

Section 6

OCCUPATIONAL HEALTH AND SAFETY ASSESSMENT

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1. TOXICOLOGY

1.1 Toxic end points

A detailed review of mammalian toxicology and toxicokinetic/metabolism data of endosulfan is available in the separate toxicology report (Department of Health & Family Services (DHFS), 1997). Below is a summary of the main toxicology findings relevant to assigning the toxic end points for the OHS risk assessment.

Endosulfan is of high oral toxicity (LD₅₀ of 9.5 mg/kg in female and 40 mg/kg in male rats), dermal toxicity (LD₅₀ of 106 mg/kg in rabbits, LD₅₀ of 45 mg/kg in abraded skin in rabbits) and inhalation toxicity (13 mg/m³ in female and 35 mg/kg in male rats). It is a slight eye and skin irritant in rabbits and not a skin sensitiser in guinea pigs. At 33.7 % endosulfan EC was a severe eye irritant and a moderate skin irritant in rabbits.

In selecting the most appropriate lowest no-observable-effect-level (NOEL) for the OHS risk assessment, consideration was given to short-term repeat-dose, subchronic, chronic, reproductive and developmental studies.

The toxicology review has concluded that the oral NOEL for endosulfan is approximately 0.6 mg/kg/d based on a 78-week dietary study in mice, 1-year dietary study in dogs and developmental study in rats. In a 13 week dietary study in rats, the toxicology review concluded the NOEL to be 1.92 mg/kg/d based on increases in kidney weights and granular formation in kidney proximal tubule cells, at the next dose of 3.85 mg/kg/d.

Endosulfan is used on a seasonal basis. For OHS risk assessment the 13-week dietary study in rats is considered relevant. The NOEL for OHS assessment is therefore 1.92 mg/kg/d. Lowest-observed-effect-levels (LOEL) in this study was 3.85 mg/kg/d.

Taking into account dermal absorption of 29% (see below), this approximates a dermal dose of 6.6 mg/kg. This dose is close to the NOEL of 9 mg/kg/d achieved in the 30 day dermal rat study.

Genotoxicity of endosulfan was studied in a variety of tests such as gene mutation assays, chromosomal effects assays, cytogenetics assays and cell transformation assays. The toxicology report concludes that endosulfan does not pose a mutagenic hazard.

Endosulfan was found to be very weakly oestrogenic and did not appear to have synergistic effects in combination with other pesticides in binding to oestrogen receptors.

Dermal absorption

TGA assessed four dermal absorption studies on endosulfan. Three were *in vivo* studies in rats and monkeys and one was an *in vitro* study.

The first study (Craine, 1986; cited by DHFS, 1997), treated male rats with ¹⁴C-endosulfan formulated similarly to 3 EC final spray mix at doses of 0.10 mg/kg (LD), 0.76 mg/kg (MD) and 10.13 mg/kg (HD) on 10.8 cm² shaved dorsal skin. Doses were equivalent to 0.002, 0.018 and 0.244 mg/cm². Animals were sacrificed at 0.5, 1, 2, 4, 10 or 24 h after dose

application and the distribution of radioactivity was assessed by routine procedures. At 24 h, systemic absorption was 21.5%, 21.5% and 8.4% for the LD, MD and HD, respectively. Between 57-67% remained at the application site.

Craine (1988; cited by DHFS, 1997) extended these findings using doses of 0.09 mg/kg (LD), 0.98 mg/kg (MD) and 10.98 mg/kg (HD) on female rats, under similar routine conditions to above. The experiment included a skin wash at 10 h and sacrifice of animals at 24, 48, 72 or 168 h after dose application. Doses were equivalent to 0.002, 0.022 and 0.244 mg/cm². Recovery of label was 84-115%. Skin penetration increased with time and skin residues declined over time. By 168 h, systemic absorption accounted for 45, 46 and 20% of the LD, MD and HD, respectively. Most was excreted in the urine and faeces. Only a small proportion of the initial dose remained in the skin, 2% (LD and MD) and 1% (HD).

Lachmann (1987; cited by DHFS, 1997) treated two Rhesus monkeys on the shaved neck and back with an aqueous suspension of 19.025 mg ¹⁴C-endosulfan (equivalent to 2.2 and 3.0 mg/kg). Treated skin was washed after 10 h. Blood, urine and faeces were collected during the experiment and tissue distribution was determined at termination (96 h after the end of exposure). Recovery of label was 50%. Twenty-two per cent was found in carcass, tissue and excreta, 11% was bound to the skin surface and 17% was not absorbed. The main metabolite in the urine was endosulfan-diol.

The final study (Noctor and John, 1995; cited by DHFS, 1997) investigated *in vitro* penetration of ¹⁴C-endosulfan in a formulation similar to the 352 g/L EC, through human and rat skin. Skin samples included intact epidermis and a portion of dermis. Test substance was applied at 0.01 mg/cm² (LD), 0.1 mg/cm² (MD) and 1 mg/cm² (HD) to eight preparations each of rat and human skin. Extra skin preparations treated with HD were washed at 10 h. Samples of receptor fluid were collected at 1, 2, 4, 8, 10, 16, 24, 48 and 72 h (termination). Recovery ranged from 110.8-67.8%. The per cent penetrated across all doses was higher for rat than human skin. At 72 h, the comparisons are:

Dose mg/cm ²	% penetrated rat:human
0.01	95.8:60.6 = 1.6
0.1	75.9:29.4 = 2.6
1	40.2:20.0 = 2.0
1 (with wash at 10h)	9.1: 4.0 = 2.3

The per cent remaining in the skin membrane increased with increasing dose, 13.3-30.7% (rat, unwashed) and 7.4-49.3% (human, unwashed). There was not a reliable trend difference between species.

The study identified endosulfan metabolites in receptor fluid. Rat fluid contained a high percentage of unchanged endosulfan (81.4% total radioactivity). In contrast, human fluid contained less endosulfan (27.3%) and higher amounts of the sulfate (8.3% vs 2.9%), diol (34.0% vs 8.8%) and OH-ether (2.7% vs none detected) metabolites.

The dermal absorption studies suggest that initial absorption is dose related, movement through skin is slow (occurring over 168 h in the rat *in vivo* study), endosulfan continues to be

absorbed from skin reservoirs after skin washing and penetration as per cent and rate is lower in human skin than rat skin. The optimum *in vivo* study for assigning a dermal absorption factor is Craine (1988), as it investigates absorption over the longest time period, includes a skin wash and recovery of label is acceptable. Rat:human data is derived from Noctor and John (1995). Dose selection depends upon the most likely occupational exposure. Predicted hand exposures from POEM for mixer/loaders wearing gloves, indicate an endosulfan concentration of 0.02-0.17 mg/cm², at standard hand size of 820 cm² (US EPA, 1996).

This corresponds to the *in vivo* study MD-HD range with maximum absorption of 46% (MD) at 168 h. In the *in vitro* study, the dose range corresponds to LD->MD range. The rat:human at the LD (maximum absorption) at termination at 72 h is 1.6. The ratio does not change if skin residues are included. Data from the skin wash is not applicable because it relates to the HD only (1 mg/cm²).

The most appropriate dermal absorption factor to use in the risk assessment is 46% / 1.6 = 29%.

1.2 Hazard classification

Active constituent

Endosulfan is listed in the National Occupational Health and Safety Commission (NOHSC) List of Designated Hazardous Substances (NOHSC, 1994a). Concentration cut-offs for endosulfan are:

3.0%	Harmful
25.0%	Toxic
20.0%	Irritant

Following risk and safety phrases have been allocated to endosulfan:

R24/25	Toxic in contact with skin and if swallowed
R36	Irritating to eyes

S28 After contact with skin, wash immediately with plenty of.....[material to be specified by the manufacturer]

S36/37 Wear suitable protective clothing and gloves

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

End use products

All endosulfan products under review are determined to be hazardous substances based on the concentration of endosulfan in each product (approximately 35 % (EC) or 24%-25% (ULV)).

2. OCCUPATIONAL EXPOSURE

2.1 Handling prior to end use

Technical grade endosulfan is imported from various sources. Most of the products are formulated in Australia. Formulators will be potentially exposed to endosulfan and endosulfan products. Transport and storage workers will handle the packaged active constituent or products.

2.2 Use pattern of the end use product

Endosulfan is an organochlorine compound for use as a broad spectrum insecticide on various crops including fruit and vegetables, cotton, cereals, legumes, turf and lawn, tobacco, nursery crops and ornamentals and other miscellaneous crops. Treatment of hides is included on some product labels.

2.2.1 Label information

Emulsifiable concentrate (EC) products

The EC products contain 350 g/L endosulfan. Most of the EC products contain liquid hydrocarbons from 53% to 65%. Thiodan Insecticide and 350 EC Bar Insecticide (Sanonda) contain 62% xylene and Farm-Oz Endosulfan 350 EC Insecticide contains 62% toluene.

The use pattern of EC products is similar and both ground and aerial spraying is possible. In Tasmania, these products must not be applied by aircraft without the specific approval of the registrar of pesticides.

Composite information across the labels indicates the products are used as follows:

Table 1: Endosulfan Insecticide: use rate by crop

Crop	Use rate
Citrus	57 mL/100 L
Fruit and nut trees	150 mL/100 L
Vegetables, some fruits, grapes, tomatoes and nursery crops	190 mL/100 L
Tobacco	125-250 mL/100 L
Broadacre including cereals, legumes, oilseeds, cotton and peanuts	0.5-1.0 and 2.1 L/ha
Turf and lawn	5 mL/20 m ² (2.5 L/ha) in 10 L water

Miscellaneous uses are included on some labels. They include treatment of hides at 2.5 L/100 L (0.9% endosulfan, a light spraying on the skin side), post-harvest dipping of export pineapples (quarantine treatment) at 160 mL/100 L (0.06% endosulfan) and pot plant earthworm treatments at 40 mL/100 m² pot surface or 7 mL/100 L (0.002% endosulfan).

Application rates are specified as mL product/100 L water (defined as high volume) or L product/100 L (defined as low volume). The ranges are 57 mL-190 mL or 200 mL/100 L (0.02-0.07% endosulfan) and 0.5-2.1, 2.5 L/ha or 2.8 L/ha (175-735 g, 875 g or 980 g/ha endosulfan). Knapsack use for vegetables is given as 30 mL/15 L (0.07% endosulfan).

Final ground spray volumes are not provided on the labels, except for some specific uses, for example pecans treated at 1400 L/ha. Both high volume and low volume specifications are given for vegetables. High volume specifications tend to be given for fruit, nuts, nursery crops and ornamentals, some legumes, turf, tobacco and tomatoes. Where necessary, the high volume spray ranges of > 2000 L/ha (trees and bushes) and > 1000 L/ha (row and field crops) (Banks et al., 1994) are used in the exposure assessment. Low volume specifications tend to be given for broadacre crops, including potatoes. Where necessary, the low volume range of 100-400 L/ha for row and field crops given by Banks et al. (1994) is used in the exposure assessment. The NRA use pattern information indicates that pome and stone fruit orchardists may use low volumes of 180-500 L/ha and 50-80 L/ha with electrostatic sprayers. A minimum volume of 50 L/ha spray is recommended to control red legged earth mite.

