## 9. OH&S ASSESSMENT TECHNICAL REPORT

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## 9.1 BACKGROUND

Following the 1998 APVMA interim report of the review of endosulfan, based on the available data, concerns were raised with regard to exposure for workers during certain end-use and re-entry activities. Consequently, the APVMA decided that these uses of endosulfan could only continue on a temporary basis until additional worker exposure data was obtained.

Due to the lack of actual worker exposure data and the high toxicity of the chemical, worker exposure data generated under actual Australian conditions was considered essential to fully assess OHS risks. Work practices identified as requiring additional exposure data were:

- Mixer/loaders in ground and aerial applications
- Manual flaggers for aerial applicators
- Orchard ground spray applicators (including re-entry)
- Broadacre ground spray applicators (including re-entry)
- Workers using hand-directed spray applicators (including nursery/greenhouses)

The Australian Centre for Agricultural Health and Safety (Moree) and the Centre for Pesticide Application Safety (Gatton) conducted exposure studies for workers treating orchard, broadacre and nursery crops by ground and aerial applications and re-entry to broadacre crops. All studies used the same formulation of endosulfan containing 350 g ai/L, which was considered representative of each of the products under review. The studies were conducted according to a protocol approved *by NOHSC/APVMA prior* to the commencement of the studies.

Assessment of the additional data was conducted by the National Occupational Health and Safety Commission (NOHSC).

For the purposes of measuring dermal exposure, the US EPA Occupational and Residential Exposure Test Guidelines were adopted to assess worker exposure to endosulfan, which includes guidance on estimating total body deposition for workers. In this regard, chromatographic paper patches affixed to cloth pads were fixed (using Velcro) either on singlets (under the overalls), on the body of the worker, or externally on overalls of workers. The distribution of the patches are presented below:

<u>Internal patches (patches fixed with Velcro) on the singlet, under the overalls)</u>

a) Two patches, one on each external (dorsal side) shoulder, on the top
b) One patch on the back of the neck (dorsal side) below the lower edge of the collar
c) One patch on the upper chest (ventral side) near the jugular notch)

<u>Internal patches (patches fixed with Velcro) on the body of the worker)</u>

a) Two patches, one on each forearm (at the back)
b) Two patches, one on each thigh (in front)
c) Two patches, one on each knee (in front)

Cotton gloves were used to measure residue deposition on hands.

<u>External patches (on the overalls)</u>

a) Two patches (one on either side) on the top of the internal shoulder (ventral side)

Estimation of total endosulfan exposure based on the surface area of the different body parts is outlined in Table 1.

**Table 1: Estimation of total endosulfan exposure based on surface area of different body parts.**

| Body parts | Deposition dosimeter quantity x surface area ($cm^2$) of body part |
|---|---|
| Head and face | (Mean of ext. shoulder, chest and back patches) x 1300 |
| Back of neck | (Back patch) x 110 |
| Front of neck | (Chest patch) x 150 |
| Chest/stomach | (Chest patch) x 3550 |
| Back | (Back patch) x 3550 |
| Upper arms | (Mean int shoulder and forearm) x 1210 |
| Forearm | (Arm patch) x 2910 |
| Hand | (Glove result) x 2 |
| Thigh | (Thigh patch) x 3820 |
| Lower leg | (Low leg patch) x 2380 |
| Feet | (Foot patch) x 1310 |

For the purpose of study control, a member of the field monitoring team for each study session was "patched" with three field blanks. This member remained outside the paddock for the duration of each session, in an area that was apparently free from direct exposure to endosulfan. Some patches and gloves were also 'spiked' with endosulfan and exposed to similar weather conditions. The field blanks were used for the purpose of estimating the cross-contamination of the patches while handling them.

Exposure samples were sealed (in test tubes and jars) and transported under cool conditions to the laboratory for analysis. Meteorological conditions during the sessions were recorded.

Estimation of inhalation exposure was not included in the study protocols for the following reasons:

(1) it has previously been established (APVMA interim review report) that contribution to overall exposure from inhalation of spray during application of EC formulated products is minimal compared to dermal exposure. For ground rig applications, inhalation contributed only 1% to total endosulfan exposure for both mixing/loading and application. For hand spraying, inhalation contributed only 2% of exposure to applicators.
(2) based on the acute toxicity of endosulfan, workers are currently required to wear a full respirator during all handling operations.

The following main groups of studies were conducted:

i) Worker exposure to endosulfan in the course of application to tree crops
ii) Worker exposure to endosulfan in the course of application to nursery crops
iii) Worker exposure to endosulfan in the course of aerial application to cotton (broadacre crops)
iv) Worker exposure to endosulfan in the course of re-entry in cotton cropping activities (broadacre crops).

Endosulfan studies in broadacre cotton industries were conducted in NSW, and studies in the horticulture industries were conducted in Southeast Queensland. Details of these studies are provided in Section 2. A full list of studies provided for this report can be found in Appendix 1. Appendix 2 provides an analysis of the quality of these studies. Appendices 3 and 4 provide statistical analysis of the study data.

## 9.2 OCCUPATIONAL EXPOSURE STUDIES

Mixer/loader and applicator exposure was estimated in the studies conducted using various application methods for treatment of tree, broadacre, and nursery crops. The EC formulation of endosulfan @ 350 g ai/L was used in all the studies. Application rates were generally in accordance with label instructions for the various crops/situations.

Section 9.2.1 outlines the parameters of each study. Section 9.2.2 summarises the dermal exposure data generated for the various occupational scenarios studied.

### 9.2.1 Parameters used in exposure studies

***Worker exposure to endosulfan in the course of application in tree crops***

The following six studies were undertaken to estimate exposure for workers using endosulfan in tree crops. A cleaning down study, though not requested as part of the initial requirements for additional data, was also provided for assessment.

| | |
|---|---|
| *Study H-1-1:* | *Mixing/Loading* |
| *Study H-1-2-U:* | *Spraying air-assist spray, no cabin* |
| *Study H-1-2-C:* | *Spraying air-assist, with cabin* |
| *Study H-2-2-C:* | *Spraying air-shear, with cabin* |
| *Study H-5-2-C:* | *Oscillating boomspray* |
| *Study H-1-4:* | *Cleaning down* |

Applications of endosulfan were made in the course of actual pest control under a range of differing weather conditions. Any chemical spills or other incidents were reported, and exposure values were adjusted accordingly.

In the above studies endosulfan was poured from 20 L steel drums either into mixing tanks or directly into spray tanks of capacity 1200 L-3000 L. Dilution was an average of 150 mL/100 L of water, with dilutions varying for different applications. The total amount of spray volume handled per session during mixing/loading and application ranged from 100 L - 4800 L, with 0.05 kg –1.58 kg ai handled per study session.

