absorption, NOEL 0.03 mg/kg/d, L sl/L pt***, based on arithmetic means	gloves, chemically resistant footwear	667	430
	no gloves, leather boots	200	170

* as determined in Section 2.1.2
** mean of 17 (applicator) or 16 (tarp puller) replicates
*** L = long, S = short, Sl = sleeves, Pt = pants
**** differences in Dow and NOHSC MOE can be accounted for by the different respiratory rate and body weight values provided in the first part of this table

Risk assessment based on POEM

The study measured combined mixer/loader/applicator exposure, therefore the relative contribution of each activity to total exposure cannot be gauged from the study. The mixing techniques used in the study were described as open (manual pouring of product into mix tank), however a description of the containers used was not given. In order to gauge exposure and risk during mixing and loading, POEM estimates were used. It is acknowledged that these estimates are conservative and the results are used only as a rough guide.

Australian products will be packaged in 5, 20 or 200 L drums. Study participants handled an average of ~22 kg ai/d or ~49 L of 45% EC. POEM estimates were conducted for workers open mixing this amount of product using 5 or 20 L containers. The estimated exposure and risk based on POEM exposure estimates are summarised in Table 48.

Table 48: Margins of exposure (MOE) for mixer/loaders during pre-construction treatment of building sites with 1% chlorpyrifos

Packaging type	Number of operations	POEM contamination estimate* (mL/operation)	Absorbed dose** (mg/kg/d)	MOE
5 L standard container	10	0.2	0.045	<1
5 L wide neck	10	0.01	0.00225	13
20 L standard container	3	0.5	0.034	<1
20 L wide neck	3	0.05 (value for 10 L container with 63 mm neck) ***	0.0034	9

* for liquid products
** number of operations per day x contamination estimate (mL) x 450 mg/mL(concentration of ai in product) ÷ 60 kg body weight, x 0.1 (transfer through gloves) x 0.03 (skin absorption)
*** no value available for 20 L wide neck; NOHSC assumes the contamination to be the same for 10 or 20 L containers

The above table shows unacceptable risk for mixer/loaders using standard 5 or 20 L containers (MOE <1) and acceptable risk for wide neck containers (MOE = 13 for 5 L container and MOE = 9 for 20 L container). The 200 L bulk containers will be used in conjunction with closed systems.

Workers applying 2% spray will handle twice as much product and will have smaller margins of exposure.

Discussion

This risk assessment is based on a short term NOEL (20 day repeat human exposure) however some PCOs may work regularly over the whole year. PCOs are usually trained and accredited and have access to better facilities (such as PPE, washing up equipment and emergency facilities), therefore margins of exposure of 10 or greater are considered acceptable in the risk assessment.

A risk assessment based on worker exposure data shows the risk to Australian workers involved in open mixing and applying 1 or 2% chlorpyrifos as a pre-construction termiticide, will be acceptable provided work practices are similar. It is noted that the study description did not include pack sizes/design.

POEM data highlight that additional protection is afforded by wide neck containers during mixing/loading. It is also established that closed mixing and transfer systems minimise mixer/loader exposure.

Overall, PCOs will be safe to use 1 or 2% chlorpyrifos as a pre-construction termiticide using closed mixing systems, provided appropriate PPE is worn. Open mixing may also be safe, but will depend on packaging design, compliance with label directions and safe work practices.

The risk to workers applying the moisture membrane to sites treated with either 1 or 2 % chlorpyrifos is acceptable.

There are no additional concerns for workers who will conduct both treatment and tarp pulling activities.

<u>Post-construction termite control</u>

Chlorpyrifos products for use post-construction on residential and commercial properties are packaged in a variety of containers, including 1, 2, 5 and 20 L containers. Products available include 45% and 50% EC formulations. WP formulations are not available for this end use situation.

Risk based on exposure data

Margins of exposure were estimated from exposure data obtained during post-construction application of chlorpyrifos. These are summarised in Table 49.

It is noted that the results in these studies are of limited use due to a number of deficiencies. The packaging types and mixing techniques are not known. Additionally it is not known whether workers were monitored for both mixing/loading and application.

Table 49: Margins of exposure (MOE) for pest control operators during post-construction application of chlorpyrifos for termite control

Source; application rate	Daily dose (mg/kg/d)*	MOE
Application method; number of tests		

	Respiratory	Dermal	Total	Respiratory	Dermal	Total
Axe (1979); 1% final ai concentration Rodding, trenching, drip nozzle and spray; 4 tests (1 house per applicator);	maximum 0.00775 (1)	not measured	-	≥ 3.9	-	-
Vaccaro and Bohl (1979); 1% final ai concentration Liquid under pressure shot into drill holes and trenches; 4 tests – 4 applicators treated 3 crawl space and 2 basement type dwellings (number of workers treating each house not provided)	maximum 0.00139 (2)	not measured	-	≥ 22	-	-
Vaccaro (1981); 1% final spray Band spray around the inside perimeter of the crawl space; 1 subject treating 1 house and the other treating 3 houses	0.00252-0.015 (3)	not measured	-	2-12	-	-
Ishikura H (1988); 1% final ai concentration, EC formulation Slab drilling and spraying; 3 houses treated by 2 operators	0.113 (4) 0.00665 (5)	0.000126 (6) minus hands and neck	0.0114 0.00678	< 1 4.5	238 minus hands and neck	<1 < 4.4
Ishikura (1989); 1% final ai concentration, ME formulation Power sprayer; 2 operators treated one crawlspace type dwelling	not measured	0.00231 (7) minus hands and neck	-	-	< 13 minus hands and neck	-
Asakawa et al. (1989); 1% oil and 1% emulsion Application method not known; 2 Japanese houses treated by 2 applicators for a total of 3 applications	0.00302 (8) (9)	0.01898 (8) (10) minus hands and neck	0.022	9.9	<1.6 minus hands and neck	<1.4
Fenske and Elkner (1990); 0.71% final ai concentration Sub-slab and soil injection; 8 replicates (2/site), 4 sites (3 with crawl space)	0.00231 (11)	0.0756 (12)	0.00779	13	< 1	< 1
Leidy et al. (1991); 1% emulsion (4.4-9.2 kg ai per house) Rodding and trenching; 16 houses of different construction types	0.00467 (13)	not measured	-	6.4	-	-

* standardised for Australian work rate: either 3 sites/d, 6 h application/d or 21 kg ai handled/d, which ever is most applicable; body weight of worker assumed to be 60 kg; respiratory dose estimated for workers wearing respiratory protection, ie. 0.1 x potential respiratory exposure; dermal dose based on dermal penetration of 3%, ie. 0.03 x actual dermal exposure
(1) maximum 1.55 mg/test for one site standardised to 3 sites/d
(2) maximum 0.25 mg/applicator for 1.8 h standardised to 6 h/d
(3) 72-412 µg/kg ai standardised to 21 kg ai/d
(4) 3230 µg/kg ai handled measured in breathing zone standardised to 21 kg ai/d
(5) 19 µg/kg ai handled measured through mask standardised to 21 kg ai/d
(6) 0.012 mg/kg ai standardised to 21 kg ai/d
(7) 1.54 mg/treatment standardised to 3 treatments/d
(8) both replicates added together to give exposure during application to 3 sites
(9) based on respiratory exposure of both replicates (total 1.817 mg)
(10) dermal exposure of both replicates (total 37.96 mg)
(11) 66 µg/kg ai standardised to 21 kg ai/d
(12) 7.2 mg/kg ai standardised to 21 kg ai/d
(13) 0.134 mg/kg ai standardised to 21 kg ai/d

Based on the above studies the risk to PCOs from inhalation exposure alone is likely to be acceptable provided respiratory protection is worn.

Three studies provided both respiratory and dermal exposure estimates. Based on the exposure estimates provided in these studies alone, Australian workers may be exposed to unacceptable levels of chlorpyrifos. It is noted that hand and neck exposures were not included in all dermal exposure estimates. Based on Fenske and Elkner (1990), combined hands, head and neck exposures contributed only 14.5% to total actual dermal exposure.