The labels recommend application by standard equipment, indicating ground boom, airblast and hand directed sprayers for ground application. Greenhouse applications are permissible and are specifically mentioned, for example for ornamentals, on some labels.

Endosulfan is not approved for home garden use.

Aerial spraying volumes are given within the range 10-35 L/ha, considering all products. This corresponds to 2.1-7.4% endosulfan at the most widespread product rate of 2.1 L/ha (735 g endosulfan/ha).

Repeated applications of endosulfan products may be given. They may be as necessary or within particular intervals stated on the labels.

Withholding periods fall within the following broad categories:

vegetables	1 day or 7 days before harvest (crop-dependent)
fruit and nuts	14 days before harvest
pastures, cereals, legumes & oilseeds for stockfood (as applicable)	4 weeks before harvest, grazing or cutting

ULV products

The ULV products contain 240 or 250 g/L endosulfan and hydrocarbon solvents at 30% to 43%.

All registered ULV products have similar use patterns. They are applied by aerial spraying on legumes, cereals, cotton, oilseeds, maize, sweetcorn and sorghum. Labels indicate they are used undiluted.. Repeat sprays may be applied.

The specified rate of application is 1.5 L to 3.0 L/ha (360-750 g endosulfan/ha).

Withholding periods fall within the following broad categories:

peas, beans	1 day before harvest
sweet corn & vegetable	7 days before harvest
other (applicable)	4 weeks before harvest, grazing or cutting for stockfood (as applicable)

2.2.2 User survey information

This information was provided through the Existing Chemical Review Program 1996 NRA Performance Questionnaires No. 1 Large Scale Users, No. 5 Chemical Industry Survey and No. 6 Commodity/Grower Group Survey. Relevant use patterns are given in Tables 2 and 3.

Of the responses to the Large Scale Users Survey: three discussed cotton use, five lucerne use, five canola use, three other broadacre crops, one orchard (apple) use, one strawberry use and two described tomatoes use. In the Chemical Industry Survey, responses were received from Hoechst Schering AgrEvo Pty Ltd (Hoechst), Nufarm Ltd and Sanonda (Australia) Pty Ltd.

The information on use relevant to the exposure assessment is derived from the NRA report, Performance Questionnaire No 1 and labels (Section 3.2.1).

The use patterns revealed by the NRA survey have been incorporated in the Predictive Operator Exposure Model (POEM), to estimate worker exposure and risk during ground application (Table 13, Section 4.3.2).

The aerial spraying use pattern is derived from the labels (Section 3.2.1) and NRA Performance Questionnaires Nos 1 and 5. The questionnaires identify aerial spraying in cotton, tomatoes, lucerne, oilseeds, other legumes and cereals. The area treated per hour ranges from 50-400 hectares. Over a 6 hour spraying day, this equates to 300-2400 hectares, using 225-1800 kg endosulfan, 640-5000 L of the 35% EC product or 900-7200 L of the 25% ULV product. At maximum container sizes (200 L EC or 1000 L ULV), this corresponds to 3.2-25 x 200 L or 0.9-7.2 x 1000 L containers.

Table 2: Large scale users; NRA Performance Questionnaire No. 1

Crop	Area treated ha/hr	Application rate	No of applications per season	Method of application	Region	Comments relevant to OHS
Apple	1	190 mL/100 L	1-5	airblast (used a cab with filters)	Bilpin, Blue Mountains, NSW	Have to use at the maximum recommended rates to be effective; uses open mixing
Canola; pasture (establishment)	not provided	500 mL/ha	1	aerial spraying	Keith, SA	Tank mix with either foliar fertilisers, pirimicarb, or malathion
Canola	40	500 mL/ha	1	boomspray	Charlton, Vic	Tank mixes sometimes
Canola	15	0.5-1.0 L/ha	1	boomspray	Old Junee, NSW	No tank mixing
Peas; canola	15-25	500 mL /ha	1	boomspray	Kendenup, WA	Tank mix with residual insecticide and other insecticide
Lucerne for seed	20	600-800 mL/ha	2	high volume boomspray with Airtec nozzles	Keith SA	Tank mix after professional advice
Lucerne for seed	100 (air);	0.8 - 1.2 L/ha (air);	2	aircraft	Keith, SA	Tank mix with foliar fertilisers or malathion
Lucerne establishment; canola	30 (ground)	0.5 L/ha (ground)	1	boomspray or mister		
Lucerne for seed	200 - 400	1 L - 1.5 L/ha	1-2	aerial spraying	Keith, SA	Tank mix with either foliar fertilisers, pirimicarb, or malathion
Lucerne seed crops (mature plants); other crops (mature plants and crop establishment)	40-50	0.5-1.2 L/ha	1-2	groundboom with air-assisted nozzles (Airtec)	Keith, SA	Tank mix with fertilisers and other pest controls
Lucerne for seed	20	400 mL/ha	2	boomspray with Airtec air-assisted nozzles	Bitown, SA Carbrook, Qld	Tank mix with compatible fungicides and miticides; packaging difficult to handle

Table 2: continued

Crop	Area treated ha/hr	Application Rate	No of applications per season	Method of application	Region	Comments relevant to OHS
Strawberries; tomatoes	1.5	190 mL/100	1 or as required	boomspray and air shear boom	Bracalba, Qld	Tank mix with Benlate (benomyl), Bt, Rovral (iprodione), spin (carbendazim), Thiram; Five litre tin containers are difficult to pour
Processing tomatoes	200 (air) or 4-15 (ground)	2.1 L/ha	1-2	aircraft or boomspray	Leeton, NSW	May be tank mixed with Mancozeb, Wettable sulphur or Sethoxydim (herbicide); Handling of 205 L drums a problem because of weight and size and spillage can occur. Special mixing tanks are now used; workers hand weeding can be affected by fumes for a couple of days after application, if sensitive
Cotton	20-50 acres/hr (ground, band spraying); 500 acres/ hr (aerial)	3.0 L/ha (aerial) or 2.1 L/ha	3	boomspray with T4 nozzles or aerial spraying	Bowenville, QLD	Tank mix with Folimat (omethoate), Larvin (thiodicarb); Design of the packaging drums could be improved
Cotton	not provided	3.0 L/ha (air); 2.1 L/ha (ground)	approximately 5	aircraft or boomspray with directed nozzles	Trangie, NSW	Tank mix with foliar fertilisers, Bt, dimethoate, or carbamates
Cotton; legumes; sunflower	400 (air); 50 (ground)	EC 2.1 L/ha ULV 3.0 L/ha	4-5 (cotton) 1-2 (legumes and sunflower)	aircraft or boomspray with hollow cone nozzles	Toobeah, Qld	Tank mix EC with foliar fertilisers; EC and ULV are mixed with Ovasyn (amitraz), organophosphates and Bt
Not provided	not provided	not provided	not provided	aircraft or ground rig	Kununurra, WA	Not provided

Table 3: Chemical Industry Survey; NRA Performance Questionnaire No. 5

Crop	Area treated ha/hr	Application Rates	Method of application
Cotton, vegetables, fruit crops and nuts, bare soil, pastures and cereals	cotton 200 ha (ULV); veg 2 ha (EC); cereals/canola 10 ha (EC)	cotton, 2.1 L/ha; veg, up to 2.1 L/ha; fruit, 1.5-2.8 L/ha; cereals, 0.5-1.0 L/ha	Air-low volume, boomspray or knapsack
Cotton	50-150 or 10-20 (EC)	2.1 L/ha (20-30 L/ha, air-LV) or (50-500 L/ha, boomspray)	Air-low volume (EC) or boomspray
Tomatoes	50-150 or 3-8 (EC)	2.1 L/ha	Air-low volume or boomspray
Vegetables pome & stone fruits	2-8 ha (EC)	2.1 L/ha (veg) or 190 mL/100 L (fruit)	Boomspray high volume airblast (fruit)
Sunflower, soybeans, lucerne canola and cereals	50-150 or 5-15 (EC)	2.1 L/ha or 0.5 to 1.0 L/ha	Air-low volume or boomspray
Tobacco	1-3 (EC)	125-250 mL/100L	Boomspray
Tropical fruits	2-5 (EC)	150 mL/100 L	High volume airblast
Bananas and avocado	1-3 (EC)	150 mL/100 L	Mister
Grape vines	2-5 (EC)	190 mL/100 L	High volume airblast
Ornamentals	< 1 (EC)	190 mL/100 L	Hand wand/nozzle
Cotton	50-150 (ULV)	3.0 L/ha	Air-ULV
Summer and winter oil seeds	50-150 (ULV)	3.0 L/ha	Air-ULV
Sorghum	50-150 (ULV)	3.0 L/ha	Air-ULV

2.3 Exposure information

Various sources of endosulfan exposure information are of relevance to the OHS risk assessment. Reports include poisoning incidents resulting from possible deliberate ingestion, health effects resulting from occupational exposure, direct measured exposure studies and re-entry exposure. Possible deliberate poisoning incidents and adverse health effects in workers provide useful information on the magnitude of acute and long term endosulfan toxicity in humans and help define the likely causes of poisoning incidents. Studies where exposure is measured or estimated under normal use conditions were provided by Hoechst. Relevant information is described below.

A public submission from Greenpeace Australia Ltd included a Greenpeace report on the effects of chlorine pesticides on human health (Allsopp et al., 1995). The report covers the

human health effects of organochlorine pesticides in general. It is not reviewed further here as it does not contain specific information concerning occupational exposure to endosulfan.

2.3.1 Poisoning incidents and illness reports involving agricultural workers

The DHFS assessed a number of reports on possibly deliberate endosulfan ingestion by humans Demeter et al. (1977), Demeter and Heyndrick (1978), Bernardelli and Gennari (1987), Shemesh et al. (1988), Sauer et al. (1989), Blanco-Coronado et al. (1992), Segasothy and Pang (1992), Lo et al. (1995) and Grimmet et al. (1996).

The Hoechst submission contained a summary of Bernardelli and Gennari (1987), Shemesh et al. (1988), Sauer et al. (1989) and additional deliberate poisoning reports (Leist and Lehr, undated, a). Human lethal doses of 35 mg/kg bw and 295 and 467 mg/kg bw are reported. The 35 mg/kg bw dose was lethal despite therapeutic treatment. Doses of 100 and 1000 mg/kg bw were not lethal in patients able to receive intensive medical treatment shortly after intoxication. The 1000 mg/kg bw patient (Shemesh et al., 1988) suffered long term health effects.

2.3.2 Health effects resulting from occupational exposure

Hoechst provided a statement on medical surveillance of manufacturing plant personnel (Leist and Lehr, undated, b). It describes the type of examination given and details one exposure incident in 1971. It states that “no abnormal changes were observed at the routine examinations or at any check-up following accidental skin contamination”. The Hoechst submission contains information from the California Department of Food and Agriculture (CDFA) mandatory reporting system for physicians plus a covering summary letter by Leist and Lehr (undated, c). It includes actual reports over the years 1974-1986, and summaries for 1949-1986 (Maddy et al., 1990) and 1976-1986 (Volger, 1988, unpublished). No deaths were due to the use of endosulfan.