In air-assisted sprayers (tractors with and without cabins), the spray droplets were generally produced by standard hydraulic nozzles, with air blown over the nozzle or spray plume to direct the spray into the tree canopy.

Exposure to endosulfan while cleaning the mixing/spraying equipment was also measured. To estimate worker exposure during cleaning down spray equipment, subjects were re-patched after they completed spraying. It should be noted however that in practice, all tasks (mixing/loading, spraying and cleaning down) are often undertaken by the same operator. Therefore, worker exposure may not be adequately measured by separating these activities.

During cleaning down operations, work was carried out (where possible) so that the wind directed any spray or fumes away from the worker, thus minimising airborne contamination and contamination of equipment. Connection and disconnection of hoses to and from the container, pump and mixing tanks was undertaken with care to avoid coming in contact with contaminated surfaces. Care was also taken to avoid touching the face and exposed skin when wearing gloves. The parameters of the above studies are outlined in Table 2.

**Table 2: Parameters of studies conducted for measuring exposure to endosulfan in the course of application to tree crops**

| Parameters | Mixing/Loading (Study H-1-1) | Air-assist spray [no cabin] (Study H-1-2-U) | Air-assist [with cabin] (Study H-1-2-C) | Air-shear [with cabin] (Study H-2-2-C) | Oscillating boomspray (Study H-5-2-C) | Cleaning down (Study H-1-4) |
|---|---|---|---|---|---|---|
| **Number of subjects/replicates** | 16/19 | 7/15 | 14/15 | 2/5 | 8/14 | 9/15 |
| **Duration of study (days)/ No. of sites/No. of sessions** | 7/7 | 3/3/3 | 8/8/8 | 1/1/1 | 4/4 | 8/8/9 |
| **Time taken for procedure (minutes)[1]** | 5-65 | 16-50 | 20-55 | 25-55 | 20-40 | 5-35 |
| **Spray volume handled (L)[2]** | 750-3000 | 100-1500 | 500-2100 | 1000-2400 | 1500-4800 | 100-9600[3] |
| **Total active ingredient (kg) handled[1]** | 0.13-1.58 | 0.05-0.79 | 0.05-1.10 | 0.53-1.26 | 0.16-0.51 | 0.05-2.36[3] |
| **Tasks/procedures** | Transport of pesticide drums, transferring chemicals to and from the storage area, pouring and mixing the chemical, loading the spray unit, removing empty containers from the working area and cleaning up spills. | Spraying tree crops, recording details of chemical prepared and loaded | Moving spray equipment to spray site, applying chemical to tree crop | | Towing trailer to site, cleaning nozzles, applying chemical to tree tops | Rinse drums and mixing tanks, wash spray equipment, hose down handling area, remove empty containers from the working area, clean up spills |
| **PPE used** | Waterproof or cotton overalls done up to neck and wrist, washable cotton hat, elbow-length gloves, full face-shield or goggles, half facepiece respirator, and water-resistant footwear/boots, worn beneath the overalls. | | | | | |

[1] per session
[2] No data were provided on application volume (L/ha), however, studies H-1-2-C; H-2-2-C and H-5-2-C were assumed to be high volume studies
[3] Amount of endosulfan and total volume sprayed before the cleaning operation. The amount of ai. handled during cleaning operations is not known.

***Worker exposure to endosulfan in the course of application to nursery crops***

The following three studies were undertaken to estimate exposure to workers using endosulfan in nursery crops. A cleaning down study, though not requested as part of the initial requirements for additional data, was also provided for assessment.

*H-3-1:* *Mixing/loading*
*H-3-2:* *Spraying*
*H-3-3:* *Cleaning down*

The above studies were conducted to define levels of worker exposure to endosulfan when mixing/loading, cleaning equipment and applying endosulfan products to nursery crops. The workers mixed endosulfan by first pouring the concentrate from 10/20 L steel drums into cylinder measuring jugs and then poured into 200 L spray tanks with water. The pad and mixing area were considered to be contaminated areas. Where possible, mixing/loading was carried out in conditions where the wind directed spray or fumes away from the workers, thereby minimising airborne contamination and contamination of equipment.

The typical operation for spraying in nurseries is by use of a spray tank on a trailer, with retractable hose and handgun permitting coverage of the whole nursery. The two types of spray systems used in nursery applications are high and low pressure systems. The high-pressure system tends to produce fine mister spray, whereas the low-pressure system tends to produce larger droplets. For both systems nozzles can be adjusted to regulate the spray pressure. It was not identified in the study (H-3-2) which system was used.

In the cleaning down study, the spray tank was filled with clean water, which was then used to clean hoses and nozzles. The 'wash residue' drained into a sump while some was washed onto a concrete area (without a drainage sump). No information was provided as to whether the amount of wash residue was measured. Potential for worker exposure was touching contaminated spray unit and hoses, contamination from leaking clamps and lines while connecting and disconnecting hoses, splashes from pad/work area and contaminated surfaces of empty containers. The duration of the cleaning-down operation depended on the size of the nursery to be treated (7-20 min), but was assumed to be up to one hour for larger nurseries. The parameters of the above studies are presented in Table 3.

**Table 3: Parameters of studies conducted for measuring exposure to endosulfan in the course of application to nursery crops**

| Parameters | Mixing/Loading (Study H-3-1) | Application (Study H-3-2) | Cleaning down (Study H-3-3) |
|---|---|---|---|
| **Number of subjects/replicates** | 8/12 | 12/18 | 10/11 |
| **Duration of study (days)/ No. of sites/No. of sessions** | 5/5/5 | 6/6/6 | 5/5/5 |
| **Time taken for procedure (minutes)[(1)]** | 4-16 | 15-76 | 7-20 |
| **Spray volume (L)[(1)]** | 25-300 L | 25-200 L | 30-300[(2)] |
| **Total ai handled/day (kg) [(1)]** | 0.03-0.2 | 0.03-0.13 | 0.03-0.20[(2)] |
| **Tasks/procedures** | Transport of pesticide drums, transferring chemicals to and from the storage area, pouring and mixing the chemical, loading the spray unit, removing empty containers from the working area and cleaning up spills. | Towing trailer to site, unrolling spray hose, spraying nursery beds, rolling up hose to move to new area | Spraying cleaned residue from spray unit, hosing down the outside of spray unit |
| **PPE** | Waterproof or cotton overalls done up to neck and wrist, washable cotton hat, elbow-length gloves, full face-shield or goggles, and half facepiece respirator, and water-resistant footwear/boots, worn beneath the overalls | | |

[(1)] per session

[(2)] Amount of endosulfan and total volume sprayed before the cleaning operation. The amount of a.i. handled during cleaning operations is not known.