The application times or work rates were generally lower in these studies than expected for Australian workers. For the purpose of this risk assessment the study exposure values were standardised to the Australian rates. It is recognized that the resultant exposures may be an overestimate. The clothing worn by the study workers was either not known or substantially less than required for Australian workers. It is therefore possible that the dermal exposures are further overestimated.

Risk based on POEM estimates

POEM estimates were conducted for a worker using open mixing techniques and applying 1% chlorpyrifos by handspray to three sites of 140 m^2 each (0.042 ha/d). Product packaging is assumed to be 5 L containers with wide necks. This packaging type is considered a best case scenario (based on POEM contamination estimates). Contamination during mixing and loading is dependent on the number of operations required. To treat three sites, 21 kg ai will be handled per day, which is equivalent to 10 operations.

There are no relevant POEM scenarios available for indoor spraying. NOHSC uses the outdoor model "Hand Held Outdoors Hydraulic Nozzles (H-Nozzles)" as a rough guide. A spray tank size of 250 L is used to reflect the use of vehicle mounted equipment. The number of operations is adjusted to reflect the number of packages used to mix the solution in the mix tank.

To account for travelling time between sites and time taken to mix and load the product, total spray time used in the model is 4 h.

Table 50: PCO risk during post-construction termite control based on POEM estimates

Formu-lation	Estimate No. (Pack type)	Application rate, spray volume	Mixer/loader		Applicator		Mixer/loader/ Applicator	
			Absorbed dose[(1)] (mg/kg bw/d)	MOE	Absorbed dose[(2)] (mg/kg bw/d)	MOE	Absorbed dose[(2)] (mg/kg bw/d)	MOE
45% EC	Estimate 17 (5 L container with wide neck)	495 kg ai/ha (49.5 g/m^2), 50000 L/ha (5 L/m^2)	0.002	15	0.039	<1	0.042	<1

POEM model used is Hand Held Outdoors Hydraulic Nozzles (H-Nozzles); estimate is for workers wearing chemically resistant clothing, gloves and respiratory protection
(1) only dermal exposure considered during mixing/loading
(2) dermal and inhalation exposure considered during application (inhalation dose contributed 3% of total absorbed dose)

Based on POEM estimates alone, the risk to PCOs during post-construction termite control is likely to be unacceptable (MOE <1).

Discussion

Application rates, work rates and final ai concentrations are similar for both pre- and post-construction termite control. Both roles are conducted by trained PCOs, with access to specialized equipment. Mixing and loading methods will be similar for these two worker groups therefore similar concerns will exist.

Post-construction application by spray is expected to be similar to pre-construction with regards to work practices, however some areas to be treated will be confined, thereby resulting in possible additional inhalation exposure.

The most reliable study was judged to be Fenske and Elkner (1990). From this study, standardised respiratory and dermal doses of 0.00231 and 0.0756 mg/kg/d were determined, respectively (estimated through one layer of clothing with most workers wearing no gloves). POEM Estimate 17 shows dermal exposure during spraying to be reduced by 76% when water proof overalls were worn instead of permeable clothing during application (total dermal exposure to spray was 33 mL/d for permeable clothing + gloves and 7.8 mL/d for waterproof overalls + gloves). Assuming most of the exposure occurs during application (as indicated by POEM), the dermal dose determined in Fenske and Elkner (1990) may be reduced to as low as 0.018 mg/kg/d when appropriate PPE are worn. The resultant MOE estimated from the combined respiratory and dermal exposure will therefore be 1.5 (0.20 mg/kg/d).

PCOs are unlikely to use chlorpyrifos every working day and also unlikely to treat three sites each time chlorpyrifos is applied. Additionally, the spraying time used in the POEM estimate

(4 h) may overestimate exposure during normal use situations. The overall conclusion, therefore, is that post-construction workers applying chlorpyrifos by spray will not be exposed to unacceptable risk, provided appropriate PPE is worn and safe work practices are observed.

Post-construction termiticide applicators are expected to use a combination of methods, including spraying, rodding or slab injection. A variety of methods were used in the available studies, some in combination, however the POEM estimates consider only spray application. Worker exposure during these different application methods is expected to be similar as the final concentrations and application rates are the same.

The use of chlorpyrifos in pre-existing under-slab reticulation systems is expected to result in lower levels of exposure due to the enclosed design of the system. In this case exposure will only occur during mixing and loading. Final ai concentration and application volumes are the same by this method as by other post-construction application methods.

In conclusion, the information available suggests that PCOs will be safe to use 1 or 2% chlorpyrifos as a post-construction termiticide using closed mixing systems, provided appropriate PPE is worn. The suitability of open mixing techniques will depend on packaging design and work practices

Termite nests or colonies and pole treatment

There were no relevant worker exposure data available or for these end use situations. This risk assessment is based on a comparison between these end use situations and post-construction building applications.

For the control of termites in buildings, PCOs will apply either 1 or 2% chlorpyrifos (depending on geographic location) and an application volume of 5 L/m^2 or 100 L/m^3.

For the control of termites in nests or colonies, PCOs will apply chlorpyrifos as a spot spray at a final ai concentration of 2%. Application volumes required to saturate affected areas may be as much or greater than those anticipated for post-construction building applications. The areas requiring treatment, however, are expected to be smaller.

For the control of termites in poles and fences, PCOs will apply chlorpyrifos to the surrounding soil at a final ai concentration of 1% and an application volume of 100 L/m^3.

Discussion

Overall, the risk to PCOs applying chlorpyrifos to termite nests and colonies, or to soil for pole treatment, is expected to be no greater than the risk during post-construction applications to buildings.

Control of general household pests

Worker studies submitted by Dow were considered inadequate for use in this risk assessment.

The product formulations available for this end use are emulsifiable concentrates containing either 45 or 50% ai, available in a range of packaging sizes and types, including 1, 2, 5, and 20 L containers or drums.

There are no relevant POEM scenarios available for indoor spraying. NOHSC uses the outdoor model "Hand Held Outdoors Hydraulic Nozzles (H-Nozzles)" as a rough guide.

POEM estimates were conducted for vehicle mounted spray application for flea control (Estimate 18) and spot spraying for spiders/cockroaches/ants using a knapsack (Estimate 19). Both scenarios assume open mixing techniques are used and chlorpyrifos is applied as a 0.5% spray. Product packaging is assumed to be 5 L containers with wide necks in both scenarios. This packaging type is considered a best case scenario (based on POEM contamination estimates).

For flea control, six sites of 140 m^2 each (0.084 ha) may be treated over an average total spray time of 2 h (allowing for travel time between sites and time taken to mix and load the product) and spray volume of 800 L. For knapsack spraying, the maximum work rate is based on the POEM upper limit of 400 L spray per day and an average total spray time of 1 h (assuming half as much spray will be applied in half the time).

Contamination during mixing and loading is dependent on the number of operations required. To treat six sites, 4.2 kg ai will be handled per day, which is equivalent to four operations (4 x 250 L tank mixes using 2 x 5 L containers). To apply 400 L of spray using a 15 L knapsack, 27 operations will be required.

PPE requirements for PCOs during general pest control as provided in the safety directions are as follows:

When opening the container, preparing the spray, using the prepared spray, wear cotton overalls buttoned to the neck and wrist, a washable hat, elbow-length PVC gloves and a face shield or goggles.

The POEM estimates are based on workers wearing PPE similar to those specified in the above safety directions.

The risk assessment based on POEM estimates is summarised in Table 51.