CDFA records over the years 1976-1987 (inclusive) implicate endosulfan in 89 incidents where medical advice was sought. According to Maddy et al. (1990) this figure would be an underestimate as it does not include incidents where medical advice was not sought and would not include most exposure incidents for self employed persons. Suspected chronic effects, such as cancer induction, developmental or reproductive effects are not included in the statistics.

Of the 89 cases involving endosulfan from 1976-1987, 47 involve mixtures and 42 concern endosulfan alone. Exposure to field residues accounted for 40% of episodes involving endosulfan alone. Other groups reporting incidents with endosulfan alone included ground applicators (2), hand applicators (3), manufacture/formulation workers (3) and mixer/loaders for aerial applicators (1). Co-incident exposure (spray drift) and a transport accident accounted for the remainder.

Cases concerning endosulfan alone involved systemic and topical effects (mostly skin rashes).

Volger (1988), in analysing the 1976-1980 endosulfan data noted that the incidence rate for all workplace related illnesses/injuries in California farm field workers was 8 per 100 employees. In comparison, the rate for endosulfan of 0.0032 per 100 employees was low.

McMullen et al. (undated) investigated pesticide exposure (RBC and plasma ChE activity, pre- and post-exposure samples), pesticide usage, work practices and use of protective clothing in fruit and vegetable growers in New South Wales, Australia during 1992-1993. Endosulfan was used by fruit and vegetable growers in the region studied. A high percentage of fruit growers (76.6%, 111/145) and vegetable growers (81%, 47/58) felt that pesticides had at some time affected their health. The findings on protective clothing suggested that a high number of growers did not wear adequate PPE. For instance, only 69% of fruit growers and 53% of vegetable growers wore gloves for mixing. The report concluded that inadequate safety precautions were practiced within the industry. The report did not identify any particular health effects from endosulfan.

A number of papers investigate chromosomal aberrations in peripheral lymphocytes of cotton field workers exposed to a mixture of pesticides including endosulfan (Rupa et al., 1989, 1991a, 1991b). There was a significant increase in chromosomal aberrations in the exposed population compared to controls but the particular contribution of endosulfan could not be defined.

2.3.3 Biological monitoring for endosulfan

Experimental studies assessed by the TGA on the metabolism and toxicokinetics of endosulfan in animals suggest that it is absorbed to a moderate to high extent after oral ingestion. Across species, excretion is essentially complete within the first couple of days, with more excreted in the faeces than in the urine. Faecal excretion in mice includes unchanged endosulfan and the sulphate and diol metabolites. Only the diol metabolite is found in mouse urine.

Tordoir and van Sittert (1994) discuss medical health surveillance and biological monitoring for humans exposed to organochlorines. The authors do not consider endosulfan in particular, but recommend either blood or urine sampling, depending on the length of the exposure period and anticipated half life in humans. There is no biological exposure index (BEI) available for endosulfan.

Biological monitoring has only been used to a limited extent in monitoring endosulfan exposure in workers.

Chandra et al. (1992) reported on biological monitoring of organochlorines, including endosulfan on 52 pesticide sprayers in mango orchards and compared results with 24 unexposed workers. The study was designed to investigate endosulfan residues following repeated use and not to define a daily or acceptable exposure. Dermal exposure was not measured and the exposed workers did not use a respirator, gloves or coveralls. Airborne endosulfan ranged from not detectable to 216.2 ng/m³, which is low in comparison to the NOHSC exposure standard of 100, 000 ng/m³. Endosulfan was detected in urine and serum. Values were higher in exposed than control workers but the difference was significant only for serum.

2.3.4 Measured worker exposure studies

Measured exposure studies on endosulfan were submitted by Hoechst. The studies were conducted in Germany and California in the USA and relate to airblast or mist blower applications or hand held applications in orchards. The studies are entitled:

- (1) Study File/Issue No. 5-End/89039, Project No. 24587, Exposure of Mixer/loader/applicators to Thiodan^R 3 EC Insecticide Applied to Fruit Trees by Airblast Equipment in California, 1987, dated 16 November 1990 (Baugher, 1990).
- (2) Endosulfan; emulsifiable concentrate; 352 g/L (Hoe 002671 OI EC33 B316), Endosulfan; oil in water emulsion; 350 g/L (Hoe 002671 OI EW31 A104), Comparative examination of the user exposure during handling and application of an emulsifiable concentrate (EC) (352 g/L) and an oil in water emulsion (350 g/L) of Thiodan. Authors: Idstein, Wolf and Merz, Report No OE89/184, Project No. RK-120/08. Study completed on 23 March 1989.
- (3) Endosulfan; emulsifiable concentrate; 352 g/l (Hoe 002671 OI EC33 B313), Examination of the user exposure during handling and application of Thiodan 35 liquid, using a knapsack sprayer. Authors: Idstein, Wolf and Merz, Report No RK-112/12. Study completed on 10 August 1992.

The studies are described below:

(1) Study File/Issue No. 5-End/89039, Project No. 24587, Exposure of Mixer/loader/applicators to Thiodan^R 3 EC Insecticide Applied to Fruit Trees by Airblast Equipment in California, 1987 dated 16 November 1990 (Baugher, 1990).

The study was conducted under US EPA Pesticide Assessment Guidelines, Subdivision U: Applicator Exposure Monitoring and sponsored by Hoechst-Roussel Agri-Vet Company, Somerville, New Jersey US.

The study monitored the systemic, dermal and inhalation exposure of workers mixing/loading and applying Thiodan^R 3 EC Insecticide containing the active ingredient (ai) endosulfan. Technical endosulfan was a mixture of alpha and beta isomers in a 70/30 ratio. The study was conducted in August 1987 in orchards near Farmersville and Snelling, California. Mature plum and apple trees were treated by tractor-drawn airblast sprayers. Mixer/loader/applicators (M/L/A) were monitored over the entire day. Exposure was estimated from dosimeters and excretion of urinary endosulfan metabolites. It was not measured for separate tasks.

The product was open-poured from a 5-gallon can into a 1 gallon pitcher, then poured into the spray tank, or it was loaded into the spray tank by a closed induction system. All tractors had cabs, namely positive pressure air-conditioned Nelson cabs, open-window Case cabs or a cab with plastic dome windows and canvas skirts. The application rate was 3.36 kg ai/ha at both sites. This compares with application of 1.33 kg ai/ha (190 mL 35% EC/100L in 2000 L spray/ha) on the Australian Thiodan Insecticide label for fruit trees (pome and stone). At Farmersville, the spray was 719 mg ai/L and applied at 4674 L/ha. At Snelling, the spray was 2337 mg ai/L and applied at 2340 L/ha. Twelve workers were monitored for a total of 18 replicates, 3 workers per day for 6 days (3 days at each location). Each replicate was a full day of, 8 to 10 tankloads. During this time workers handled from 13.64 kg ai (over one day) to 54.55 kg ai (over 2 days).

Workers wore long denim trousers and long sleeved cotton/polyester shirts. They also wore an apron, chemical resistant gloves, and goggles while mixing/loading.

Chromatography paper and glassine dosimeters were attached to the inside of the clothing. The chest and back dosimeters were used to calculate exposure to the face and front and back of neck. Hand exposure was estimated from water rinses. Inhalation exposure was monitored by attaching a personal air pump set at 2 L/min and equipped with a 600 mg charcoal tube to each worker during a part of the work period (usually 5 tank loads). Dosimeters, described as multilayer, and pumps were also placed outside tractor cabs for a corresponding length of time to simulate monitoring of worker exposure while spraying from an open tractor. Dermal and inhalation exposure from dosimeters is summarised in Table 4 using the geometric mean (GM) and range.

Table 4: Dermal and inhalation exposure to Thiodan 3 EC using open pour and closed mixing systems and airblast equipment in apple and plum orchards (dosimeter data)

Task scenario	Dermal Exposure ug/kg ai handled GM ± GSD (range)	Inhalation Exposure ug/kg ai handled* GM ± GSD (range)
<u>Mixer/loader/applicator</u>		
1. Open-pour, Nelson cab with positive pressure and A/C:	n = 6 91.4 ± 2.2 (49.77-353.45)	n = 3 3.5 ± 1.5 (2.66-5.48)
2. Open-pour, Case cab with open windows:	n = 3 1106.2 ± 2.6 (465.56-2991.84)	n = 4 10.4 ± 4.7 (5.61-13.49)
3. Closed-system, Nelson cab with positive pressure and A/C:	n = 6 62.6 ± 2.4 (22.79-232.10)	n = 3 1.2 ± 9.7 (0.15-43.49)
4. Closed-system, canvas skirt cab with plastic dome windows:	n = 3 72.7 ± 2.3 (38.73-187.81)	n = 3 5.9 ± 3.2 (1.54-13.42)
Sprayer only (outside tractor cab) All tractors	n = 18 1510.3 ± 3.0 (248.05-38,403.68)	n = 13 18.0 ± 3.6 (4.33-759.48)

Source: Exposure of Mixer/loader/applicators to Thiodan[®] 3 EC Insecticide Applied to Fruit Trees by Airblast Equipment in California, 1987, revised version 16 November 1990 (Baugher, 1990).

* Inhalation exposure while using Thiodan EC

Inhalation exposure was 0.9% to 8.2% of dermal exposure. The highest inhalation exposure would be for an applicator on an open tractor (18.0 ug/kg ai), followed by an applicator using a cab with an open window (Case cab, 10.4 ug/kg ai).

Similarly, highest dermal exposure would be for an applicator on an open tractor (1510.3 ug/kg ai), followed by an applicator using a cab with an open window (Case cab, 1106.2 ug/kg ai). Lowest dermal exposure was observed in a M/L/A using enclosed mixing and a positive pressure airconditioned cab (Nelson cab, 62.6 ug/kg ai). Slightly higher exposure was seen for a worker using the same cab but open mixing (Nelson cab, 91.4 mg/kg ai).

Enclosed cabs reduced dermal exposure by > 90% and inhalation exposure by > 65% compared with either no cab or a cab with an open window.

Workers in enclosed cabs had similar contamination beneath the clothed body and on the face and neck. Workers using the cab with open windows had most contamination beneath the clothed body. All workers had low and similar contamination on the hands.

Urinary excretion of the metabolite endosulfan-diol was measured as an indicator of endosulfan uptake and to estimate internal endosulfan dose and skin exposure.

No residues of endosulfan-diol were recovered from the workers urine samples, even the M/L/A using the cab with open windows. However, Baugher estimated absorbed dose and dermal exposure from the urinary metabolite, using a value of 50% of the limit of detection (1 ug/L). The calculations used dermal absorption and excretion parameters from the study in Rhesus monkeys (Hoechst AG Document No. A 36685, Lachmann G, Dermal Absorption of ¹⁴C-Endosulfan in Rhesus monkeys. Unpublished Report, May 9, 1987). They included 82.6% of the administered (10 h) dose absorbed and 1.93% of the administered dose excreted as endosulfan-diol.

As the endosulfan diol metabolite was not detected, it was not possible to differentiate between worker groups. For all workers, endosulfan absorbed dose was 8.869 ug/kg ai handled (GM). The corresponding dermal exposure of 10.737 ug/kg ai handled, was lower than potential measured dermal exposure in any of the M/L/A groups.