***Worker exposure to endosulfan in the course of aerial application in broadacre cropping industries***

The following six studies were undertaken to estimate exposure for workers in the course of aerial application in broadacre crops.

*A-1-1: Mixing/Loading Bulk and Mini Bulk (closed base)*
*A-1-2: Mixing/Loading small containers (open/remote)*
*A-1-3: Aerial applicators*
*A-1-4: Support workers (vehicles)*
*A-1-5: Support workers (ATVs)*
*A-1-6: Cleaning down*

The above studies were conducted to define levels of exposure to endosulfan for workers mixing and loading endosulfan products for aerial application to cotton, using bulk and mini bulk (closed/base and open/remote) containers, aerial application and assessment of exposure for support workers and those involved in cleaning down operations.

Mixing/loading was done at three different airbases. Where possible, mixing was carried out so that the wind directed any spray or fumes away from the worker, minimising airborne contamination and contamination of equipment. Connection and disconnection of hoses to and from the container, pump and mixing tanks/aircraft tanks was undertaken with care to avoid undue contact with contaminated surfaces. Loaders were directed not to approach aircraft until the aircraft was stationery, and until they had received a clear signal from the pilot to proceed with loading the aircraft. The mixer/loader vacated the pad while the aircraft was taxiing to minimise airborne contamination.

Dermal contamination with endosulfan during mixing and loading was measured. Application rates for the studies were made generally in accordance with label specification for cotton. The average rate of application of endosulfan was 2.1 L/ha, with a range of 2.09 L to 2.11 L/ha. The total volume of spray applied was either 30 or 40 L/ha, however, the amount of endosulfan used per hectare was maintained at 2.1 L/ha, irrespective of spray volume.

Leaking equipment was attended to immediately, and spills of concentrate were cleaned up by workers wearing full waterproof clothing.

In the studies conducted on ATVs (All Terrain Vehicles) and vehicle support workers, it was noted that the points of potential exposure to markers were spray drift (from aircraft), contaminated surfaces of vehicles and splashes from contaminated puddles. The workers were advised to observe safe marking procedures (detailed in the Chemical Handling Manual for Agricultural Aviation, AAAA, Operation Spray Safe, 1998) and to move away from the aircraft's flight path quickly after marking. If unable to move away, support workers were advised to lie face down on the ground. If contaminated by spray, they were advised to cease marking activities, wash themselves and change into clean clothes before resuming work. However no such incidents were reported.

Cleaning down operations following aerial application were estimated to be one hour, with potential exposure to endosulfan being, splashes from spills and wet surfaces, contact with

**Table 4: Parameters of studies conducted for measuring exposure to endosulfan in broadacre cropping industries using aerial application**

| Parameters | Mixing/loading bulk and mini bulk (closed base) (Study A-1-1) | Mixing/Loading small containers (open/remote) (Study A-1-2) | Aerial applicators (Study A-1-3) | Support workers (vehicles) (Study A-1-4) | Support workers (ATVs) (Study A-1-5) | Cleaning down (Study A-1-6) |
|---|---|---|---|---|---|---|
| **Number of subjects /replicates** | 9/13 | 9/13 | 10/16 | 11/14 | 6/7 | 10/11 |
| **Duration of study (days)/No. of sites/No. of sessions** | 7/6/11 | 8/6/9 | 7/9/15 | 7/8/13 | 5/5/6 | 8/7/8 |
| **No. of airbases/airstrips** | 3 | 3 | 3/3 | 7 | 4 | 6 |
| **Area sprayed (ha)[1]** | NA[2] | NA[2] | 37.66-459.76 | 38.5-496.20 | 38.50-393.93 | 47.77-1150 |
| **Time taken for procedure (minutes)[1]** | 40-255 | 20-220 | 25-220 | 65-370 | 45-385 | 10-50 |
| **Spray volume (L) [4]** | 1461-13792 | 1500-19261 | 1155-13792 | 1155-15759 | 1155-15759 | 1911-34500[3] |
| **Total ai handled per session (kg)[1]** | 27.69-337.90 | 32.17-353.87 | 27.69-337.90 | 28.28-364.68 | 28.28-289.55 | 35.11-845.25[3] |

| | | | | |
|---|---|---|---|---|
| **Tasks/procures** | Transport of pesticides, transferring chemicals to and from store room/storage area, mixing chemicals (dilution) to pilot's instructions, loading of chemical into aircraft, removal of empty containers from the working area, cleaning up significant spills, re-fuelling the aircraft, cleaning aircraft lights and windscreen, recording details of chemical prepared and loaded | General instructions regarding mixing/loading/spraying and flagger procedures. Pre-flight inspection of aircraft and spray equipment, supervision of loading/refilling, carrying out the spraying. Checking nozzles/micronairs/filters/flow rates, checking wind speed, drift etc, cleaning and adjusting nozzles, cleaning boom filter, supervising changes to spray configuration, maintenance of flight/application and maintenance records | Indicate the paddock to be sprayed by waving a 1 $m^2$ white, yellow or red flag, or activating a flashing light | Decontamination and cleaning of mixing/filling systems, rinsing and disposal of containers, crushing and removal of drums, general clean up of aircraft and equipment, wash down mixing and loading area |
| **PPE** | Cotton overalls done up to the neck and wrists, full length waterproof bib apron, elbow-length gauntlet gloves cuff folded outwards, washable cotton hat, full face-shield/or goggles, and half-face piece respirator, water-resistant footwear/boots, worn beneath the overalls, and hearing protection for work conducted around 'working aircraft'. | Cotton overalls, flying helmet, flying glasses during the day, nitrile gloves for adjusting CP (pressure control) nozzles, fire protective or waterproof boots, and hearing protection (optional) | White full length cotton overalls buttoned to the neck and wrist, mask/respirator, goggles, washable broad-brimmed hat, PVC gloves, and water resistant boots | Cotton overalls done up to the neck and wrists, full length waterproof bib apron, elbow-length gloves, cuff folded outwards, full face-shield/or goggles, and half-face piece respirator, water-resistant footwear/boots, worn beneath the overalls, and hearing protection for work conducted around 'working aircraft'. |

(1)Per session; (2)not applicable

(3)Amount of endosulfan and total volume sprayed before the cleaning operation. The amount of a.i. handled during cleaning operations is not known.