Table 51: PCO risk during general pest control based on POEM estimates

Formulation type Application rate Spray volume (Packaging type)	Estimate No. Scenario	Mixer/loader	Applicator	Mixer/loader/ Applicator

		Absorbed dose(1) (mg/kg bw/d)	MOE	Absorbed dose(2) (mg/kg bw/d)	MOE	Absorbed dose(2) (mg/kg bw/d)	MOE
50% EC; 50 kg ai/ha (5 g/m^2) 10000 L/ha (1 L/m^2) (5 L container with wide neck)	Estimate 18 Vehicle mounted	0.001	30	0.041	<1	0.046	<1
	Estimate 19 Knapsack	0.007	4	0.021	1.4	0.029	1

POEM model used is Hand Held Outdoors Hydraulic Nozzles (H-Nozzles); estimate is for workers wearing cotton overalls and gloves
(1) only dermal exposure considered during mixing/loading
(2) dermal and inhalation exposure considered during application
(3) inhalation dose contributed ~7% of total absorbed dose
(4) inhalation dose contributed ~10% of total absorbed dose

Discussion

Based on POEM estimates, the risk to PCOs during general pest control is unacceptable (MOE <1 using vehicle mounted equipment and MOE = 1 using knapsack). POEM estimates are only a rough guide and are expected to be an overestimate based on the conservative nature of the model.

The risk assessment considers the risk to PCOs applying chlorpyrifos to each site they visit and each day they work. In practice, most workers may apply other chemicals to some sites and in some cases (such as during a routine pest inspection) may not apply any pesticides at all. Therefore the NOEL based on 20 day repeat exposure is considered to be an overestimate for this end use.

Based on the relative dose estimates in Table 50 (PCO risk during post-construction termite control based on POEM estimates) and Table 51 above (PCO risk during general pest control based on POEM estimates), the risk during general pest control is expected to be similar to the risk during post-construction termite control.

Although PCOs use half the spray concentration (0.5%) and 1/5 of the spray volume (1 L/m^2) for general pest control compared to termite control (1%, 5 L/m^2), they are required to wear less PPE (cotton overall, gloves but no respirator during general pest control; waterproof clothing, gloves and respirator during termite control).

Overall, the risk to PCOs during general pest control will be comparable to during termite control and is expected to be acceptable provided appropriate work practices and PPE are used.

Mosquito control

Mosquito control is a minor use in Australia. Products available for this end use are the same as those available for general pest control, namely 45 and 50% emulsifiable concentrates packaged in 1, 2, 5 or 20 L containers or drums.

Mosquito control will be conducted by council workers or PCOs, as required. Based on label information, handspray will be the predominant method of application to vegetation. Water impoundments will be treated by spray or direct product incorporation. Survey information suggests that application to swamps will be by fogging equipment. Fogging is not considered in this review, as it is not provided for on the product labels.

Worker studies submitted by Dow for mosquito control were considered inadequate for use in this risk assessment.

POEM estimates were obtained for handheld applications to vegetation. A risk assessment based on these estimates is provided in Table 52.

Table 52: Worker risk during mosquito control based on POEM estimates

Formulation type Application rate Spray volume (Packaging type)	Estimate No. Scenario	Mixer/loader		Applicator		Mixer/loader/ Applicator	
		Absorbed dose(1) (mg/kg bw/d)	MOE	Absorbed dose(2) (mg/kg bw/d)	MOE	Absorbed dose(2) (mg/kg bw/d)	MOE
50% EC; 0.06 kg ai/ha 240 L/ha (5 L container with wide neck)	Estimate 20 Knapsack	0.007	4.3	0.002	15	0.009	3.3

POEM model used is Hand Held Outdoors Hydraulic Nozzles (H-Nozzles); estimate is for workers wearing cotton overalls (or one layer of own clothing) and gloves
(1) only dermal exposure considered during mixing/loading
(2) dermal and inhalation exposure considered during application (inhalation dose contributed ~7% of total absorbed dose)

Modelling was conducted for workers using open mixing techniques and applying the highest rate of product (0.06 kg ai/ha). The spray volume is not provided on the label. A spray volume of 240 L spray/ha is used in the modelling to give a final ai concentration which is similar to knapsack applications for crop protection. The maximum work rate is based on the POEM upper limit of 400 L spray per day and an estimated spray time of 2 h. Product packaging used in the estimation is 5 L containers with wide necks, in keeping with other POEM estimates used in this review.

The POEM estimates are based on workers wearing PPE similar to those specified in the safety directions:

When opening the container, preparing the spray, using the prepared spray, wear cotton overalls buttoned to the neck and wrist, a washable hat, elbow-length PVC gloves and a face shield or goggles.

Discussion

Based on POEM estimates, the risk to PCOs applying chlorpyrifos to vegetation by handspray is unacceptable (MOE 3.3). However, the use pattern parameters used in the risk assessment are representative of the worst case scenario (highest label rate), and the model is recognised as being conservative. Additionally, the use of a 20-day repeat dose NOEL is considered unsuitable for the estimation of risk to council workers, as they are expected to apply chlorpyrifos to public land infrequently.

Overall the risk to PCOs or council workers using chlorpyrifos for the control of mosquitoes on vegetation is considered acceptable when used in accordance with label directions.

The POEM estimate is based on product packaging with wide opening. Standard packaging may result in unacceptable exposure.

5.3.3 Other uses

Chlorpyrifos use on animal hides and skin is expected to be a minor use. Survey information was provided by state coordinators and the chemical industry but not by end users themselves. As specific use pattern information (eg frequency of use, work practices, worker controls or exposure mitigation methods used) was not available, an assessment of this end use is not possible.

5.5 Risk from post-application exposure

5.5.1 Crop protection

A summary of the risk to re-entry worker exposure following chlorpyrifos applications to crops is summarised in Table 53.

Table 53: Summary of risk of workers re-entering treated crops

Crop group Source	Crop and *work task* Representative PPE	Re-entry time (h)	Transfer factor (cm^2/h)	Dislodgeable residues ($\mu g/cm^2$)	Calculated actual dermal exposure(1) (µg/person)	Estimated dose (mg/kg/d) (2)	MOE
Orchards Honeycutt and Day (1993)	Orange *pickers* One layer of clothing and cotton gloves	0	6201*	1.46**	54321	0.027	1.1
		24		0.212	7888	0.0039	7.7
		43 days	measured total actual exposure: 129.4 µg/person (dermal + inhalation)			0.000065	460
	Orange *pruners* (wet weather at 48 h) One layer of clothing and cotton gloves	0	2812*	1.82*	30707	0.015	2
		24		0.547	9229	0.0046	6.5
		48	measured total actual exposure: 2919.3 µg/person (dermal + inhalation)			0.0015	21
	Lemon *pruners* One layer of clothing and cotton gloves	0	1896*	1.48*	16836	0.0084	3.6
		24		0.367	4175	0.0021	14
		48	measured total actual exposure: 1049.3 µg/person (dermal + inhalation)			0.00053	57
High field crops Bohl and Parsons (1983)	Corn *Field scouts* One layer of clothing and cotton gloves	2	based on measured total actual exposure (dermal + inhalation, excluding head and neck exposure; arithmetic means)			0.0053	<5.7
		4				0.0039	<7.7
		8				0.0063	<4.8
		12				0.0014	<21
		24				0.0064	<4.7
		48				0.0092	<3.2
High field crops Kamble et al. (1992)	Corn *Field scouts* One layer of clothing, no gloves	2	based on measured total actual exposure (dermal + inhalation; arithmetic means, results pooled from 3 separate experiments ie n = 9)			0.0045	6.7
		4				0.0018	17
		8				0.00048	63
		24				0.00031	96
		48				0.000092	330
Low crops Shurdut et al. (1993)	Cauliflower *Scouts* One layer of clothing, no gloves	24	729	based on measured total actual exposure (dermal + inhalation; arithmetic means, 5 replicates): 2242 µg/person		0.0012	25
	Tomatoes *Scouts* One layer of clothing, no gloves	24	670	based on measured total actual exposure (dermal + inhalation; arithmetic means, 5 replicates): 935µg/person		0.00066	45
High field crops Buck et al. (1980)	Cotton Only DFR measured in this study	0	10000 ***	3.64	218400****	0.110	<1
		24		0.13	7800****	0.0039	8
		28		0.071	4260****	0.0021	14
		72		0.055	3299****	0.0016	17
		96		0.034	2040****	0.00102	30

NA – not applicable

(1) all based on 6 hour exposure except Shurdut et al. (1993) which is based on actual exposure time (~ 4 h)

(2) based on 3% dermal absorption and 60 kg worker (µg/person divided by 1000 to give mg/person, x 0.03 dermal absorption, divided by 60 kg)

* based on 75th percentile exposures

** immediately after application

*** based on default transfer factor for crops with medium to high potential for dermal transfer

**** represents potential exposure

Orchards

The transfer factors reported in Honeycutt and Day (1993) (Section 4.3.1.1), which were calculated at 2 and 43 days post-application, have been used by NOHSC to estimate worker exposure at 0 and 1 days from measured foliar residues collected at these time points. It is noted that these estimates will depend on a number of factors, including the amount of chlorpyrifos applied, the types of re-entry activities, the crop type and the stage of crop growth. Due to these differences in crop stage and climatic conditions, caution is needed when extrapolating transfer factors from one re-entry time to another.