Measured exposures are standardised to the Australian use pattern and used to assess worker risk in Section 4.

(2) Endosulfan; emulsifiable concentrate; 352 g/l (Hoe 002671 OI EC33 B316), Endosulfan; oil in water emulsion; 350 g/L (Hoe 002671 OI EW31 A104), Comparative examination of the user exposure during handling and application of an emulsifiable concentrate (352 g/l) and an oil in water emulsion (350 g/L) of Thiodan. Authors: Idstein, Wolf and Merz, Report No: OE89/184, Project No. RK-120/08. Study completed on: 23 March 1989.

The study was sponsored by Hoechst AG, Geschäftsbereich Landwirtschaft Produktentwicklung - Ökologie II - Hessendamm 1-3, 6234 Hattersheim. The study was conducted under the Good Laboratory Practice (GLP) regulations.

The study compared end user exposure during applications of Thiodan 35 Liquid, an EC (352 g/L, 0.5 L container), and a recently developed "oil in water" emulsion (EW, 350 g/L, 1 L container). The products were applied by a narrow-track tractor (without cab) with a mounted mist blower (capacity 400 L) with hollow cone nozzles, to high-growing crops, namely apples and pears.

Both products were applied at 1.5 L/ha in 500 L water/ha (a worst case spray concentration of 0.3%). The 4-day field trial was conducted at various locations in Germany. Separate formulations were applied each day with 2 days per formulation. There were 6 applications per day with samples taken after the second application. The applications were divided into operations of mixing/loading, application and cleaning of spray equipment. Each operation was carried out by a separate worker and monitored separately. There were 12 mixing/loading and application replicates and 4 cleaning replicates. Mixing/loading replicates used 2 operators for 0.2-0.5 h; application replicates used 2 operators for 0.8-1.0 h and cleaning replicates (one operation) lasted about 0-2 h.

Weather conditions were monitored near the trial fields on the days of testing.

Workers wore a peaked cap and solid shoes, dungarees and a 100% cotton jacket over normal work clothes. They also wore plastic gloves and goggles during preparation and application of the spray liquid. Applicators wore a half mask respirator with a combination filter. The protective suit and gloves complied with BBA crop protection requirements.

Dermal exposure on and below the protective clothing was determined via filter papers (pads) and ethanol rinsing of hands and gloves. To measure inhalation exposure, air was aspirated from the workers respiratory area via adsorption tubes (Tenax), using personal air samplers with a suction capacity of 30 L/min. All samples were stored frozen until analysis for endosulfan (alpha and beta isomers) via extraction and gas chromatography.

Recoveries and storage stability were determined by laboratory and field spiking. Field recovery from hand washings was adjusted to cover the 40% recovery. Details of analytical methods and quality controls are given in the study.

Mixer/loaders added the concentrate directly to the partially filled spray tank from the container or using a graduated beaker. Empty containers were rinsed and the spray tanks filled up to 400 L. Cleaners loaded the spray tank with approximately 50 L of water and sprayed out over the treated area. They hosed the sprayer and tractor and simulated dismantling the sprayer from the tractor.

Results

Results were pooled across both formulations because of only minor differences between the two and presented as mg ai/person/kg ai handled. Greater differences were found between individuals.

The greatest exposure was observed on the outer side of the gloves of the mixer/loader handling the undiluted product (5.92 to 78.13 mg ai/person/kg ai handled). Table 5 shows potential exposure from the individual routes, giving the GM and range.

Inhalation exposure during all three tasks was low, contributing 0.8%, 0.5% and 2.5% of total exposure for mixing/loading, application and cleaning, respectively. Applicators experienced the highest dermal exposure, of which most was on the head area, followed by contamination below protective clothing and beneath gloves. Mixer/loaders had similar exposure on the head and beneath protective clothing and gloves. Cleaners had lowest exposure, also similar

across the head and beneath protective clothing and gloves. Total exposure was highest for applicators (3.6 mg ai/person/kg ai handled), followed by mixer/loaders and cleaners (0.18 and 0.02 mg ai/person/kg ai handled, respectively).

Table 5 Dermal, inhalation and total exposure (mg ai/person/kg ai handled) for mixer/loaders, applicators and cleaners involved in applying endosulfan by mistblower to high crops

Task (replicates)	Inhalation exposure GM (range)	Dermal exposure GM (range)			Total potential exposure ¹ GM (range)
		head	below protective clothing	hands	
Mixing/loading (n = 12)	0.0015 (0.0003-0.0057)	0.058 (0.012-1.16)	0.039 ² (0.21-0.084)	0.058 (0.008-0.627)	0.18 (0.05-1.19)
Application (n = 12)	0.017 (0.006-0.060)	3.41 (0.80-29.46)	0.15 (0.05-0.85)	0.017 (0.008-0.067)	3.6 (0.88-30.42)
Cleaning (n = 4)	0.0005 (0.0002-0.0014)	0.009 (0.002-0.028)	0.004 ³	0.007 (0.002-0.029)	0.02 (0.009-0.058)

Source: (Idstein et al., 1989)

1. geometric mean (GM) of total exposure of test persons (not of parts of body). Potential exposure is that available for uptake
2. mean of 4 values
3. only one value was determined

The study authors calculated a GM exposure of 22.2 mg ai/person/day for an 8-hour working day during which one worker did 1.5 hours of mixing/loading, 6 hours of application and 30 minutes of cleaning. The study application rate of 1.5 L/ha (525 g ai/ha) corresponds to 5.84 kg ai/task or spraying for 11 ha/day.

Exposure on the outside of protective clothing and on the gloves was given in the report. Maximum penetration through gloves was 4.2%, 3.5% and 4.3% for mixer/loaders, applicators and cleaners, respectively. However replicate times were a fraction of a work day (0.5 h maximum for M/L/A and 1.0 h maximum for applicators).

Maximum penetration through protective clothing during application was 2.2%. Penetration through clothing for mixer/loaders was very variable (0.2-57.6%) because of the spasmodic nature of contamination. Information on clothing penetration for the cleaner was limited to one worker only and indicated 3% penetration.

The total potential exposures from this study are used to assess the risk to Australian workers applying endosulfan in pome fruit orchards (Section 4).

(3) Endosulfan; emulsifiable concentrate; 352 g/l (Hoe 002671 OI EC33 B313), Examination of the user exposure during handling and application of Thiodan 35 liquid, using a knapsack sprayer. Authors: Idstein, Wolf and Merz, Report No:RK-112/12. Study completed on : 10 August 1992.

The study was sponsored by Hoechst AG, Geschäftsbereich Landwirtschaft Produktentwicklung - Ökologie II - Hessendamm 1-3, 6234 Hattersheim. The study was conducted under GLP regulations.

The study investigated end user exposure during mixing/loading and application of Thiodan 35 liquid EC formulation (325 g ai/L, 0.5 L container) to high-growing apple crops in Germany. Applicators used a motor-driven knapsack sprayer (without carrier air stream) with spray lance and hollow cone nozzles. Product was applied at 1.5 L/ha. The aim to apply 1500 L water/ha was approximated on days 1 and 2 but day 3 used 796 L/ha because of a difference in foliage density.

The exposure was determined separately for mixing/loading and application.

The trial was conducted over 3 days, on late-ripening apple varieties (2 days) and trees where fruit was already harvested (one day). Each day, 5 exposure replicates with 2 operations/replicate, were conducted for mixing/loading and application. Mixing/loading and application replicates were of approximately 7 minutes and 35 minutes duration, respectively. On days one, two and three, 0.12, 0.11 and 0.2 ha were treated, respectively, over 10 mixing/loading and application cycles.

Weather conditions were monitored near the trial fields on the days of testing.

Workers wore dungarees and a jacket made of cotton blended fabric over normal work clothes, plastic gloves, goggles, a peaked cap and solid shoes during preparation and application of the spray liquid. Applicators also wore fine dust filter mask. The protective suit and gloves complied with the BBA crop protection requirements.

Dermal exposure was estimated using filter paper pads fixed on or below the protective clothing and ethanol rinsing of hands. Head area exposure was estimated from pads located on the head and adjacent body parts. For inhalation exposure, all test persons were equipped with a personal air sampler (Tenax tubes) with a suction capacity of 120 L/min. All samples including gloves were stored frozen until analysis for endosulfan (alpha and beta isomers) via extraction and gas chromatography.

Recoveries and storage stability was determined by laboratory and field spiking. Details of analytical methods and quality control are given in the study. Recoveries did not require correction. One sample was taken from each spray tank filling per replicate. The mean spray concentration of 356 ug ai/mL of ai was almost equivalent to the recommended spray concentration of 352 ug ai/mL.

Mixer/loaders half filled the spray tank with water, measured 16 mL of concentrate into a volumetric cylinder using a funnel, added the concentrate to the tank, stirred it in with a wooden stick and filled the tank up to volume (16 L). The applicator shouldered the sprayer and after moving to the application area, sprayed along the tree rows in an upwards and downwards movement. Applicators moved away from direct contamination with spray mist.

Results

Exposures on protective gloves for mixer/loaders ranged from 115-5575 mg ai/person/kg ai handled. Hand exposure was below the limit of determination (LOD) of 2 ug ai/sample in 11 of 15 replicates, and just above the LOD in the remaining 4 replicates. From all results, the penetration of endosulfan through gloves was < 0.1%. However, M/L replicates only averaged 7 minutes. Exposure on and below covered body surfaces was similar for mixer/loaders. Most values were close to or below the LOD (0.01 ug ai/sample).

During application, glove contamination was 11.5-159.3 mg ai/person/kg ai handled and hand contamination was 0.088-1.86 mg ai/person/kg ai handled. Maximum penetration was 5.8%. Application replicates averaged 35 minutes only.

Potential dermal and inhalation exposure for the two worker groups (GM, range, as mg ai/person/kg ai handled) is given in Table 6. Applicators had exposure of 1.56 mg ai/person/kg ai handled beneath clothing. Clothing penetration was estimated at a maximum of 2.2% (over an average of 35 minutes).

Head area exposure was low for mixer/loaders and higher but very variable (1.05-230.4 mg ai/person/kg ai handled) for applicators.

Inhalation exposure was below the LOD (0.04 ug ai/Tenax tube) for mixer/loaders and 0.49 mg ai/person/kg ai (GM) for applicators.

Table 6: Dermal, inhalation and total exposure (mg ai/person/kg ai handled) for mixer/loader and applicators involved in applying endosulfan to high crops by hand spraying

Task (replicates)	Inhalation exposure GM (range)	Dermal exposure GM (range)			Total potential exposure ¹ GM (range)
		head	below protective clothing	hands	
Mixing/loading n = 15	0.024 ² (0.023-0.025)	0.08 ³ (0.019-0.303) (222 ⁴)	0.17 ² (0.13-0.36)	0.12 (0.09-0.45)	0.51 (0.26-0.72) (57.76 ⁴)
Application n = 15	0.49 (0.09-1.64)	21.5 ³ (1.1-230)	1.56 (0.17-20)	0.15 (0.09-1.86)	25.16 (1.73-235.16)

Source: (Idstein et al., 1992)

1. geometric mean (GM) of total exposure of test person (not of parts of body). Potential exposure is that available for uptake
2. all values were below the determination limit of 0.04 ug ai/Tenax tube
3. calculated in accordance with US EPA
4. outlier (chest pad was contaminated)

The GM total exposure was 0.51 mg/person/kg ai for mixer/loaders, and 25.16 mg/person/kg ai for applicators.