(4) Data on acreage sprayed indicates low volume spraying (~200 L/ha)

contaminated surfaces of mixing/loading and spray equipment, and contamination from residues and rinsings from drums. Workers were required to use the recommended PPE before touching any contaminated surface. Other specific label instructions were observed during the study. The parameters of the above studies are presented in Table 4.

***Worker exposure to endosulfan in the course of re-entry in broadacre cropping industries***

The following five studies were provided to estimate exposure to endosulfan for workers when re-entering treated areas or to measure residues following endosulfan applications:

*RC-1-1:* *Cotton chipping*
*RC-1-2:* *Crop checking*
*RC-1-3:* *Irrigating*
*RC-1-4:* *Siphon residue*
*RC-1-5:* *Foliar residue*

Re-entry studies involved in cotton chipping, crop checking and foliar residue estimation from areas treated with endosulfan. Studies were conducted to define levels of exposure and to set a safe re-entry interval(s) for workers entering treated cotton fields.

For the study on cotton chipping, 10 dosimeter-patched and gloved workers wearing full PPE (refer Table 5) were allowed to enter the field 48 hours after spraying endosulfan, for 2 hours work. The study was set up to investigate re-entry following both ground rig and aerial application of endosulfan to crops of varying heights (mean 26 cm (short) and 82 cm (high)).

Similarly, for the crop checking study, 10 dosimetry-patched workers were allowed to enter the field 48 hours after endosulfan application, for their normal work, which included checking the crops for pests, counting flowers, bolls, number of nodes and measuring plant height (per linear metre of crop). The crop checkers spent 30 minutes in the field.

These activities were repeated at random within the sprayed block.

For the irrigating study, 10 dosimetry-patched workers were allowed to enter the field immediately after endosulfan application, to simulate the starting of 10 siphons (pumping each 5 times and then laying each back on the head ditch). Crop irrigators were monitored for 10 minutes during these activities.

The points/areas of potential contamination during re-entry activities were identified as contact with contaminated leaves, plants and soil while moving around sprayed sites. Irrigators are also expected to be exposed from siphon contamination.

In a Dislodgeable Foliar Residue (DFR) study, endosulfan residue deposition and the dissipation pattern in foliar samples was measured. Sixty 22 mm leaf discs (total surface area was 228.17 $cm^2$) were cut from leaves sampled at random from the first fully expanded leaf on primary and secondary plant terminals. The leaf discs were then placed in 350 mL jars, sealed and sent for analysis. This procedure was repeated for each of three blocks at the selected site.

Parameters of the above studies are presented in Table 5.

**Table 5: Parameters of studies conducted for measuring exposure during re-entry/re-handling broadacre crops treated with endosulfan**

| Parameters | Cotton Chipping (Study RC-1-1) | | | Crop checking (Study RC-1-2) | | | Irrigating (Study RC-1-3) | | Siphon residue (Study RC-1-4) | | Foliar residue (DFR) (Study RC-1-5) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RC-1-1A | RC-1-1B | RC-1-1C | RC-1-2A | RC-1-2B | RC-1-2C | RC-1-3A | RC-1-3B | RC-1-4A | RC-1-4B | RC-1-5A | RC-1-5B |
| **Date of endosulfan application** | 15/01/00 | 9/12/00 | 9/12/00 | 15/01/00 | 9/12/00 | 9/12/00 | 12/12/00 | 7/03/01 | 12/12/00 | 7/03/01 | 15/01/00 | 9/12/00 |
| **Application method** | Ground rig | Aerial | Aerial | Ground rig | Aerial | Aerial | Aerial | Aerial | Aerial | Aerial | Ground rig | Aerial |
| **Crop height** | 82 cm | 26 cm | 26 cm | 82 cm | 26 cm | 26 cm | 26 cm | NA | 26 cm | NA | 82 cm | 26 cm |
| **Application rate (kg ai/ha)** | 0.735 | 0.735 | 0.735 | 0.735 | 0.735 | 0.735 | 0.735 | 0.735 | 0.735 | 0.735 | 0.735 | 0.735 |
| **Post application re-entry days** | 2, 3, 4, 5, 7, 13 | 2, 3, 4 | 2, 3, 4 | 2, 3, 4, 5, 7, 13 | 2, 3, 4 | 2, 3, 4 | -1, 0, 1 | -1, 0, 1, 2 | -1, 0, 1, 2, 3, 4, 5, 7, 13 | -1, 0, 1, 2, 3, 4, 5 | -1[(1)], 0, 1, 2, 3, 4, 5, 7, 13 | -1[(1)], 0, 1, 2, 3, 4, 5 |
| **Tasks involved** | Hand weeding, or weeding using a hoe | | | Checking crops for pests, counting flowers, bolls, number of nodes and measuring plant height | | | Picking up siphon, pumping siphon and laying back on head ditch | | NA | | | |
| **PPE** | Full length light cotton trousers, long-sleeved light cotton shirt, washable cotton hat, cotton gloves and comfortable boots | | | | | | Shorts, short sleeved shirt and work boots | | NA | | NA | |

[(1)] refers to the day before endosulfan application

NA Not applicable

### 9.2.2 Exposure assessment

To overcome deficiencies in data presentation, surrogate values were utilised for missing data and raw exposure data to estimate exposure, adjusting for high and low exposure values by log transformation of data and standardising to local working conditions. Since the interim report, additional data on dermal absorption were provided to OCS for evaluation (a dermal absorption factor of 29% was used for exposure estimates in the interim report). The re-evaluation of all available data resulted in OCS recommending a human dermal absorption factor of 10%.

All study hand exposure data is assumed as being derived from use of protective gloves (ie, internal cotton glove dosimetry data). As such, "without glove" exposure profiles could not be obtained from the available data.

A number of "issues" arose from a quality analysis of the study data, which are discussed in OHS Appendix 2.

***End use exposure (tree crops, nursery and broadacre crops)***

Dermal exposure values in workers were estimated for the various crops/situations based on the geometric mean of the total endosulfan handled per day and standardised to normal working conditions (average crop sizes and work rates) and a body weight of 70 kg.

Tables 6-8 summarise dermal exposure values obtained from the studies for workers mixing/loading and applying endosulfan to tree crops, nursery and broadacre crops, including cleaning down operations. Individual worker exposure is presented in Appendix 4.

Dermal exposure for workers conducting ground application to broadacre crops was not included in the worker exposure studies as exposure was found to be acceptable based on PHED using 29% dermal absorption (Interim Report 1998). Dermal exposure was further reassessed based on 10% absorption (revised estimate). The data are presented in Table 9.