Estimates based on transfer factors indicate that exposure at 24 h after application may be marginal to acceptable. Given that the study application rate is approximately six times higher than the Australian rates, these values are expected to be overestimates.

The study participants wore cotton gloves during both picking and pruning activities. It is expected that some Australian workers will not wear gloves while picking fruit, however gloves are expected for most workers during pruning. Working without gloves is expected to increase the risk, however, this is off-set by the differences in application rates.

High field crops

The Bohl and Parsons study (1983) shows low to marginal MOE for field scouts entering treated corn fields. A clear interpretation of these results is not possible given that (a) the study application rate was higher than Australian rates for field crops, (b) chemigation does not cover crops evenly, (c) scouts are not expected to work as long as the study duration of 6 h, and (d) the estimates do not include head and neck exposure.

The results from the Kamble et al. study (1992) show marginal MOE at 2 h and acceptable MOE from 4 h (3 h not studied). It is noted that these values are based on 6 hours of scouting and actual monitoring times were only 30 min, and extrapolation to 6 hours may result in overestimation. Additionally, scouting activities are unlikely to occupy the whole work day, therefore risk to workers under normal work conditions should be lower.

Cotton

Dislodgeable residues were estimated in treated cotton over a range of post-application times (Buck et al. 1980). Using a default transfer factor value for crops with high potential for dermal transfer (10000 cm^2/h), NOHSC estimated dermal dose for cotton scouts working 6 hours. The resultant MOE show acceptable risk for scouts from 24 h post-application. Re-entry immediately after treatment may result in unacceptable risk.

Cotton chippers have a high potential for foliar contact when pulling or chipping out weeds. These workers are usually contract workers who work on a regular basis depending on the season. Due to the high potential for exposure during chipping, these workers should be required to follow recommended work practices and wear appropriate clothing.

Low crops

The results from the Shurdut et al. study (1993) show acceptable risk to field scouts re-entering low crops 24 h after treatment with chlorpyrifos.

Workers re-entering low crops in greenhouses shortly after application may be exposed to significant amounts of chlorpyrifos due to spray taking longer to dry. These workers may also be exposed to significant amounts of residues via the inhalation route.

Discussion

Workers may re-enter treated crop after pesticide application to check, irrigate, prune or harvest crops.

Overall the available measured and calculated data indicate acceptable risk to re-entry workers from 4-24 h post-application (depending on the study). It is noted however that the use of TF (including defaults) and DFR may result in overestimation of exposure and application rates in most studies were significantly higher than Australian rates.

Considering all of the above, it is not recommended that workers re-enter treated areas before the spray has dried, unless appropriate PPE are worn.

Cotton chippers have greater potential for worker exposure, due the contractual nature of their work requiring them to work long periods of time (possibly in excess of 6 hours) over consecutive days at different sites. Therefore the risk to these workers may be greater than other re-entry workers.

The withholding period for chlorpyrifos products ranges from nil to 21 days depending on the crop. The withholding period for orchard crops is at least 7 days, therefore the risk to workers involved in hand picking fruit will not be a concern. A concern however exists for manual harvesting of crops with no withholding period (such as vegetables) as harvesting may occur before the spray has dried. Broadacre crops have a withholding period of at least 2 days and are generally harvested mechanically, therefore significant worker exposure during harvesting is not expected.

Chlorpyrifos is a slight skin irritant in experimental animals, however at it is applied to crops at low concentrations, the potential for topical effects during re-entry activities is low.

5.5.2 Pest control

Termite control

The risk to tarp pullers has been considered earlier (Section 5.3.2) as this task may be conducted by the same workers as those applying the product.

The current labels carry a re-entry statement specifying that treated areas should be completely dry and ventilated prior to re-entry.

Discussion

This re-entry statement is considered adequate to protect workers re-entering areas treated with termiticide.

General pest control

Office workers may be exposed to chlorpyrifos residues following the treatment of office spaces by PCOs.

The risk assessment is based on the study of Currie et al. (1990).

The rate of dissipation is useful when considering the best time for workers to re-enter, however without worker exposure estimates the risk cannot be quantified. As a very rough guide, the surface contamination estimates are used to estimate worker exposure assuming transfer from furniture will be of the order of 1000 cm^2/h (default estimate for low level contact).

The highest surface contamination estimates in the furnished office were 3.3 ng/cm^2 at 1-2 hours and 3.0 ng/cm^2 at 24 hours. Using a theoretical transfer factor of 1000 cm^2/h, the resultant dermal dose (over 8 hours for a 60 kg worker) will be 0.000013 mg/kg/d (0.00033 µg/cm2 x 10000 cm2/h x 8 h ÷ 60 kg ÷ 1000 µg/mg x 0.03), equivalent to an MOE of 2300. The NOEL used for this MOE estimation may be conservative given that office spraying will be infrequent and the spray is expected to dissipate within a few days, however it is not possible to tell how long the residues persist from the available data. Australian application rates are up to 33 times greater than study rates. Using this factor, a straight extrapolation will bring the MOE to 67.

The current labels carry a re-entry statement specifying that treated areas should be completely dry and ventilated prior to re-entry.

Discussion

It is acknowledged that exposure monitoring studies provide the most appropriate estimates of exposure. Exposure estimates generated from air and surface monitoring are less useful.

However, the overall conclusion is that office workers will not be exposed to unacceptable levels of chlorpyrifos provided the label re-entry period is observed.

6. OCCUPATIONAL CONTROLS

6.1 Hazardous substances

Chlorpyrifos is listed in the National Occupational Health and Safety Commission (NOHSC) List of Designated Hazardous Substances (NOHSC, 1994a). A full classification including risk and safety phrases have been provided earlier (Section 2.2).

The National Model Regulations [NOHSC:1005(1994b)] and National Code of Practice [NOHSC:2007(1994b)] for the Control of Workplace Hazardous Substances apply to all hazardous substances, as defined in the national model regulations, and extend to all workplaces in which hazardous substances are used or produced and to all persons (consistent with the relevant Commonwealth/State/Territory occupational health and safety legislation) with potential for exposure to hazardous substances in those workplaces.