Results are used to assess the risk to Australian workers applying endosulfan by hand spraying in pome fruit orchards (Section 4).

2.3.5 Measured worker exposure during re-entry

No worker exposure studies relevant to re-entry into endosulfan treated areas were submitted by registrants for assessment.

No data on foliar dislodgeable residues were submitted for assessment.

A research study undertaken by the Agricultural Health Unit, Moree District Hospital (Clarke and Churches, 1992), investigated potential pesticide exposure of cotton chippers in the Gwydir Valley in the North-West of NSW in 1991 and 1992. Chipping refers to the use of a short hoe to chip out weeds. The study estimated pesticide exposure over the growing season. It used depression of erythrocyte cholinesterase as an indirect indicator of exposure to all classes of pesticide and as a direct indicator of exposure to organophosphate pesticides. In addition, investigators measured the distribution of pesticide over different parts of the body in the course of chipping work. The study included recommendations for research on re-entry intervals and appropriate clothing for workers and for improved practices and facilities for chippers within the cotton industry.

There was no evidence of acute toxicity amongst the cotton chippers who participated in the study despite the fact that erythrocyte cholinesterase was significantly depressed in cotton chippers compared to control values. More than 19% of chippers reported problems with skin rashes on the forearm and lower legs (Note the causes were not ascertained).

The investigation of residue distribution on chippers used two fields sprayed with endosulfan, widely used in cotton industry, and one field sprayed with profenophos. Only the endosulfan data is reported here. Four volunteers were dressed in specially designed calico whole body suits, calico over-boots, whole cotton gloves, surgical theatre caps and half-face respirators with activated charcoal filters. They entered the endosulfan treated crops (249 g/L ULV, 3.0 L/ha) and chipped for one hour. In Trial 1 the field had been sprayed 7 hours earlier and had a crop height of approximately 30 cms. In Trial 2 the field had been sprayed 24 hours earlier and had an approximate crop height of 50 cms. The results of the trials giving arithmetic mean deposition rate ($\mu\text{g}/\text{cm}^2$) on various body part, surface area and calculated exposure is given in Table 7 and Table 8. This report has estimated whole body exposure using standard body part sizes from the US EPA Occupational and Residential Exposure Test Guidelines (US EPA, 1996).

Table 7: Endosulfan exposure (crop height 30 cm, Trial 1) during re-entry by cotton chippers after 7 hours of application

Body part	Mean deposition rate ¹ $\mu\text{g}/\text{cm}^2$	Surface area ² cm^2	Calculated exposure μg
Head	0.28	1300	364
Hands	0.96	820	787
Forearms	0.19	1210	230
Upper arms	0.07	2910	204
Chest	0.04	3550	142
Back	0.02	3550	71
Upper thighs	0.78	3820	2980

Shins/knees	2.68	2380	6378
Feet/ankles	0.77	1310	1009
Total exposure			12165 ug

1. Clarke and Churches (1992), one hour chipping time
2. US EPA Occupational and Residential Exposure Test Guidelines (1996)

Table 8: Endosulfan exposure (crop height 50 cm, Trial 2) during re-entry by cotton chippers after 24 hours of application

Body part	Mean rate ¹ ug/cm ²	deposition	Surface area ² cm ²	Calculated exposure ug
Head	0.67		1300	871
Hands	3.0		820	2460
Forearms	1.22		1210	1476.2
Upper arms	0.14		2910	407
Chest	0.03		3550	107
Back	0.05		3550	178
Upper thighs	1.64		3820	6265
Shins/knees	2.5		2380	5950
Feet/ankles	1.58		1310	2070
Total exposure				19784 ug

1. Clarke and Churches (1992), one hour chipping time
2. US EPA Occupational and Residential Exposure Test Guidelines (1996)

Total calculated exposure was 12.2 mg and 19.8 mg in Trials 1 and 2, respectively suggesting that an extension in the re-entry time from 7 to 24 hours did not compensate for an increase in crop height. Highest exposures were found on the legs and feet, followed by the hands and forearms and head. Clarke and Churches incorporated a factor for the relative percutaneous absorption rate per body part. Using this, the highest contribution to absorption came from the legs, feet, hands and forearms. The clothing worn by over 50% of the chippers surveyed was shoes or boots, shorts, short-sleeved shirt and a hat. Only 21% wore gloves. The study recommended that, as a minimum requirement, chippers should wear shoes or boots, socks, long trousers, long sleeved shirt (sleeves to be worn down), gloves and hat. Section 4.4 estimates the risk to chippers working in endosulfan treated fields over the day, wearing the recommended clothing.

The report describes an incident where chippers were subjected to endosulfan spray when the wind changed during an aerial spraying operation. Droplets fell on the skin and clothing. Predominant symptoms experienced by at least ten of the sixteen chippers were throat irritation/sore throat, headache, eye irritation and cough. The contribution of endosulfan or the solvent in the product could not be separated.

Hoehst referenced a 1992 statement of W. Lehr on re-entry in the submission. The statement quoted US EPA and California Department of Agriculture re-entry intervals (24 and 48 hours, respectively). The statement indicates a re-entry period of 2 to 3 days. No data has been provided to support this recommendation.

3. RISK ASSESSMENT

Workers may be exposed to endosulfan when mixing/loading, applying spray, cleaning up spills and maintaining equipment. In addition re-entry workers may contact endosulfan residues on treated foliage. Re-entry tasks would include crop checking and maintenance, manual weeding (eg in cotton crops) and harvesting.

The vapour pressure of endosulfan is low (9×10^{-3} mm Hg at 20°C), indicating that inhalation of vapours from the concentrate is unlikely.

The main routes of occupational exposure will be through skin contamination while performing any routine tasks. Sprayers may inhale spray mist.

Agricultural workers whether farm-based operators or contract sprayers, may be repeatedly exposed to endosulfan over the application season. The frequency and duration would depend on the crop type and area to be treated. The NRA PQ No. 1 Large Scale User Survey indicated that crop such as canola, lucerne, legumes and oilseeds may receive at most two treatments per year which may span a number of days. Other crops like apples and cotton could receive up to five, again, possibly over days.

3.1 Acute toxic potential

The dermal LD₅₀ of endosulfan is 45 mg/kg. An average 60 kg worker would need to become contaminated on the skin with 2.7 g of endosulfan, 7.7 mL of EC formulation at 350 g/L or 11.3 mL of ULV formulation at 240 g/L, to reach the dermal LD₅₀. The amount of working strength solution needed to reach the dermal LD₅₀ will be 3.9 L of EC spray solution at the maximum high volume concentration of 0.07% endosulfan. Low volume spraying can result in high end use concentrations of endosulfan. For instance 0.74% endosulfan is possible with low volume (100 L/ha) spraying to vegetable and broadacre crops. In this case the amount of working strength solution needed to reach the dermal LD₅₀ is 0.4 L. The maximum concentration of endosulfan in EC aerial spraying solution is 7.4%. The volume of working strength solution needed to reach the dermal LD₅₀ is 40 mL. These calculations do not include a safety factor.

Fatal cases of human poisoning have been documented after ingestion of endosulfan at doses equivalent to 35, 295 and 467 mg/kg bw (Section 3.3.1). At the lowest dose, and assuming 60 kg body weight and 29% dermal absorption, this equates to a dermal dose of 7.2 g endosulfan or 20.3 mL of Thiodan Insecticide at 35%.

Endosulfan is a slight eye and skin irritant in experimental animals and may cause these effects in workers splashed with the concentrate. The CDFA reporting system (Section 3.3.2) revealed one case of skin irritation in manufacturing and formulation workers and skin and eye irritation in other workers exposed to endosulfan products and residues. The spray drift incident investigated by Clarke and Churches (1992) in cotton chippers also revealed a high incidence of eye, nose and throat irritation. The contribution of other product ingredients, in particular the solvents that make up a high proportion of EC and ULV formulations, could not be excluded.

3.2 Repeat dose toxic potential

The oral NOEL of 1.92 mg/kg bw/d and percutaneous absorption of 29% is used. The amount of skin contamination needed to exceed this dose for an average 60 kg worker is 397 mg endosulfan, 1.1 mL of 35% EC, 1.6 mL of 24% ULV, or 567 mL, 54 mL and 5.4 mL working strength solution at 0.07%, 0.74% and 7.4% endosulfan, respectively. These calculations do not include a safety factor.

The LOEL in the study used to derive the NOEL is 3.85 mg/kg bw/d. This corresponds to skin contamination with 797 mg endosulfan, 2.3 mL of the 35 % EC product or 3.3 mL of the 24% ULV product.

3.3 Assessment of end-use exposure

CDDFA records over the years 1976-1987 (inclusive) implicated endosulfan in 89 incidents where medical advice was sought. Worker groups reporting incidents with endosulfan alone included two ground applicators, three hand applicators and one mixer/loader for aerial application.

The end use exposure data available for assessment by crop groups is given in Table 9.

Table 9: End use exposure data by crop groups

Crop	Worker exposure data	POEM Estimates
fruit and nut trees	high volume (Baugher, 1990), low volume, mistblower (Idstein et al., 1989) and high volume hand held (Idstein et al., 1992)	high volume & low volume air-blast (Estimates I-V & VIII) electrostatic (air-blast as default) (Estimates VI-VII)
Vegetables	-	high volume & low volume boomspray (Estimates IX-XI & XIII-XV) hand-held low (Estimate XII)
Berries	-	high volume boomspray (Estimates XIII-XV) hand-held low (Estimate XII)
Ornamentals	-	high volume boomspray (Estimates XIII-XV) hand-held low (Estimate XII)
Vines	high crop as default high volume (Baugher, 1990), low volume, mistblower (Idstein et al., 1989) and high volume hand held (Idstein et al., 1992)	high volume air-blast (Estimates XVI-XVIII)
Tobacco	-	high volume air-blast (Estimates XVIII-XIX)
Broadacre*	-	low volume boomspray (Estimates XX-XXI)
Turf	-	high volume boomspray (Estimate XXII)

* PHED data submitted by Hoechst for ground and aerial spraying (Wicke and Lunchick, 1998)

3.3.1 Measured worker exposure

Endosulfan is used in a variety of crop types using different application equipment. However, measured worker exposure data available for endosulfan is limited to German studies in

orchards using air-blast sprayers mistblowers and hand held motorised knapsack applications (Baugher, 1990; Idestein et al., 1989, 1992).

Baugher (1990) can be used to estimate risk in high volume spraying. In the study, final volumes of 4674 L/ha and 2340 L/ha were used, at 3.36 kg ai/ha. The corresponding high volume use in Australia, at say 2000 L/ha at 190 mL product/100 L, would be 1.33 kg ai/ha. Over the range of 6 ha to 21 ha/6 hr day (information derived from NRA PQ No. 1 and supplementary NRA use pattern information), this corresponds to workers handling 8 to 28 kg endosulfan per day. Internal doses derived from the dermal and inhalation exposure for the five scenarios described in Table 4, are presented in Table 10. Margins of exposure (MOE) are calculated, using the oral NOEL of 1.92 mg/kg bw/d and average worker weight of 60 kg.