To estimate exposure for workers using ground application for broadacre crops, the Pesticide Handlers Exposure Database (PHED) Surrogate Exposure Guide (1998) was used. The following scenarios were assessed:

PHED surrogate scenario 3: All liquids, open mixing and loading
PHED surrogate scenario 13: Ground boom application, open cab
PHED surrogate scenario 28: All liquids, open pour, ground boom, open cab

Exposure was estimated based on an application rate of 2.1 L/ha, handling 36.75 kg ai/day, work rate of 50 ha/day, a 6-hour working day, and 10% dermal absorption.

**Table 6: Mean dermal exposure values and absorbed doses for workers mixing/loading/applying endosulfan in tree crops and those involved in cleaning down**

| Studies | Mean Exposure (mg/kg bw/kg ai) [1] | Mean Exposure (study rates) (mg ai/kg bw/day) [2] | Mean Exposure (standardised to amount of ai handled /day (mg ai/kg bw/day) [3] | Mean dermal absorbed dose (mg ai/kg bw/day) [4] | | | |
|---|---|---|---|---|---|---|---|
| | | | | M/L | A | C | M/L/A/C |
| **Mixing/Loading (H-1-1)** | 0.0005 | 0.0076 | 0.0200 | 0.0020 | | | |
| **Air-assist spray-no cabin (H-1-2-U)** | 0.0048 | 0.0730 | 0.1920 | | 0.0192 | | 0.0232 |
| **Air-assist-with cabin (H-1-2-C)** | 0.0014 | 0.0213 | 0.0560 | | 0.0056 | | 0.0096 |
| **Air-shear-with cabin (H-2-2-C)** | 0.0005 | 0.0076 | 0.0200 | | 0.0020 | | 0.0060 |
| **Oscillating boomspray (H-5-2-C)** | 0.0013 | 0.0198 | 0.0520 | | 0.0052 | | 0.0092 |
| **Cleaning down (H-1-4)** | 0.0005 | 0.0076 | 0.0200 | | | 0.0020 | |

[1] Geometric mean of exposures standardised for 70 kg body weight;
[2] Mean exposure based on 15.2 kg ai handled/day (study rates)
[3] Mean exposure based on 40 kg ai handled/day (190 mL/100 L; spray volume 2000 L/ha, work rate 30 ha/day, (standardised work rates);
[4] Mean dermal absorbed dose (mg ai/kg bw/day)= mean dermal exposure x dermal absorption factor (10%)
M/L=mixing/loading; A=application; C=cleaning down; M/L/A/C=mixing/loading/application/cleaning down

**Table 7: Mean dermal exposure values and absorbed doses for workers mixing/loading/applying endosulfan to nursery crops and those involved in cleaning down**

| Studies | Mean Exposure (mg/kg bw/kg ai) [1] | Mean Exposure (study rates) (mg ai/kg bw/day) [2] | Mean Exposure (standardised to amount of ai handled /day (mg ai/kg bw/day) [3] | Mean dermal absorbed dose (mg ai/kg bw/day) [4] | | | |
|---|---|---|---|---|---|---|---|
| | | | | M/L | A | C | M/L/A/C |
| **Mixing/Loading (H-3-1)** | 0.0043 | 0.0022 | 0.0022 | 0.0002 | - | - | - |
| **Application (H-3-2)** | 0.0082 | 0.0041 | 0.0041 | | 0.0004 | - | - |
| **Cleaning down (H-3-3)** | 0.0024 | 0.0012 | 0.0012 | | - | 0.0001 | - |
| | | | | | | | 0.0007 |

[1] Geometric mean of exposures, standardised for 70 kg body weight
[2] Mean exposure based on 0.5 kg ai handled/day and 2 hours spraying/day (study rates)
[3] Mean exposure based on 0.5 kg ai handled/day with 2 hours spraying/day (no standardisation required, current work rates)
[4] Mean dermal absorbed dose (mg ai/kg bw/day) = mean dermal exposure x dermal absorption factor (10%)
M/L=mixing/loading; A=application, hand-held); C=cleaning down; M/L/A/C=mixing/loading/application/cleaning down

**Table 8: Mean dermal exposure values and absorbed doses for workers mixing/loading/applying endosulfan aerially in broadacre crops, exposure for support workers, and those involved in cleaning down**

| Studies | Mean Exposure (mg/kg bw/kg ai) [1] | Mean Exposure (study rates) (mg ai/kg bw/day) [2] | Mean Exposure (standardised to amount of ai handled /day (mg ai/kg bw/day) [3] | Mean dermal absorbed dose [4] (mg ai/kg bw/day) | | | |
|---|---|---|---|---|---|---|---|
| | | | | M/L | A | C | S |
| **Mixing/Loading Bulk and Mini bulk (closed base) (A-1-1)** | 0.00012 | 0.097 | 0.176 | 0.018 | | | |
| **Mixing/Loading small containers (open/remote) (A-1-2)** | 0.00011 | 0.089 | 0.162 | 0.016 | | | |
| **Aerial applicators (A-1-3)** | 0.00003 | 0.024 | 0.044 | | 0.004 | | |
| **Support workers (vehicles) (A-1-4)** | 0.00001 | 0.008 | 0.015 | | | | 0.001 |
| **Support workers (ATVs) (A-1-5)** | 0.00005 | 0.041 | 0.074 | | | | 0.007 |
| **Cleaning down (A-1-6)** | 0.00002 | 0.016 | 0.029 | | | 0.003 | |

[1] Geometric mean of exposures, standardised for 70 kg body weight
(2) Based on 811 kg ai handled/day (study rates),
(3) Based on 1470 kg ai handled/day, application rate of 2.1 L/ha; work rate 2000 ha/day (standardised work rates)
(4) Mean dermal absorbed dose (mg ai/kg bw/day) = mean dermal exposure x dermal absorption factor (10%)
M/L=mixing/loading; A=application; C=cleaning down; S= support workers

**Table 9: Systemic absorbed doses for workers mixing/loading/applying endosulfan to broadacre crops using ground boom open cab (PHED)**

| Scenarios | | Absorbed doses following exposure to endosulfan* (mg/kg bw/day) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Dermal | | | Inhalation | | Total |
| | Gloves | Mixer/Loader | Applicator | | Mixer/Loader | Applicator | |
| Scenario 3- all liquids open mixing and loading | N | 0.336 | - | | 0.001 | - | 0.337 |
| | Y | 0.003 | - | | 0.001 | - | 0.004 |
| Scenario 13: Ground boom application, open cab | N | - | 0.002 | | - | 0.001 | 0.003 |
| | Y | - | 0.002 | | - | 0.001 | 0.003 |
| Scenario 28- liquid/open pour/groundboom/open cab | N | 0.043 | | | 0.001 | | 0.044 |
| | Y | 0.007 | | | 0.001 | | 0.008 |

*Based on 70 kg person, 10% dermal absorption and 100% inhalation absorption.