6.2 Safety directions

The safety directions for chlorpyrifos in the Handbook of First Aid Instructions and Safety Directions (1998) are as follows:

HG BA 5 g/kg or less in plastic labyrinths	
Nil	Nil
BL 500 g/L or less	
Product is poisonous if absorbed by skin contact or swallowed	120, 130, 131, 132, 133
Repeated minor exposure may have a cumulative poisoning effect	190
Avoid skin contact with eyes and skin	210, 211
Obtain an emergency supply of ipecac syrup and atropine tablets 0.6 mg	371, 372
When using the product wear cotton overalls buttoned to the neck and wrist and a washable hat and elbow-length PVC gloves	279, 283, 290, 292, 294
If product on skin, immediately wash area with soap and water	340, 342
After use and before eating, drinking or smoking, wash hands, arms and face thoroughly with soap and water	350
After each day's use, wash gloves and contaminated clothing	360, 361, 366
DU 30-50 g/kg	
Poisonous if absorbed by skin contact, inhaled or swallowed	130, 131, 132, 133
Avoid skin contact with eyes and skin	210, 211

Do not inhale dust	220, 221
When using the product wear elbow-length PVC gloves and disposable respirator	279, 283, 290, 294, 315
Wash hands after use	351
After each day's use, wash gloves	360, 361

EC for termiticide application except as otherwise specified

Product is poisonous if absorbed by skin contact, inhaled or swallowed	120, 130, 131, 132, 133
Repeated exposure may cause allergic disorders	180
Repeated minor exposure may have a cumulative poisoning effect	190
Obtain emergency supply of atropine tablets 0.6 mg	373
Will irritate the eyes and skin	161, 162, 164
Avoid contact with eyes and skin	210, 211
Do not inhale vapour or spray mist	220, 222, 223
When opening the container and preparing spray wear cotton overalls buttoned to the neck and wrist and a washable hat and elbow-length PVC gloves and goggles and half facepiece respirator with combined dust and gas cartridge	279, 280, 281, 290, 292, 294, 297, 300, 303
When using the prepared spray wear cotton overalls buttoned to the neck and wrist and a washable hat and elbow-length PVC gloves and half facepiece respirator with combined dust and gas cartridge	279, 282, 290, 292, 294, 300, 303
If clothing becomes contaminated with product or wet with spray remove clothing immediately	330, 331, 332
If product on skin, immediately wash area with soap and water	340, 342
If product in eyes, wash it out immediately with water	340, 343
After use and before eating, drinking or smoking, wash hands, arms and face thoroughly with soap and water	350
After each day's use, wash gloves, goggles, respirator (and if rubber wash with detergent and warm water) and contaminated clothing	360, 361, 363, 364, 366

EC 500 g/L or less

EC ME 500 g/L or less termiticide application by hand spray

Product is poisonous if absorbed by skin contact, inhaled or swallowed	120, 130, 131, 132, 133
Repeated exposure may cause allergic disorders	180
Repeated minor exposure may have a cumulative poisoning effect	190
Obtain an emergency supply of atropine tablets 0.6 mg	373
Will irritate the eyes and skin	161, 162, 164

Avoid contact with eyes and skin	210, 211
Do not inhale vapour or spray mist	220, 222, 223
When opening the container, preparing spray and using the prepared spray wear chemical resistant clothing buttoned to the neck and wrist and washable hat and elbow-length (nominate other specific material) gloves, goggles and chemical resistant footwear and half facepiece respirator with combined dust and gas cartridge	279, 280, 281, 282, 290, 291b, 295, 297, 298a, 300, 303
If clothing becomes contaminated with product or wet with spray remove clothing immediately	330, 331, 332
If product on skin, immediately wash area with soap and water	340, 342
If product in eyes, wash it out immediately with water	340, 343
After use and before eating, drinking or smoking, wash hands, arms and face thoroughly with soap and water	350
After each day's use, wash gloves, goggles, respirator (and if rubber wash with detergent and warm water) and contaminated clothing	360, 361, 363, 364, 366

EC ME 200 g/L or less

Will irritate the eyes	161, 162
Avoid contact with eyes and skin	210, 162, 164
Repeated minor exposure may have a cumulative poisoning effect	190
Obtain an emergency supply of atropine tablets 0.6 mg	373
When opening the container, preparing spray and using the prepared spray wear cotton overalls buttoned to the neck and wrist and a washable hat and elbow-length PVC gloves and face shield or goggles	279, 280, 281, 282, 290, 292, 294, 299
After use and before eating, drinking or smoking, wash hands, arms and face thoroughly with soap and water	350
After each day's use, wash gloves, face shield or goggles and contaminated clothing	360, 361, 365, 366

EC greater than 200 g/L, 500 g/L or less

EC ME greater than 200 g/L, 500 g/L or less

ULV 500 g/L

WP 500 g/kg or less

Product is poisonous if absorbed by skin contact, inhaled or swallowed	120, 130, 131, 132, 133
Repeated minor exposure may have a cumulative poisoning effect	190
Obtain an emergency supply of atropine tablets 0.6 mg	373
Avoid contact with eyes and skin	210, 211
Do not inhale (dust WP), vapour or spray mist	220, (221 WP), 222, 223

When opening the container, preparing spray or using the prepared spray wear cotton overalls buttoned to the neck and wrist and a washable hat and elbow-length PVC gloves and face shield or goggles	279, 280, 281, 282, 290, 292, 294, 299
If product on skin, immediately wash area with soap and water	340, 342
After use and before eating, drinking or smoking, wash hands, arms and face thoroughly with soap and water	350
After each day's use, wash gloves, face shield or goggles and contaminated clothing	360, 361, 365, 366

HG GR 50 g/kg or less

Harmful if swallowed	129, 133
May irritate the eyes and skin	160, 162, 164
Avoid contact with eyes and skin	210, 211
Repeated minor exposure may have a cumulative poisoning effect	190
Do not inhale dust	220, 221
When using the product wear rubber gloves	279, 283, 290, 312
Wash hands after use	351
After each day's use, wash gloves	360, 361

HV ME 50 g/L or less

May irritate the eyes and skin	160, 162, 164
Avoid contact with eyes and skin	210, 211
Wash hands after use	351

LD 10-20 g/L

Poisonous if absorbed by skin contact or swallowed	130, 131, 133
Avoid contact with eyes and skin	210, 211
Do not inhale	220
When using the product wear elbow-length PVC gloves and half facepiece respirator	279, 283, 290, 294, 300
Wash hands after use	351
After each day's use, wash gloves and respirator and if rubber wash with detergent and warm water	360, 361, 364

SR 10 g/kg or less

Wash hands after use	351

SR (impregnated paper)

Do not open inner envelope until ready for use	380
Do not allow children to play with collar	382
Wash hands after use	351

SR (pet collar)

Do not open inner envelope until ready for use	380
(Do not remove insecticidal strip from collar)	(381)
Do not allow children to play with collar	382

SR 140 g/kg

Poisonous if absorbed by skin contact, inhaled or swallowed	130, 131, 132, 133
Avoid contact with eyes and skin	210, 211
Do not inhale vapour	220, 222
When using the product wear half facepiece respirator	279, 283, 290, 300
Wash hands after use	351
After each day's use, wash respirator and if rubber wash with detergent and warm water	360, 364

6.3 Information provision

6.3.1 Labels

<u>Active constituent label</u>

Technical grade chlorpyrifos is determined to be a hazardous substance. Therefore, it must be labelled in accordance with the NOHSC Code of Practice for the Labelling of Workplace Substances (NOHSC, 1994b)

<u>Product labels</u>

All chlorpyrifos product labels must include a reference to the MSDS for further information.

Refer to Section 7.3 for product labelling requirements arising from this review.

6.3.2 MSDS

The active ingredient and products require MSDS in accordance with the NOHSC Code of Practice for the preparation of Material Safety Data Sheets (NOHSC, 1994d).

It is noted that it is the responsibility of manufacturers and importers of chlorpyrifos, active ingredient and products, to produce MSDS where required, and review/revise these MSDS in accordance with Commonwealth/State/Territory hazardous substances legislation.

6.4 Occupational exposure monitoring

6.4.1 Atmospheric monitoring

A NOHSC Exposure Standard exists for chlorpyrifos (NOHSC, 1995a). The Exposure Standard is 0.2 mg/m^3 TWA with a “sk” skin notation, indicating that absorption through the skin may be a significant route of exposure. A STEL has not been established for chlorpyrifos.

6.4.2 Health surveillance

NOHSC has placed OP pesticides (including chlorpyrifos) on the Schedule for Health Surveillance (Schedule 3 Hazardous Substances for which Health Surveillance is Required). Guidelines are available for monitoring OP pesticides (NOHSC, 1995*)*. The employer is responsible for providing health surveillance where a requirement has been established as a result of the workplace assessment process.