Table 10: Total absorbed dose and margins of exposure for air-blast application in apple and plum orchards derived from Baugher (1990)¹

Task Scenario	Total absorbed dose ² Ug/kg ai handled/day		Margin of exposure (MOE) ³	
	GM (range)		GM (range)	
	8 kg ai/6 ha/day	28 kg ai/21 ha/day	8 kg ai/6 ha/day	28 kg ai/21 ha/day
Mixer/loader/applicator				
1. Open-pour, Nelson cab with positive pressure and A/C	239 (136-861)	836.3 (476-3013)	483 (134-864)	138 (38-240)
2. Open-pour, Case cab with open windows	2641 (1121.2-7076)	9243.5 (3924-24768)	42 (16-102)	13 (3-29)
3. Closed-system, Nelson cab with positive pressure and A/C	154.2 (53.9-642.8)	539.8 (188.6-2249.9)	736 (179-2144)	211 (51-611)
4. Closed-system, canvas skirt with plastic dome windows	214.5 (101.8-539.8)	750.7 (356-1889.2)	538 (211-1152)	154 (61-323)
Sprayer only (outside tractor cab) All tractor	3635.6 (607.8-94812.4)	12725 (2127-331,843)	32 (1-189)	10 (<1-54)

1 High volume spraying with 0.190 mL/100 L in 2000L spray/ha

2 29% dermal absorption and 100% inhalation absorption

3 NOEL of 1.92 mg/kg/d

M/L/A treating small areas, by high volume airblast spraying have adequate MOE as long as they use tractor cabs that are not open to spray drift. The cab with open windows and the simulated sprayer without a cab have low MOE (42 and 32, respectively) at 6 ha/day and even lower MOE at 21 ha/day (13, range 3-29 and 10, range <1-54, respectively).

It is not possible to definitely separate out differences between open-pour and closed-system mixing. Indications are that when the same cab (Nelson cab with positive pressure and air-conditioning) is used with open and closed mixing, higher MOE for M/L/A are obtained for the closed mixing scenario. The type of cab was also influential. M/L/A using the Nelson cab with positive pressure and air-conditioning had higher MOE than M/L/A using the cab with canvas skirt and plastic dome windows, when both workers used closed-system mixing.

MOE become low as amount handled and area treated increases.

Idestein et al. (1989) studied exposure for M/L/A and cleaners treating apple trees using a mist blower. The 35% product was used at 1.5 L/ha, (0.525 kg ai/ha), in a final volume of 500 L water/ha. The product rate/ha, indicative of low volume spraying corresponds to 3.15-11.03 kg ai/day, in the Australian range of 6-21 ha/day. The equivalent high volume rate at 500 L/ha and 190 mL product/100 L, would be 2-7 kg ai/day in the Australian range of 6-21 ha/day. Internal dose and MOE are estimated using the low volume spraying range of 3.15-11.03 kg ai/day (Table 11).

Table 11: Total absorbed dose and margins of exposure for mistblower application in apple and plum orchards derived from Idstein et al. (1989)¹

Task Scenario	Total absorbed dose ² mg/kg ai handled/day		Margin of exposure (MOE) ³	
	GM (range)		GM (range)	
Mistblower	3.15 kg ai/6 ha/day	11.03 kg ai/21 ha/day	3.15 kg ai/6 ha/day	11.03 kg ai/21 ha/day
Mixing/loading	0.17 (0.046-1.08)	0.575 (0.17-3.79)	704 (106-2496)	202 (29-672)
Application	3.28 (0.80-27.70)	11.51 (2.81-97.00)	35 (3-144)	10 (1-42)
Cleaning	0.019 (0.009-0.053)	0.07 (0.032-0.19)	6080 (2176-12800)	1632 (608-3520)
All tasks ⁴	3.47 (0.86-28.83)	12.16 (3.01-100.98)	32 (3-134)	10 (1-38)

1. Low volume spraying
2. 29% dermal absorption
3. NOEL of 1.92 mg/kg d
4. MOE are the same if tasks are restricted to M/L/A.

MOE from this study are low if range is considered for workers who perform M/L/A and cleaning at both 6 and 21 ha/day. Exposure during application has the largest influence on the low MOE. This is despite the fact that spray penetration through the protective clothing was low at a maximum of 2.2%. Workers performing the separate tasks of mixing/loading or cleaning had high MOE. Applicators in this study did not have cabs on the tractors. As with the previous study (Baugher, 1990), the importance of cabs in reducing exposure is emphasised.

Idestein et al. (1992) studied exposure for mixer/loaders and applicators spraying endosulfan on apple trees with a motor-drive knapsack sprayer. The study aimed to maintain a final spray volume of 1500 L/ha, at 1.5 L 35% product/ha. This corresponds to a high volume use in Australia of 1.0 kg ai/ha (190 mL product/100 L, 1500 L/ha). The corresponding low volume use would be 0.525 kg ai/ha. Internal dose and MOE are estimated using the high volume rate of 1.0 kg ai/ha, in the range 0.1-1.0 ha/day. The hectare range is selected from the minimum area treated in the apple tree spraying trial (0.1 ha) to a maximum default value (1 ha/day).

Table 12: Total absorbed dose and margins of exposure for hand held motorised knapsack application in apple orchards derived from Idstein et al. (1992)¹

Task scenario	Total absorbed dose ² mg/kg ai handled/day		Margin of exposure (MOE) ³	
	GM (range)		GM (range)	
Hand held knapsack motorised	0.1 kg ai/0.1 ha/day	1 kg ai/1 ha/day	0.1 kg ai/0.1 ha/day	1 kg ai/1 ha/day
Mixing/loading	0.015 (0.008-0.021)	0.15 (0.079-0.21)	7680 (5440-14400)	768 (547-1472)
Application	0.73 (0.05-6.82)	7.3 (0.50-68.00)	160 (16-2304)	16 (3-230)
All tasks ⁴	0.75 (0.058-6.84)	7.45 (0.58-68.21)	154 (16-1984)	16 (3-198)

1. High volume spraying
2. 29% dermal absorption
3. NOEL of 1.92 mg/kg d
4. MOE are the same if tasks are restricted to M/L/A.

MOE for mixer/loaders are high, irrespective of the treatment area. Applicator absorbed dose is high and this has a strong influence on the MOE for M/L/A. At 0.1 ha/day, MOE are adequate for M/L/A (GM MOE 154, range 16-1984).

Workers treating trees at 1 ha/day by this method have adequate MOE for about half the time (GM MOE for M/L/A of 16 with a range of 3-198).

3.3.2 Pesticide Handlers Exposure Database

The Pesticide Handlers Database (PHED Version 1.1), jointly developed by the Pest Management Regulatory Agency/Health Canada, the US Environmental Protection Agency, and the American Crop Protection Association, was used to estimate the dermal and inhalation exposure resulting from the use of Thiodan 35 EC and Thiodan ULV, (**Wicke and Lunchick, 1998**). The exposure was estimated for ground and aerial application of endosulfan to cotton, grain legumes, oilseed crops and other broadacre crops in Australia. In the database, subsets of overall data based on the specific use pattern were created, the most appropriate one was selected based on the amount and quality of data and similar use pattern of interest.

Data in PHED are graded for quality based on analytical quality assurance. The data are assigned to one of five grades, A through E, based on the recovery of the active ingredient from fortified samples, fortified laboratory samples, and storage stability samples. Grade A and B data are considered to be of high quality.

Exposure assessment was done for mixer/loader (open and closed system), groundboom applicator (open and closed cab), pilots for aerial application and flaggers. The exposure estimates were based on the use of trousers, a long-sleeved shirt, and chemical resistant gloves while mixing/loading and on the use of trousers and a long-sleeved shirt while applying endosulfan from a tractor. The mixer/loader and applicator were the same person. The pilots and flaggers were assumed to use trousers and long-sleeved shirts. For aerial spraying, closed system loading and large containers were assumed.

The following assumptions were used in the model:

Concentration of product:	350 g/L (ground) and 240 g/L (aerial)
Formulation type:	EC and ULV (for aerial)
Maximum in-use concentration:	735 g ai/ha (ground) 720 g ai/ha (aerial)
Product rate:	2.1 L for ground application 3 L for aerial application
Application area:	50 ha (average for ground) 600-1000 ha (aerial)
Spray volume:	100 L/ha (ground) 20-30 L/ha (aerial)

The margins of exposure using PHED data are provided in Table 13. All exposures estimates were of high confidence datasets with the exception of the enclosed cab applicator dermal exposure which was of medium confidence.

Table 13: PHED exposure for ground and aerial application and margins of exposure (MOE) based on endosulfan use patterns, Wicke and Lunchick (1998)¹

Task Scenario	Dermal exposure (ug/kg handled) ai	Inhalation exposure (ug/kg handled) ai	Total exposure ² (dermal+inhalation) mg/kg bw/day	Margin of exposure (MOE) ³
Open cab groundboom applicator with open pour	128	3.50	0.78+.002	78
Enclosed cab				

groundboom applicator with open pour	106	2.38	0.065+0.001	96
Enclosed cab groundboom applicator with closed mixing/loading	36	0.33	0.022+0.0002	291
Aerial ULV application				
Mixer/loader	21	0.25	(0.40+0.005) ⁴	16
Pilots	10	0.11	(0.19+0.002) ⁴	34
Flaggers	24	0.66	(0.46+0.013) ⁴	13

1. Low volume spraying
2. At maximum application rate of 0.735 kg ai/ha (operator handling 36.75 kg ai/d for 50 ha/d) and operator body weight of 60 kg
3. 29% dermal absorption and 100% inhalation absorption, and a NOEL of 1.92 mg/kg d
4. At maximum application rate of 0.720 kg ai/ha (operator handling 1152 kg ai/d for 1600 ha/d)

Results

Considering the exposures for broadacre crops using PHED data, MOE for M/L/A are acceptable for workers using open or closed cabs. MOE are low for mixer/loaders and flaggers for aerial ULV application. MOE are acceptable for pilots doing aerial spraying.

3.3.3 Predicted worker exposure

UK POEM was used to calculate predicted exposure and risk for ground spraying with the 35% EC product, under the Australian use pattern. POEM estimates are 75th percentiles. Since endosulfan is used on such a wide variety of crops, the POEM scenarios tested are grouped around similar crop types with similar application methods. The scenarios aim to derive exposures for users treating small or large areas with application times lasting the full or partial day. Where possible high volume and low volume scenarios are included. The crop categories covered by POEM are described in Table 9.

In compiling the scenarios, use pattern information was derived from the label, NRA PQ No. 1, supplementary use pattern details from the NRA and Banks et al. (1994). POEM can only test container sizes of up to 20 L. Bulk handling with the 200 L container for mixing/loading is not covered in the POEM estimates. Certain use pattern scenarios tested in POEM revealed an impractical number of operations (> 20) (defined as containers of product used or knapsack refills). These included hand held uses (low and high spraying) at 1 ha/day and low volume boomspray application on 300 ha. They are not included in Table 13.