***Exposure to workers undertaking re-entry/rehandling activities (following ground and aerial application)***

According to information provided in Study No. RC 1-2, crop checkers usually spend 1/3 of the working day (assumed to be 8 hours) in the field checking crops for pests, and the remaining time in other activities such as data entry, traveling etc in their work schedule. Cotton chippers usually perform 8 hours work/day (Study RC 1-1) in the field. Therefore exposure for crop checkers was estimated based on a 3-hour/day work period, and for cotton chippers based on a 8 hour/day work period.

The study authors indicated that irrigation workers spend 8 hours at work but that not all of this time is spent in the field (no time estimate was provided). Therefore exposure for crop irrigators was estimated based on a 2-hour/day work period.

To determine a safe re-entry interval(s) for workers entering treated fields for various activities, the following data were used:

- measured (mean) dermal exposure dosimetry data provided in the ground rig and aerial studies, and
- exposure calculated from DFR data (from foliar sampling).

The mean measured dermal exposure values for workers (wearing PPE) conducting crop checking, cotton chipping, and crop irrigation at different time intervals following ground and aerial application of endosulfan are presented in Table 10.

Exposure for workers (with PPE) re-entering treated areas was estimated from DFR data. The transfer coefficients (TC) for crop checking and cotton chipping were determined from the DFR using the measured dermal exposure values for these activities (refer to equation in Table 11 footnote). Results are outlined in Table 11.

**Table 10: Mean dermal exposure values for workers conducting crop checking, cotton chipping, and crop irrigation at different time intervals following ground and aerial application of endosulfan**

| Re-entry (day) | Mean measured dermal exposure (mg/kg bw/day)[1] (dosimeter data) (with PPE) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Cotton chipping | | | Crop checking | | | Irrigating | |
| | Ground application (RC-1-1A) | Aerial application (RC-1-1B) | Aerial application (RC-1-1C) | Ground application (RC-1-2A) | Aerial application (RC-1-2B) | Aerial application (RC-1-2C) | Aerial application (RC-1-3A) | Aerial application (RC-1-3B) |
| 0 | ND | ND | ND | ND | ND | ND | 0.0103 | 0.0175 |
| 1 | ND | ND | ND | ND | ND | ND | 0.0050 | 0.0128 |
| 2 | 0.0075 | 0.0013 | 0.0008 | 0.0038 | 0.0007 | 0.0014 | ND | 0.0069 |
| 3 | 0.0016 | 0.0007 | 0.0007 | 0.0016 | 0.0007 | 0.0008 | ND | ND |
| 4 | 0.0014 | 0.0004 | 0.0004 | 0.0012 | 0.0004 | 0.0006 | ND | ND |
| 5 | 0.0005 | ND | ND | 0.0007 | ND | ND | ND | ND |
| 7 | 0.0006 | ND | ND | 0.0006 | ND | ND | ND | ND |
| 13 | 0.0002 | ND | ND | 0.0003 | ND | ND | ND | ND |

[1] geometric mean measured (dosimeters) dermal exposure (mg/kg bw/day) based on 3 hours of crop checking and 8 hours of cotton chipping and 2 hours crop irrigation. These values are based on the author's raw exposure data (µg/cm$^2$, uncorrected for field blanks) and 70 kg bw per person
ND: not determined

**Table 11: Transfer coefficients calculated from the dislodgeable foliar residues and dermal exposure data for workers (wearing PPE) following ground and aerial application of endosulfan**

| Application method /crop height | Sampling days | DFR (µg/cm$^2$)[1] | Study dermal exposure estimates (mg/kg bw/day) (with PPE) | | | Transfer coefficient (cm$^2$/hr)[2] (calculated) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Cotton chipping | Crop checking | Irrigating | Crop checking | Cotton chipping | Irrigating |
| **Ground rig (82 cm crop)** | | *RC 1-5A* | *RC 1-1A* | *RC 1-2A* | | | | |
| | -1[3] | 0.0011 | ND | ND | ND | ND | ND | ND |
| | 0 | 2.826 | ND | ND | ND | ND | ND | ND |
| | 1 | 4.927 | ND | ND | ND | ND | ND | ND |
| | 2 | 2.526 | 0.0075 | 0.0038 | ND | 26 | 13 | ND |
| | 3 | 0.444 | 0.0016 | 0.0016 | ND | 32 | 32 | ND |
| | 4 | 0.480 | 0.0014 | 0.0012 | ND | 26 | 22 | ND |
| | 5 | 0.278 | 0.0005 | 0.0007 | ND | 16 | 22 | ND |
| | 7 | 0.332 | 0.0006 | 0.0006 | ND | 16 | 16 | ND |
| | 13 | 0.150 | 0.0002 | 0.0003 | ND | 12 | 18 | ND |
| | | | | | | ***Average 21*** | ***Average 20*** | |
| **Aerial (26 cm crop)** | | *RC 1-5B* | *RC 1-1B* | *RC 1-2B* | *RC 1-3A* | | | |
| | -1 | 0.0019 | ND | ND | ND | ND | ND | ND |
| | 0 | 3.003 | ND | ND | 0.0103 | ND | ND | 30 |
| | 1 | 3.407 | ND | ND | 0.0050 | ND | ND | 13 |
| | 2 | 0.929 | 0.0013 | 0.0007 | ND | 12 | 7 | ND |
| | 3 | 0.582 | 0.0007 | 0.0007 | ND | 11 | 11 | ND |
| | 4 | 0.381 | 0.0004 | 0.0004 | ND | 9 | 9 | ND |
| | 5 | 0.263 | ND | ND | ND | ND | ND | ND |
| | | *RC 1-5B* | *RC 1-1C* | *RC 1-2C* | *RC 1-3B* | | | |
| | -1 | 0.0019 | ND | ND | ND | ND | ND | ND |
| | 0 | 3.003 | ND | ND | 0.0175 | ND | ND | 51 |
| | 1 | 3.407 | ND | ND | 0.0128 | ND | ND | 33 |
| | 2 | 0.929 | 0.0008 | 0.0014 | 0.0069 | 8 | 13 | 65 |
| | 3 | 0.582 | 0.0007 | 0.0008 | ND | 11 | 12 | ND |
| | 4 | 0.381 | 0.0004 | 0.0006 | ND | 9 | 14 | ND |
| | 5 | 0.263 | ND | ND | ND | ND | ND | ND |
| | | | | | | ***Average 10*** | ***Average 11*** | ***38*** |

[1] measured DFR values for endosulfan from 2 study sites and 2 crop heights provided in the submitted studies, with sampling starting from the day before endosulfan was sprayed until day 13 for RC 1-5A, and day 5 for RC 1-5B; [2] Transfer coefficient (cm$^2$/hr) calculated using measured dermal exposure values for cotton chipping and crop checking and measured DFR following aerial application of endosulfan, TC (cm$^2$/hr) = dermal exposure (mg/day) ÷ time spent for activity (hrs/day) x DFR (µg/cm$^2$); [3] refers to the day before endosulfan was sprayed; ND no data

From Table 11 it is noted that DFR varied on the different days with values higher on day 1 when compared to day 0, and days 4 and 7 having higher residues when compared to days 3 and 6. According to the study author, this variation in residues may have been due to incomplete settling of residue following endosulfan application.