The NOHSC guidelines recommend one, or preferably two pre-exposure tests at least 3 days apart, to establish baseline ChE activity (an average is used when two samples are obtained). It is also recommended that a period of 4 weeks elapse between last exposure to OP pesticides and testing to establish baseline levels.

The NOHSC guidelines require estimation of RBC and plasma ChE levels. It is preferable if testing is carried out in the latter half of the working day when OP pesticides are used. If a 20% depression in ChE activity is seen, the worker should be re-tested. If ChE levels fall by 40% or more, the worker should be removed from exposure to OP pesticides until such time as the level returns to baseline level.

7. REVIEW OUTCOMES

A good worker exposure data package provided by DowAgroSciences assisted in the quantitative risk assessment for chlorpyrifos. Modelling was required to a limited degree to support the measured data and to gauge the exposure during individual tasks where measured data was not available.

The main findings arising from the assessment were that all existing crop and pest control uses are supported with the minor exception of handspraying of overhead greenhouse plants. The use of chlorpyrifos for handspraying of overhead plants is not expected to be relevant for registered uses of chlorpyrifos. There are no outstanding issues or data requirements arising from the OHS assessment.

No re-entry periods are currently set for products used in crop protection. Due to concern for workers entering treated crops shortly after application, re-entry statements are required for these products. The existing re-entry statements on pest control product labels are considered adequate.

Detailed conclusions for each use pattern are given below.

7.1 End use

7.1.1 Crop protection

Airblast application

Chorpyrifos is applied by airblast in a range of crop situations. The use pattern parameters used in the exposure and risk assessment for airblast application represents a reasonable worst-case scenario (pome and stone fruit) for this application method.

Exposure data were available for airblast application using two formulations of chlorpyrifos, WP and EC. Exposure modelling was used to fill data gaps, in particular to estimate exposure to workers handling WP formulations in water-soluble packaging and liquid formulations packaged in wide neck containers.

For reasons specified in Section 5.3.1 (Risk Assessment), the MOE from measured data and model data may overestimate the risk in some cases.

Noting:

(i) the frequency of use and intermittent nature of chlorpyrifos use in orchards,

(ii) that the risk assessment was based on a reasonable worst case scenario for airblast application, and

(iii) the possible overestimation of risk from exposure estimates obtained from exposure studies and predictive modelling,

it is concluded that the overall risk to workers during airblast applications of chlorpyrifos is likely to be acceptable under the following conditions:

(a) that exposure mitigation methods specified in Section 7.1.4 are instituted, where applicable; and

(b) the product is used in accordance with good agricultural practice and label instructions.

Oscillating boom

It is anticipated that oscillating booms will be used to apply chlorpyrifos predominantly in citrus. The use pattern parameters used in the risk assessment are considered to be a reasonable representation of actual use of the chemical in citrus. No exposure data are available for this application method and exposure modelling cannot be used. As indicated in

Section 5.3.1 (Risk Assessment), it is feasible to use exposure estimates generated for airblast application as an indication of exposure during the use of oscillating boom.

Noting:

(i) the frequency of use and intermittent nature of application over the growing season, and

(ii) that potential mixer/loader and applicator exposure during oscillating boom spraying is expected to be comparable to airblast spraying,

it is concluded that the overall risk to workers during application by oscillating boom is likely to be acceptable under the following conditions:

(a) that exposure mitigation methods specified in Section 7.1.4 are instituted, where applicable; and

(b) the product is used in accordance with good agricultural practice and label instructions.

Boom application

The use pattern parameters used in the exposure and risk assessment represent:

(i) a reasonable worst case scenario (lawn and turf) and

(ii) the major use situation (broadacre crops).

Exposure data were available for boom application using WP and EC formulations of chlorpyrifos, using normal and high clearance boom sprayers. These data were normalised for the major use scenario (broadacre crops), therefore the degree of risk will be greater for maximum exposure scenarios which utilise more concentrated sprays (for example lawn/turf).

Exposure modelling was used to estimate exposure for scenarios which had data gaps, for example water-soluble packs for WP formulations and wide neck containers for EC formulations, and also to compare potential exposure and risk associated with major uses (broadacre crops) with relatively minor uses (lawn/turf).

Noting:

(i) the frequency of use and intermittent nature of chlorpyrifos use in field crops and amenity turf,

(ii) that the risk assessment was based on a reasonable worst case scenario for amenity turf, and

(iii) the possible overestimation of risk from exposure estimates obtained from exposure studies and predictive modelling,

it is concluded that the overall risk to workers during boom applications of chlorpyrifos is likely to be acceptable under the following conditions:

(a) exposure mitigation methods specified in Section 7.1.4 are instituted, where applicable; and
(b) the product is used in accordance with good agricultural practice and label instructions.

Aerial application

The use pattern parameters used in the exposure and risk assessment are considered to be representative across all possible crops treated by aerial application.

The measured exposure data provided for this review were unsuitable for regulatory purposes (refer to Section 4.1.1 for details). Model data were used to estimate exposure to mixer/loaders for aerial operations. There were no suitable models within POEM to estimate exposure to aerial applicators or flaggers.

Aerial crew have potential for exposure to large volumes of product, however noting that:
(i) most aerial spraying crews use closed mixing systems (dry coupling and closed filling systems),
(ii) aerial applicator exposure is expected to be minimal,
(iii) aerial spray operators are required to undergo appropriate training and accreditation, and
(iv) flaggers are used only for night spraying when GPS is not available,
it is concluded that the overall risk to workers during aerial applications of chlorpyrifos is likely to be acceptable under the following conditions:

(a) exposure mitigation methods specified in Section 7.1.4 are instituted, where applicable; and
(b) the product is used in accordance with best practice guidelines and label instructions.

Handspray

Some exposure data were available for handspraying in greenhouses. However, these data were interpreted with caution given the difference in formulation type used in the study using ME formulation and deficiencies in study design for the studies using WP formulations.

Model data were used to estimate worker exposure for scenarios where suitable measured exposure data were not available.

For handspray application to **low level greenhouse plants** or **field crops**, noting that:
(i) the use pattern parameters used in the exposure and risk assessments represent a reasonable worst-case scenario for this application method,

(ii) the frequency of use and intermittent nature of chlorpyrifos use in field crops and greenhouse crops, and
(iii) extrapolations from study results using ME formulations to WP and EC formulations are used as a guide only,

it is concluded that the overall risk to workers applying chlorpyrifos by handspray to low level greenhouse plants or field crops is likely to be acceptable under the following conditions:

(a) exposure mitigation methods specified in Section 7.1.4 are instituted, where applicable; and
(b) the product is used in accordance with good agricultural practice and label instructions.

For handspray application **overhead greenhouse plants**, noting that:

(i) this is likely to be a high exposure scenario, and
(ii) available measured data indicated unacceptable exposure and risk when treating overhanging plants for workers wearing PPE additional to Australian requirements,

the use of chlorpyrifos products in this manner is not acceptable. However, as handspray of greenhouse ornamentals is an off-label use, the treatment of overhead plants will not occur under normal use situations.

<u>Basal application</u>

Exposure data were not available for this application method. Theoretical calculations and exposure modelling were used where possible to estimate potential exposure.

The use pattern parameters used in the risk assessment are based on information obtained from the performance questionnaires.

For workers applying chlorpyrifos as a **liquid mixture** to the base of trees, or the ground around them, noting that:

(i) the information available on extent of use is limited,
(ii) the use pattern parameters used in the exposure and risk assessments represent a reasonable worst-case scenario for this application method and workers may treat smaller areas,
(iii) no suitable exposure data are available for this end use with modelling information used only as a rough guide, and
(iv) model data is likely to overestimate risk during basal application,

it is concluded that the overall risk is likely to be acceptable under the following conditions:

(a) that exposure mitigation methods specified in Section 7.1.4 are instituted, where applicable; and
(b) the product is used in accordance with good agricultural practice and label instructions.