The application equipment used in the model is:

Vehicle mounted with cab (boomspray) with hydraulic nozzles (V-Nozzle);

Vehicle mounted (without cab) Air-Assisted (Air-Blast) both high (V-500) and low volume (V-100); and

Hand Held (knapsack) Outdoor Rotary Disc Atomisers (H-RDA-low).

The following data points were entered:

Concentration of product:	350 g/L
Formulation type:	EC
Maximum in-use concentration:	various, at 0.18, 0.44, 0.67, 0.70, 0.88, 2.00, 7.35, 11.08, 12.50 or 39.90 mg/mL
Container size:	20 L
Product rate:	various, at 0.5, 1.9, 2.1, 2.5, 2.8, 2.85, 3.8, 4, 5 or 5.7 L/ha
Application area:	various, at 0.1, 1, 2, 6, 9, 21, 30, 40 or 50 ha
Spray volume:	various, at 50, 80, 100, 180, 500, 1000, 1400, 2000 or 5000 L/ha
Duration of exposure:	various, at 1, 2 or 6 h
Percent absorbed:	29%
NOEL (oral):	1.92 mg/kg/day
Average body weight:	60 kg
Transfer through gloves and one layer of clothing:	POEM default values
Transfer through waterproof clothing transmission:	an additional 10% (NOHSC default)
Other parameters:	POEM default values (75th percentile)

POEM scenarios, use patterns, absorbed dose and MOE are provided in Table 13.

Table 13: POEM exposure for ground application and margins of exposure (MOE) using the endosulfan use pattern described on Endosulfan product labels, NRA use pattern information and NRA Performance Questionnaire No. 1

Crop	Estimate Number (equipment)	Spray volume ⁽¹⁾ (L/ha)	Product rate (L/ha)	Application area/time in hours (ha/h)	Active handled (kg/day)	Mixer/loader Absorbed dose dermal	Applicator absorbed dose dermal	M/L/A ⁽³⁾ absorbed dose ⁽⁴⁾ dermal + inhalation		MOE ⁽⁶⁾ mixer/loader	MOE applicator	MOE M/L/A	
						(mg/kg bw/day)	(mg/kg bw/day)	Gloves	Gloves +WPC ⁽⁵⁾	Gloves	Gloves	Gloves	Gloves +WPC
Fruit & nut trees high volume HV	I air-blast-no cab	2000	3.8	21/6	27.9	0.338	0.274	0.616	0.438	6	7	3	4
Fruit trees HV	II air-blast-no cab	2000	3.8	6/6	7.98	0.169	0.274	0.446	0.269	11	7	4	7
Fruit trees HV	III air-blast-no cab	2000	3.8	2/2	2.66	0.085	0.091	0.177	0.118	23	21	11	16
Fruit trees-LV	IV air-blast-no cab	180	5.7	21/6	41.9	0.508	2.531	3.06	0.927	4	1	1	2
Fruit trees-LV	V air-blast-no cab	500	2.85	21/6	20.95	0.254	0.456	0.713	0.329	6	4	3	6
Fruit trees electrostatic ⁽⁷⁾	VI air-blast-no cab	50	5.7	21/6	41.9	0.508	9.112	9.67	2.02	4	< 1	< 1	1
Fruit trees electrostatic ⁽⁷⁾	VII air-blast-no cab	80	2.85	21/6	20.95	0.254	2.848	3.126	0.726	8	1	1	3
Pecans	VIII air-blast-no cab	1400	2.8	21/6	20.58	0.254	0.288	0.546	0.36	8	7	4	5
Vegetables-low volume LV peanuts-LV	IX boomspray+cab	100	2.1	30/6	22.05	0.338	0.229	0.575	-	6	8	3	-
Vegetables HV	X boomspray+cab	1000	1.9	30/6	19.95	0.254	0.021	0.275	-	8	91	7	-
Vegetables HV	XI boomspray+cab	1000	1.9	50/6	33.25	0.423	0.021	0.444	-	5	91	4	-
Vegetables ornamentals-HV berries-HV	XII hand-held low	1000	1.9	0.1/6	0.067	0.592	0.07	0.663	0.603	3	27	3	3
Berries-HV ornamentals-HV vegetables	XIII boomspray+cab	1000	1.9	1/2	0.665	0.085	0.007	0.092	-	23	274	21	-

Table 13: continued

Crop	Estimate Number (equipment)	Spray volume ⁽¹⁾ (L/ha)	Product rate (L/ha)	Application area/time in hours (ha/h)	Active handled (kg/day)	Mixer/loader absorbed dermal (mg/kg bw/day)	Applicator absorbed dose dermal (mg/kg bw/day)	M/L/A ⁽³⁾ absorbed dose ⁽⁴⁾ +		MOE ⁽⁶⁾ mixer/loader	MOE applicator	MOE M/L/A	
						Gloves	Gloves ⁽²⁾	Gloves	Gloves +WPC ⁽⁵⁾	Gloves	Gloves	Gloves	Gloves + WPC
Berries-HV ornamentals-HV vegetables	XIV boomspray+cab	1000	1.9	2/2	1.33	0.085	0.007	0.092	-	23	274	21	-
Berries-HV ornamentals-HV vegetables-HV	XV boomspray+cab	1000	1.9	9/6	5.985	0.085	0.021	0.106	-	23	91	18	-
Vines-HV	XVI air-blast-no cab	2000	4	1/6	1.4	0.085	0.29	0.376	0.19	23	7	5	10
Vines-HV	XVII air-blast-no-cab	2000	4	1/1	1.4	0.085	0.048	0.133	0.102	23	40	14	19
Tobacco-HV vines-HV	XVIII air-blast-no cab	2000	5	30/6	52.5	0.677	0.36	1.041	0.808	3	5	2	2
Tobacco-HV	XIX air-blast-no-cab	2000	5	40/1	70	0.846	0.06	0.907	0.868	2	32	2	2
Broadacre-LV	XX boomspray+cab	100	2.1	50/6	36.75	0.508	0.229	0.744	-	4	8	3	-
Broadacre-LV	XXI boomspray+cab	400	0.5	50/6	8.75	0.169	0.014	0.183	-	11	137	10	-
Turf-HV	XXII boomspray+cab	5000	2.5	50/6	43.75	0.592	0.005	0.598	-	3	384	3	-

(1) The final spray concentration 0.018 to 4.0% endosulfan

(2) Absorbed dose for applicators wearing gloves and waterproof clothing is not given in Table 13. It is 0.004 mg/kg bw/day to 0.46 mg/kg bw/day (1.46 mg/kg bw/d in Estimate VI)

(3) M/L/A = mixer/loader/applicator

(4) Combined dermal and inhalation absorbed dose (0.001- 0.08 mg/kg bw/day for all Estimates, incorporating dermal absorption (29%), inhalation retention and absorption (100%) and an average worker weight of 60 kg

(5) WPC = Waterproof clothing on trunk and legs

(6) MOE = Margin of exposure, derived using the oral NOEL of 1.92 mg/kg/day

(7) Airblast scenario is used as electrostatic sprayers are not included in POEM

Results

Considering the range in uses for fruit and nut trees, vegetables, berries, ornamentals, vines, tobacco, broadacre crops and turf, MOE for M/L/A are low, from < 1 to 21 (MOE 21 in Estimate XIII and XIV). When an additional layer of protective clothing is added for workers not using cabs, the MOE are not substantially changed. If mixer/loader exposure were completely eliminated, exposure and risk would be acceptable for high volume, small area and short time air-blast application to fruit and nut trees (Estimate III), high volume boom spray applications to berries, ornamentals and vegetables (Estimates X to XV), short time air-blast spray on vines and tobacco (Estimates XVII and XIX), broadacre low volume spray applying 0.5 L/ha (Estimate XXI) and boom spray high volume turf application (50 ha over 6 hrs) (Estimate XXII).

3.3.4 Conclusion on worker exposure and risk - ground spraying

Fruit and nut trees

High volume The measured worker exposure study of Baugher (1990) extrapolated to Australian conditions, indicates acceptable risk for M/L/A treating small areas (6 ha/day) providing workers use tractor cabs that are not open to spray drift. Applicator exposure had the most influence on MOE. The use of effectively enclosed cabs provided at least eleven times more protection for M/L/A than cabs with an open window. Where the use of cabs is not possible, workers wearing an additional layer of protective clothing, using a default value of 10% penetration, may have sufficiently increased MOE to indicate acceptable risk when spraying small but not large areas. The risk is not acceptable for M/L/A treating large areas (21 ha/day), even if cabs are effectively enclosed or additional protective clothing is worn. Furthermore, the use of a closed mixing system would not substantially reduce the overall risk for these workers.

Predicted exposure for M/L/A from POEM support the finding that exposure is unacceptable using tractors without cabs. Estimates I, II and VIII (nuts) for airblast spraying without cabs indicate low and unacceptable MOE irrespective of the area or duration of spraying. Similarly, elimination of mixer/loader exposure did not substantially reduce the overall risk for these workers. An additional layer of protective clothing did not substantially reduce the overall risk.

Low volume The measured worker exposure study of Idstein et al. (1989) extrapolated to Australian conditions, indicates low and unacceptable risk for M/L/A treating either small (6 ha/day) or large (21 ha/day) orchards by mist blower using tractors without cabs. The mist blower study is used as a surrogate for airblast spray exposure under the same conditions. Exposure during spraying has the strongest influence on the low MOE. Exposure was measured below one layer of protective clothing. An additional layer of protective clothing, using a default value of 10% penetration, may sufficiently alter the MOE to indicate acceptable risk when spraying small but not large areas. Similarly, workers using enclosed cabs (such as those that offered at least eleven times more protection in the Baugher (1990) study), are likely to be sufficiently protected spraying small but not large areas.

Predicted exposure for M/L/A from POEM for low volume airblast spraying without cabs at 180 or 500 L/ha, results in low and unacceptable MOE for workers spraying large areas (21

ha/day) (Estimates IV and V). Elimination of mixer/loader exposure or the addition of an extra layer of protective clothing did not substantially reduce the risk.

Hand held spraying from motorised knapsack The measured worker exposure study of Idstein et al. (1992) extrapolated to Australian conditions, indicates unacceptable risk for M/L/A treating large (1.0) orchard areas by hand spraying from a knapsack. Exposure during spraying has the strongest influence on the low MOE. Exposure was measured below one layer of protective clothing. An additional layer of protective clothing may sufficiently alter the MOE to indicate acceptable risk when spraying large areas.

Electrostatic spraying POEM estimates for airblast spraying without cabs are used to substitute for a lack of data (Estimates VI and VII). Spray volumes of 50 and 80 L/ha result in low and unacceptable MOE when spraying large areas (21 ha/day). Elimination of mixer/loader exposure or the addition of an extra layer of protective clothing did not substantially reduce the risk.

Spraying of small areas (6 ha/day) at 2.8 L product rate/ha in the 80 L/ha scenario does not result in acceptable MOE for M/L/A without cabs (extrapolated from the mist blower study of Idstein et al. (1989)). The MOE of 5 would not be sufficiently increased if additional protection were available in the form of enclosed cabs or extra protective clothing, using default values of ten times more protection for each.

Vegetables, peanuts, berries and ornamentals

Measured worker exposure data is not available for high volume and low volume spraying of vegetables and peanuts.