Table 11 shows the TC determined from dermal exposure estimates and DFR data (both provided in the study) were found to be low; TCs 21, & 20 for crop checking & cotton chipping (ground rig application), and TCs 10 and 11 for crop checking and cotton chipping (aerial application). TC for irrigation following aerial application was 38. No data were provided for irrigation following ground rig application. These TCs were determined from workers using PPE (ie, from dosimeters placed underneath gloves and protective clothing).

To determine actual TC (i.e. amount transferred to workers'skin), the data were recalculated assuming 90% protection is provided to workers using PPE. The results are presented in Table 12.

Dermal doses (on different re-entry days) were estimated using the mean DFR ($\mu g/cm^2$), and the average TCs estimated for workers using PPE with work rates of 3 hrs/day for crop checking, 8 hrs/day for cotton chipping and 2 hours/day for irrigation, and a 10% dermal absorption factor. For comparison, generic transfer coefficients available in the US EPA Re-entry risk calculator were also used to estimate dermal doses. These values are presented in Table 13 together with dermal dosimetry data.

**Table 12: Transfer coefficients calculated from the dislodgeable foliar residues and dermal exposure data for workers not wearing PPE following ground and aerial application of endosulfan**

| Application method /crop height | Sampling days | DFR (µg/cm²)[1] | Study dermal exposure estimates (mg/kg bw/day) (without PPE)[2] | | | Transfer coefficient (cm²/hr)[3] (calculated) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Cotton chipping | Crop checking | Irrigating | Crop checking | Cotton chipping | Irrigating |
| | | *RC 1-5A* | *RC 1-1A* | *RC 1-2A* | | | | |
| **Ground rig (82 cm crop)** | -1[4] | 0.0011 | ND | ND | ND | ND | ND | ND |
| | 0 | 2.826 | ND | ND | ND | ND | ND | ND |
| | 1 | 4.927 | ND | ND | ND | ND | ND | ND |
| | 2 | 2.526 | 0.075 | 0.038 | ND | 260 | 132 | ND |
| | 3 | 0.444 | 0.016 | 0.016 | ND | 315 | 315 | ND |
| | 4 | 0.480 | 0.014 | 0.012 | ND | 255 | 219 | ND |
| | 5 | 0.278 | 0.005 | 0.007 | ND | 157 | 220 | ND |
| | 7 | 0.332 | 0.006 | 0.006 | ND | 158 | 158 | ND |
| | 13 | 0.150 | 0.002 | 0.003 | ND | 117 | 175 | ND |
| | | | | | ***Average*** | ***210*** | ***203*** | |
| | | *RC 1-5B* | *RC 1-1B* | *RC 1-2B* | *RC 1-3A* | | | |
| **Aerial (26 cm crop)** | -1 | 0.0019 | ND | ND | ND | ND | ND | ND |
| | 0 | 3.003 | ND | ND | 0.103 | ND | ND | 30 |
| | 1 | 3.407 | ND | ND | 0.050 | ND | ND | 13 |
| | 2 | 0.929 | 0.013 | 0.007 | ND | 122 | 66 | ND |
| | 3 | 0.582 | 0.007 | 0.007 | ND | 105 | 105 | ND |
| | 4 | 0.381 | 0.004 | 0.004 | ND | 92 | 92 | ND |
| | 5 | 0.263 | ND | ND | ND | ND | ND | ND |
| | | *RC 1-5B* | *RC 1-1C* | *RC 1-2C* | *RC 1-3B* | | | |
| | -1 | 0.0019 | ND | ND | ND | ND | ND | ND |
| | 0 | 3.003 | ND | ND | 0.175 | ND | ND | 510 |
| | 1 | 3.407 | ND | ND | 0.128 | ND | ND | 33 |
| | 2 | 0.929 | 0.008 | 0.014 | 0.069 | 75 | 132 | 65 |
| | 3 | 0.582 | 0.007 | 0.008 | ND | 105 | 120 | ND |
| | 4 | 0.381 | 0.004 | 0.006 | ND | 92 | 138 | ND |
| | 5 | 0.263 | ND | ND | ND | ND | ND | ND |
| | | | | | ***Average*** | ***99*** | ***109*** | ***380*** |

[1] measured DFR values for endosulfan from 2 study sites and 2 crop heights provided in the submitted studies, with sampling starting from the day before endosulfan was sprayed until day 13 for RC 1-5A, and day 5 for RC 1-5B

[2] dermal exposure (without PPE) = dermal exposure (with PPE) x 100% ÷ 10%

[3] Transfer coefficient (cm²/hr) calculated using measured dermal exposure values for cotton chipping and crop checking and measured DFR following aerial application of endosulfan, TC (cm²/hr) = dermal exposure (mg/day) ÷ time spent for activity (hrs/day) x DFR (µg/cm²)