For workers applying chlorpyrifos as a **dry mixture** with sand, noting that:

(i) the potential for dermal and inhalation exposure is high, and

(ii) no suitable exposure data are available for this end use with modelling information used only as a rough guide,

however:

(i) this method of application is used only on bananas and applications in this crop are conducted once per season, and

(ii) alternative application methods (spray application) are available and currently used by Australian workers,

it is concluded that the overall risk is likely to be acceptable under the following conditions:

(a) that exposure mitigation methods specified in Section 7.1.4 are instituted, where applicable; and

(b) the product is used in accordance with good agricultural practice and label instructions.

For use on bananas it is preferable that chlorpyrifos products be applied as a liquid rather than a dry mixture.

Seed treatment

No exposure data were available to estimate worker exposure during seed treatment and no appropriate model was available to estimate worker exposure for a full work cycle during seed treatment. Model data were used to estimate exposure during mixing and loading only. This data included hand exposure only and therefore was interpreted with caution and used as a rough guide estimate of exposure.

Use pattern parameters and information regarding work practices used in the risk assessment were obtained from regular users of chlorpyrifos products from the performance questionnaires. Work rates were estimated by NOHSC based on work rates for other ground application methods.

Potential exposure scenarios during seed treatment were identified as being during mixing and loading only. No worker exposure is expected during planting.

For workers using WP formulations, noting that:

(i) open pouring has a high potential for dermal and inhalation exposure,

(ii) manual mixing of product with seed is also expected to result in dermal and inhalation exposure, however the extent of exposure cannot be quantified,

(iii) label safety directions do not recommend the use of a respirator or dust mask, and

(iv) modelling information was used only as a rough guide and is expected to be an underestimate of risk, however considering chlorpyrifos will be used at sowing only, it is concluded that the overall risk to workers applying WP chlorpyrifos as a seed dressing will be acceptable under the following conditions:

(a) exposure mitigation methods specified in Section 7.1.4 are instituted, where applicable; and
(b) the product is used in accordance with good agricultural practice.

For workers using EC formulations, noting that:
(i) seed treatments will be conducted at sowing only,
(ii) inhalation exposure to EC formulations is not expected to be significant during open mixing/loading,
(iii) the risk assessment assumes workers wear PPE as recommended on product labels,

it is concluded that the overall risk to workers applying EC chlorpyrifos as a seed dressing is likely to be acceptable under the following conditions:

(a) exposure mitigation methods specified in Section 7.1.4 are instituted, where applicable; and
(b) the product is used in accordance with good agricultural practice.

<u>Soil baits</u>

No exposure data or appropriate models were available to estimate exposure for this application method.

Use pattern parameters and work practice details used in the risk assessment were obtained from survey information.

Application of chlorpyrifos in soil baits is not expected to be a major use in Australia and only EC formulations are registered for this use. Potential exposure scenarios identified for this use were during mixing and loading for both ground (including fertilizer spreader and hand application) and aerial application of bait. Worker exposure during application of bait is not anticipated.

For ground applications, noting that:
(i) two applications are anticipated per season with an exposure free period between them,
(ii) the risk assessment is based on maximum work rates for other ground based applications,
(iii) small quantities of chlorpyrifos are handled, and
(iv) exposure is limited to mixing/loading,

it is concluded that the overall risk to workers applying soil baits is likely to be acceptable under the following conditions:

- (a) exposure mitigation methods specified in Section 7.1.4 are instituted, where applicable; and
- (b) the product is used in accordance with good agricultural practice and label instructions.

For aerial applications, noting that:

- (i) two applications are anticipated per season with an exposure free period between them,
- (ii) mixer loader potential is limited due to use of automatic mixing and closed loading systems, and
- (iii) aerial applicator exposure is expected to be minimal,

it is concluded that the overall risk to workers applying soil baits is likely to be acceptable under the following conditions:

- (a) exposure mitigation methods specified in Section 7.1.4 are instituted, where applicable; and
- (b) the product is used in accordance with good agricultural practice and label instructions.

<u>Applications at sowing (bandspray or gravity feed)</u>

No exposure data were available to assess risk during bandspray or gravity feed.

EC and ULV formulations are applied by bandspray, while gravity feed applications are conducted using either EC or granular products in sugarcane only. Overall, applications at sowing are expected to be a minor use of chlorpyrifos.

Exposure during open mixing and loading has potential for significant exposure and risk. Model data were used to assess exposure during mixing and loading using EC and granular formulations, and are considered only as a rough guide.

Applicator exposure and risk is not expected to be significant, as applications will be conducted low to the ground and treated areas will be covered immediately by soil.

Noting that:

- (i) applications are infrequent (only at sowing),
- (ii) slow-release granulated formulations limit the amount of chlorpyrifos available for inhalation or dermal contact,
- (iii) liquid formulations are used undiluted, requiring no mixing,
- (iv) closed transfer systems are used when handling bulk containers of liquid products, and

(v) applicator exposure is not expected to be significant,

it is concluded that the overall risk to workers applying chlorpyrifos by bandspray or gravity feed is likely to be acceptable under the following conditions:

(a) exposure mitigation methods specified in Section 7.1.4 are instituted, where applicable; and
(b) the product is used in accordance with good agricultural practice and label instructions.

7.1.2 Pest control

The risk assessment considers exposure and risk during each of the individual types of pest control separately. In practice however, some tasks may be conducted by the same worker.

In the review outcomes, all workers involved in termite control (such as pre- and post-construction termiticide application, as well as spot treatments of poles and termite nests) are grouped together. PCOs conducting general pest control (eg control of ants, cockroaches and fleas) and mosquito control, may also be the same workers, however they have lesser PPE requirements and less potential for exposure, and so are considered separately.

Termite control

The frequency and extent of chlorpyrifos usage may vary significantly for these workers. At the low end of the scale, some operators may use a variety of pesticides and may combine chemical applications with other activities which do not result in chemical exposure (such providing quotes, conducting pest inspections and writing reports). At the other end of the scale, large operators may contract work out to termite specialists who may use chlorpyrifos for most of their applications.

The use pattern parameters used in the exposure and risk assessment of pre- and post-construction termiticide application were obtained from regular users (via performance questionnaires) and the registrant, and are considered to be representative of the Australian use of chlorpyrifos by termite control specialists. Therefore, these parameters represent a worst case.

Good quality exposure data were available to assess worker exposure during pre-construction termite control. Model data were used as a rough guide only, in an attempt to identify the contribution of mixing/loading exposure to total mixer/loader/applicator exposure, as this could not be established from the exposure study given the study design.

Although several studies were provided for post-construction use of chlorpyrifos, they were inadequate for regulatory purposes due to factors such as (i) inadequate information on application parameters, and (ii) lack of measured dermal and/or inhalation exposure or incomplete measurements (particularly of dermal exposure). Model data were utilised in an attempt to estimate exposure under Australian conditions, due to the inadequacies of the measured data.

In the absence of exposure studies and based on use pattern information, the exposure and risk during treatment of termite nests/colonies or during pole treatment, was determined in relation to post-construction application.

Noting that:

(i) PCOs may apply chlorpyrifos either pre-construction, post-construction or as a spot spray (to treat termite nests or for pole treatment) depending on the job requirement,

(ii) most workers are not expected to treat sites daily, however some have potential for frequent and extensive usage of chlorpyrifos all year round,

(iii) modelling data showed a concern for workers during mixing and loading when using containers of standard design,

(iv) overseas pest controllers have shown significant ChE inhibition following a full termite control season (Asakawa et al., 1989 and Jitsunari et al., 1989),

however given that PCOs:

(i) are required to have access to health surveillance facilities in accordance with the NOHSC Control of Workplace Hazardous Substances (NOHSC, 1994c),

(ii) are adequately trained and accredited and have access to more sophisticated equipment and facilities than other categories of workers, and

(iii) are required to wear extensive PPE,

it is concluded that the overall risk to workers applying chlorpyrifos termiticide by any approved method is likely to be acceptable under the following conditions:

(a) exposure mitigation methods specified in Section 7.1.4 are instituted, where applicable; and

(b) the product is used in accordance with good agricultural practice and label instructions.