Measured worker exposure data is not available for high volume spraying of berries and ornamentals.

Predicted exposures using POEM are considered together for this group because the high volume sprays or hand held uses are tested at the same product application rate (1.9 L/ha) and the same default field crop spray volume of 1000 L per hectare. In recognition of the variety of crop or plot sizes, a range of spraying times and hectares covered per day is incorporated. Parameters extend from a minimum of one hectare over 2 hours to a maximum of 50 hectares over 6 hours by boomspray and cover 0.1 hectare over a 6 hour day by hand held spray.

Low volume spraying indicates low and unacceptable MOE for M/L/A using tractors with cabs over large areas (30 ha/day, Estimate IX). High volume spraying over the same or larger areas (30 and 50 ha/day, Estimates X and XI) for M/L/A is also unacceptable. Elimination of mixer/loader exposure would result in acceptable MOE.

High volume spraying over reduced spraying times and areas (1-2 ha/day over 2 hr) would result in acceptable MOE for high volume spraying, assuming cabs continued to be used (Estimates XIII and XIV).

High volume spraying of a reduced spraying area but still over the day (9 ha/day over 6 hr) results in acceptable MOE (Estimate XV).

Hand held spraying from a knapsack at 0.1 ha over the day (Estimate XII), indicated low and unacceptable MOE from predicted exposure. However, exposure generated spraying high crops by hand (Idstein et al., 1992) is likely to be acceptable if workers wear additional protective clothing. Workers spraying low crops are expected to have less exposure than those spraying high crops. Therefore exposure and risk for workers handspraying low crops is judged acceptable if they wear additional protective clothing and spray only small areas (1 ha/day).

There was no measured or predicted exposure data available to enable a risk assessment for workers spraying endosulfan inside greenhouses. These workers need to be restricted to small areas (0.1 ha/day) and wear additional protective clothing as an interim measure pending submission and assessment of further information.

Vines

Vine high volume spraying is conducted at a similar product rate and spray volume (4 L in 2000 L/ha) and with similar airblast equipment as orchard spraying. Therefore the conclusions are the same as those given for fruit and nut trees over small and large areas by high volume, low volume, motorised knapsack and electrostatic sprayers, if appropriate.

Predicted exposure from POEM indicates unacceptable MOE for M/L/A using high volume application without tractor cabs, over treatment periods of one hectare in one hour to 30 ha in 6 hours (Estimates XVI, XVII and XVIII). Elimination of mixer/loader exposure or the addition of an extra layer of protective clothing reduced exposure and MOE is acceptable for treating a small area of 1 ha for an hour (Estimate XII) .

Tobacco

Measured worker exposure data is not available for this use. Exposure and MOE from Baugher (1990) for high volume spraying can be extrapolated for airblast spraying of tobacco over small areas, say 6 ha/day and 2000 L/ha using the label application rate of 250 mL product/100 L. For this small area, MOE are acceptable using closed cabs and are likely to be acceptable with additional protective clothing if cabs cannot be used. Safe treatment of areas larger than 6 ha/day of tobacco could not occur without cabs and as with the orchard use, handling of more than approximately 28 kg ai/day (corresponding to 16 ha of tobacco) results in unacceptable exposure even using cabs.

Treatment of small areas (say 0.1 ha) by handheld airblast sprayer is likely to involve a similar risk as for orchard and vine sprayers. Accordingly, an additional layer of protective clothing would be needed.

MOE from predicted exposures are unacceptable for high volume spraying without tractor cabs, using air blast sprayers. Slow or rapid treatment time across a similar area did not influence the risk (Estimates XVIII and XIX).

Broadacre crops, including cereals, legumes, oilseeds and cotton

Measured worker exposure data is not available for this use.

Low volume MOE are unacceptable for low volume boomspray applications from tractors with cabs, at 2.1 L product/100 L spray/ha and covering 50 ha per day (Estimate XX). MOE are still unacceptable if 0.5 L product is diluted in 400 L spray/ha and covering 50 ha per day (Estimate XXI). Higher work rates occur but are not tested in POEM as unacceptable exposure is already reached at 50 ha per day. Given these crops are grown over large areas, spraying times occupying part of the day are not included. Elimination of mixer/loader exposure reduced the risk for the lower product use (Estimate XXI). Overall MOE are acceptable only for small quantities of endosulfan handled in a spraying day.

MOE are acceptable for M/L/A considering the PHED data, for workers using open or closed cabs.

Turf

Measured worker exposure data is not available for this use.

High volume Predicted exposure from POEM indicates a low and unacceptable MOE for M/L/A treating a large number (50) hectares per day by boomspray and using tractors with cabs (Estimate XXII). Mixer/loader exposure has a strong influence on the overall exposure and risk. The handling of one 20 L container of 35% EC formulation, sufficient to treat 8 hectares, still maintains mixer/loader exposure at unacceptable levels. It would be necessary to eliminate mixer/loader exposure to produce an acceptable risk for M/L/A.

3.3.5 Conclusion on worker exposure and risk - aerial spraying

Aerial spraying There are no measured exposure studies available for workers involved in the aerial spraying of endosulfan and it is not possible to predict exposure using POEM.

Endosulfan is sprayed by air over large areas of broadacre crops and vegetables and operators may be involved in multiple applications. The container sizes available are 20 L, 200 L or 1000 L. However considering the large amounts of endosulfan needed, the 200 L or 1000 L bulk handling containers would be most frequently used. Mixer/loaders using bulk containers are likely to receive special training in chemical handling and should be able to exercise more effective control over exposure. This is essential as the theoretical lowest repeat toxic dose of the 24% ULV product is 1.6 mL. Spray pilots are protected from direct spray contamination when located inside the plane. On balance, the risks to mixer/loaders and spray pilots should be acceptable. For aerial spraying, closed mixing/loading system will be used in most workplaces. MOE are acceptable for pilots considering PHED data.

Flaggers involved in aerial spraying may become contaminated with spray mist. The chances of exposure are high and cannot be quantified. Therefore the risk to human flaggers is considered unacceptable, unless they are protected by engineering controls such as cabs. MOE are low for flaggers for aerial ULV application, considering PHED data.

3.3.6 Conclusion on worker exposure and risk - other uses

Hides This use is not assessed as the NRA has indicated that it no longer occurs.

Post-harvest treatment dipping of export pineapples No information was received to assess this use. It is conducted under AQIS requirements.

Pot plant earthworm treatments No information was received to assess this use. It is likely to involve only a small component of overall endosulfan use. However, the repeat dose assessment (Section 4.2) indicates that 1.1 mL of concentrated 35% product on the skin is the lowest repeat dose causing toxic effects. Considering that small easy to manage container sizes are not available and that the toxic dose is low, continued use of endosulfan for this type of use is unacceptable. Given the repeat dose toxicity of endosulfan, this rationale would apply to other small, non-essential uses of this chemical.

3.4 Re-entry Assessment

Official reports of endosulfan overspraying or re-entry exposure for workers in treated fields in Australia are limited. In California, reporting incidents involving endosulfan and health effects comprised a small proportion of overall workplace injury reports, but exposure to field residues made up a high proportion (40%) of the total end user incident reports involving endosulfan alone (Section 3.3.2).

There is no re-entry period on the product labels.

Considering the withholding periods, a default re-entry period for harvest exists for some vegetables with a withholding period of 7 days and for all fruit and nuts where the withholding period is 14 days. Other vegetables however have a withholding period of only one day. Broadacre crops have a 4 week withholding period where relevant.

No information was provided by the registrants on worker exposure during re-entry. One of the Large Scale Users growing processing tomatoes in NSW (Table 2) indicated that certain workers hand weeding could be affected by fumes for a couple of days after application. As the withholding period for tomatoes is one day, a similar response is possible for workers involved during harvesting.

Clarke and Churches (1992) investigated re-entry exposure to cotton chippers in NSW. The total potential skin exposure was 12.2 mg/hr seven hours after endosulfan spraying to a 30 cm high crop and 19.8 mg/hr twenty-four hours after endosulfan spraying to a 50 cm high crop. The authors recommended head, arm, hand, body, leg and foot protection for cotton chippers. Assuming this protection, at 10% penetration of endosulfan through clothing and uniform and cumulative deposition throughout an 8 hour working day, MOE are 12 and 8 for each situation above. Results indicate that a re-entry period would need to consider crop height as well as whether or not foliar residues were dry. A re-entry period of 24 hours would be inadequate. In the absence of data, an interim re-entry period of 2-3 days is recommended pending submission and assessment of further information. Where it is possible to inspect or work in crops without significant contact with treated foliage such as in crops under 50 cm in height or in orchards, a 2 day re-entry period can be used. Where the crops are over 50 cm in height or

foliage canopies are closed (not including tree crops), observing a 3 day re-entry period is advised as a precaution.

4. OCCUPATIONAL CONTROLS

4.1 Statement of hazardous nature

Endosulfan and endosulfan products are classified as hazardous substances according to NOHSC criteria. Hazardous substances are subject to the workplace controls outlined in the NOHSC Control of Workplace Hazardous Substances (NOHSC, 1994b).

4.2 Safety Directions

The existing safety directions entry in the Handbook of First Aid Instructions and Safety Directions (1996) needs to include amended formulation codes, standard statements regarding hazard (as per DHFS, 1997) and personal protective equipment requirements as follows:

EC ULV all strengths

100	Very dangerous
130 131 132 133	Poisonous if absorbed by skin contact, inhaled or swallowed
207 162	Will damage eyes
161 164	Will irritate the skin
210 211	Avoid contact with eyes and skin
220 222 223	Do not inhale vapour or spray mist
279 280 281 282 290 291 294 298b 301 (or 297 300)	When opening the container, preparing the spray and using the prepared spray wear protective waterproof clothing, elbow-length PVC gloves, water resistant footwear and full-facepiece respirator (or goggles and half facepiece respirator)
340 341 343	If product or spray in eyes, wash it out immediately with water
340 342	If product on skin, immediately wash area with soap and water
350	After use and before eating, drinking or smoking, wash hands, arms and face thoroughly with soap and water
360 361 363 364 366	After each day's use, wash gloves, goggles, respirator and if rubber wash with detergent and warm water and contaminated clothing

4.3 Information provision

4.3.1 Labels

Registrants provided labels for endosulfan technical grade active constituent. The labels need to be revised in accordance with NOHSC regulations (NOHSC, 1994c).

All current endosulfan products are hazardous substances and require a reference to the material safety data sheet (MSDS).

4.3.2 Material Safety Data Sheet (MSDS)

A MSDS is required for endosulfan technical grade active constituent where it is handled by Australian workers.

MSDS are required for all current endosulfan products, prepared in accordance with NOHSC regulations (NOHSC, 1994d).

4.4 Occupational Exposure Monitoring

4.4.1. Atmospheric monitoring

There is a NOHSC Exposure Standard for endosulfan of 0.1 mg/m³ Time Weighted Average (TWA) with a skin notation indicating that absorption through the skin may be a significant source of exposure (NOHSC, 1995).

4.4.2. Health Surveillance

NOHSC has not placed endosulfan on the Schedule for Health Surveillance (Schedule 3 Hazardous Substances for which Health Surveillance is Required).

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