It is preferable that alternative methods of termite control (eg physical barriers) be employed where possible.

<u>Control of general household pests</u>

Few exposure studies were available, however they were determined to be unsuitable for regulatory purposes. The risk assessment relied in the main on the relative exposure potential (as determined using POEM) of this end use method compared to post-construction termite control.

Noting that:

(i) the use pattern parameters used to estimate exposure and risk represent a reasonable worst case situation, and

(iii) no suitable exposure data are available for this end use with modelling information used only as a rough guide, however PCOs:

(i) are required to have access to health surveillance facilities in accordance with the NOHSC Control of Workplace Hazardous Substances (NOHSC, 1994c), and

(ii) are adequately trained and accredited and have access to more sophisticated equipment and facilities than other categories of workers,

it is concluded that the overall risk to workers applying chlorpyrifos for general pest control is likely to be acceptable under the following conditions:

(a) exposure mitigation methods specified in Section 7.1.4 are instituted, where applicable; and

(b) the product is used in accordance with good agricultural practice and label instructions.

<u>Mosquito control</u>

A number of exposure studies were available, however they were determined to be unsuitable for regulatory purposes. Model data were used to estimate worker exposure for mixer/loaders and applicators by this method.

Noting:

(i) that the frequency of application by this method is low for some workers (council workers),

(ii) that the end use parameters used in the exposure and risk assessment represent a reasonable worst case scenario,

(iii) insufficient end use information resulted in the use of default estimates, and

(iv) the possible overestimation of risk from exposure estimates obtained from predictive modelling,

it is concluded that the overall risk to workers applying chlorpyrifos for mosquito control is likely to be acceptable under the following conditions:

(a) exposure mitigation methods specified in Section 7.1.4 are instituted, where applicable; and

(b) the product is used in accordance with good agricultural practice and label instructions.

7.1.3 Exposure mitigation methods

<u>Hazardous substances legislation</u>

Chlorpyrifos and products currently registered in Australia are determined to be hazardous substances (refer to Section 7.1). In accordance with Commonwealth/State/Territory Hazardous Substances legislation, the following control measures must be instituted, where applicable (NOHSC, 1994c).

1. Induction and training - Appropriate induction and on-going training of all workers with the potential for exposure to chlorpyrifos products, in relation to those substances in the workplace and commensurate with the risk identified by the workplace assessment process.

It is recommended that appropriate training courses (eg. Farm Chemical User Course or recognised equivalent) be identified for all workers involved in the use of chlorpyrifos products.

2. Workplace assessment - A suitable and sufficient assessment of the risks to health created by work involving potential exposure to chlorpyrifos.

3. Control - As far as practicable, the prevention or adequate control of exposure of workers to hazardous substances should be secured by measures other than the provision of PPE. Control measures should be implemented in accordance with the hierarchy of controls.

It is <u>preferable</u> that the following engineering controls be adopted where possible:

(a) mixer/loaders;
- (i) container/pack designed to minimise spillage, eg. water-soluble packs for WP formulations and wide neck or any other "no-glug" container design for liquid formulations;
- (ii) use of closed mixing/loading (mechanical transfer) systems, eg. closed filling/loading systems or dry coupling; and
- (iii) use of closed mixing techniques for dry mixing of dry formulations (eg WP).

(b) ground applicators;
- (i) use of closed cab tractors – inclusion of air-conditioning and pesticide filters will provide added protection as well as worker comfort.

(c) flaggers in aerial operations;
- (i) use of closed cab vehicles.

It is recommended that industry-based standard operating procedures (including safe work practices) be developed, where appropriate.

The use of PPE for exposure mitigation should be limited to situations where other control measures are not practical or where PPE is used in conjunction with other measures to increase protection. Where PPE is used, it should be selected and used in accordance with the relevant Australian Standards. Protective equipment should be properly selected for the individual and task, be readily available, clean and functional, correctly used and maintained.

4. Health surveillance – OPs including chlorpyrifos are listed on the Schedule for Health Surveillance. Therefore, workers should have access to health surveillance facilities in accordance with the NOHSC Control of Workplace Hazardous Substances (NOHSC, 1994c).

5. Record keeping – Records should be maintained in accordance with the NOHSC Control of Workplace Hazardous Substances (NOHSC, 1994c).

7.2 Post-application

7.2.1 Crop protection

The review indicated that the risk to re-entry workers is likely to be acceptable, provided the chemical is used in accordance with good agricultural practices and label instructions.

The following REPs must be included on the product label:

Restricted-entry period - field crops: Do not allow entry into treated fields until spray deposits have dried. If prior entry is required, limit duration of entry and wear cotton overalls buttoned to the neck and wrist (or equivalent clothing) and chemical resistant gloves. Clothing must be laundered after each day's use.

Restricted-entry period - greenhouses: Do not allow entry into greenhouses until spray deposits have dried and treated areas are adequately ventilated. If prior entry is required, limit duration of entry and wear cotton overalls buttoned to the neck and wrist (or equivalent clothing), chemical resistant gloves and half-facepiece respirator. Clothing must be laundered after each day's use.

Cotton chippers may be at risk of unacceptable exposure during repeated and prolonged re-entry activity. These workers should follow recommended guidelines. To protect cotton chippers, the following REP must be included on the product label:

Cotton chippers: Do not allow entry into treated areas until spray deposits have dried. After this time, wear shoes, or boots, socks, long trousers, long sleeved shirt, gloves and hat.

7.2.2 Pest control

The review identified the main sources of re-entry exposure to be (a) during the application of the moisture membrane following pre-construction termite control or (b) during the re-entry of treated buildings by office staff.

The review indicated that the risk to these workers is likely to be acceptable, provided the chemical is used in accordance with recommended work practices and label instructions.

Products used for pre-construction termite control must carry the following re-entry/re-handling statement:

> **Suspended floors:** allow treated areas to completely dry (normally 3-4 hours) and ventilate buildings before re-occupying
> **Concrete slabs:** cover immediately after treatment with a moisture membrane

Products used for post-construction termite control and general pest control carry the following re-entry/re-handling statement:

> **Re-entry to treated areas:** allow treated areas to completely dry (normally 3-4 hours) and ventilate buildings before re-occupying

7.3 Labeling requirements

As indicated in Section 7.2.1, the following REPs must be included on the product label:

> **Restricted-entry period - field crops:** Do not allow entry into treated fields until spray deposits have dried. If prior entry is required, limit duration of entry and wear cotton overalls buttoned to the neck and wrist (or equivalent clothing) and chemical resistant gloves. Clothing must be laundered after each day's use.

> **Restricted-entry period - greenhouses:** Do not allow entry into greenhouses until spray deposits have dried and treated areas are adequately ventilated. If prior entry is required, limit duration of entry and wear cotton overalls buttoned to the neck and wrist (or equivalent clothing), chemical resistant gloves and half-facepiece respirator. Clothing must be laundered after each day's use.

> **Cotton chippers:** Do not allow entry into treated areas until spray deposits have dried. After this time, wear shoes, or boots, socks, long trousers, long sleeved shirt, gloves and hat.

The REP should be located on the product label as specified in the NRA Code of Practice for Labelling Agricultural Chemicals (NRA, 1997).

As indicated in Section 7.2.2:

(1) Products used for pre-construction termite control must carry the following re-entry/re-handling statement:

> **Suspended floors:** allow treated areas to completely dry (normally 3-4 hours) and ventilate buildings before re-occupying
> **Concrete slabs:** cover immediately after treatment with a moisture membrane

(2) Products used for post-construction termite control and general pest control carry the following re-entry/re-handling statement:

> **Re-entry to treated areas:** allow treated areas to completely dry (normally 3-4 hours) and ventilate buildings before re-occupying

8. REFERENCES

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ATTACHMENTS

ACTIVE INGREDIENT: Chlorpyrifos

ATTACHMENT A POEM Estimates (1 - 20)