[4] refers to the day before endosulfan was sprayed ND no data

**Table 13: Standardised dermal absorbed doses for workers (without PPE) conducting re-entry activities (crop checking, cotton chipping and irrigating) determined from foliar residue data (using calculated and generic transfer coefficients and dosimetry data)**

| Re-entry day | Dermal absorbed dose (mg ai/kg bw/day) [1] (without PPE) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cotton chipping | | | | Crop checking | | | | Irrigating | | | |
| | Calculated [2] | | | Measured exposure [3] | Calculated [2] | | | Measured exposure [3] | Calculated [2] | | | Measured exposure [3] |
| | Study TC (average) 203 | Generic TC - low exposure (100) | Generic TC –medium exposure (1500) | | Study TC (average) 210 | Generic TC - low exposure (100) | Generic TC –medium exposure (1500) | | Study TC (average) ND | Generic TC - low exposure (100) | Generic TC – medium exposure (1500) | |
| **Ground rig (82 cm crop)** | | | | | | | | | | | | |
| 0 | 0.0066 | 0.0032 | 0.0484 | ND | 0.0025 | 0.0012 | 0.0182 | ND | ND | ND | ND | ND |
| 1 | 0.0114 | 0.0056 | 0.0845 | ND | 0.0044 | 0.0021 | 0.0317 | ND | ND | ND | ND | ND |
| 2 | 0.0059 | 0.0029 | 0.0433 | 0.0075 | 0.0023 | 0.0011 | 0.0162 | 0.0038 | ND | ND | ND | ND |
| 3 | 0.0010 | 0.0005 | 0.0076 | 0.0016 | 0.0004 | 0.0002 | 0.0029 | 0.0016 | ND | ND | ND | ND |
| 4 | 0.0011 | 0.0005 | 0.0082 | 0.0014 | 0.0004 | 0.0002 | 0.0031 | 0.0012 | ND | ND | ND | ND |
| 5 | 0.0006 | 0.0003 | 0.0048 | 0.005 | 0.0003 | 0.0001 | 0.0018 | 0.0007 | ND | ND | ND | ND |
| 7 | 0.0008 | 0.0004 | 0.0057 | 0.0006 | 0.0003 | 0.0001 | 0.0021 | 0.0006 | ND | ND | ND | ND |
| 13 | 0.0003 | 0.0002 | 0.0026 | 0.0002 | 0.0001 | 0.0001 | 0.0010 | 0.0003 | ND | ND | ND | ND |
| **Aerial (26 cm crop)** | **109** | | | | **99** | | | | **383** | | | |
| 0 | 0.0037 | 0.0034 | 0.0515 | ND | 0.0013 | 0.0013 | 0.0193 | ND | 0.0033 | 0.0009 | 0.0129 | 0.0103 |
| 1 | 0.0042 | 0.0039 | 0.0584 | ND | 0.0014 | 0.0015 | 0.0219 | ND | 0.0037 | 0.0010 | 0.0146 | 0.0050 |
| 2 | 0.0012 | 0.0011 | 0.0159 | 0.0013 | 0.0004 | 0.0004 | 0.0060 | 0.0007 | 0.0010 | 0.0003 | 0.0040 | ND |
| 3 | 0.0007 | 0.0007 | 0.0100 | 0.0007 | 0.0002 | 0.0002 | 0.0037 | 0.0007 | 0.0006 | 0.0002 | 0.0025 | ND |
| 4 | 0.0005 | 0.0004 | 0.0065 | 0.0004 | 0.0002 | 0.0002 | 0.0024 | 0.0004 | 0.0004 | 0.0001 | 0.0016 | ND |
| 5 | 0.0003 | 0.0003 | 0.0045 | ND | 0.0001 | 0.0001 | 0.0017 | ND | 0.0003 | 0.0001 | 0.0011 | ND |

[1] dermal absorbed dose (mg ai/kg bw/day) = mean dermal exposure x dermal absorption (10%).

[2] dermal absorbed dose calculated using average study TC (calculated from measured dermal exposure data) or generic TC (100 for low exposure and 1500 for medium exposure, US EPA Re-entry calculator TC values for Transfer Coefficient Group: Field/row crop, low/medium) and measured DFR; dermal absorbed dose (mg/kg bw/day) = TC ($cm^2$/hr) x time spent for activity (hr/day) x DFR mg/$cm^2$ ÷ 70 kg x 10% (absorption).

[3] data derived from measured worker exposure (dosimeters) following ground and aerial applications, ND no data

## 9.3 OCCUPATIONAL RISK ASSESSMENT

The OHS risk assessment takes into consideration the intrinsic hazards of endosulfan as provided in the interim report (APVMA 1998), the worker exposure data (generated from the studies provided), label instructions and use patterns (where deficient in labels). The deterministic approach (margin of exposure) was used to quantify risks to workers from exposure to endosulfan.

Endosulfan is of high acute oral, dermal and inhalation toxicity. It is an eye irritant and a slight skin irritant in rabbits, but is not a skin sensitiser in guinea pigs.

Endosulfan does not pose a mutagenic hazard (based on gene mutation assays, chromosomal effects assays, cytogenetics assays and cell transformation assays). No treatment related neoplastic lesions were seen in chronic studies in mice and rats.

The toxicological assessment showed that endosulfan, alone or in combination with other pesticides, may have some oestrogenic binding capacity and therefore might be capable of disturbing the normal balance of the endocrine hormone system. However, all available studies show only very weak binding to hormone receptors *in vitro,* and there is no evidence for any adverse physiological effects *in vivo.* Long-term bioassays, and reproductive and developmental toxicology studies in experimental animals, do not indicate that endosulfan induces any functional aberrations, which might result from disruption of the endocrine hormone system.

Endosulfan is classified in the List of Designated Hazardous Substances, with the following risk phrases:

| | |
|---|---|
| R26 | Very toxic by inhalation |
| R24/25 | Toxic in contact with skin and if swallowed |
| R36 | Irritating to eyes |

The following cut-off concentrations apply to endosulfan:

| | |
|---|---|
| Concentration >25% | R26; R24/25; R36 |
| >20%, <25% | R26; R21/22; R36 |
| >7%, <20% | R26; R21/22 |
| >3%, <7% | R23; R21/22 |
| >1%, <3% | R23 |
| >0.1%, <1% | R20 |

Based on the seasonal use pattern of endosulfan, it was concluded that the most appropriate NOEL for the purpose of assessing occupational risks to workers was 1.92 mg/kg bw/day, determined in a 13-week dietary study in rats. Effects seen at the LOAEL in this study were increased kidney weights and granule formation in the proximal tubular cells. No data was provided to suggest that such effects are not relevant to humans.

Since the selected NOEL was established in experimental animals, margins of exposure (MOE) of approximately 100 or more are generally considered acceptable (in terms of risks to workers), in order to account for intra-species (10x) and inter-species (10x) variability.

Generation of data on inhalation exposure was not included in the study protocol, since workers are currently required to wear respirators during mixing, loading and application (by virtue of the acute

inhalation toxicity of endosulfan), and overall contribution to exposure for applicators has been shown to be minimal (see section 9.1). Therefore exposure to endosulfan from inhalation was not included in the risk assessment.

The dermal exposure data provided in the studies was assessed both as:

i) total body exposure; and
ii) ii) exposure excluding head/face.

This was undertaken to establish the contribution to total dermal exposure of wearing a respirator and hat (i.e. the reduction in dermal exposure from head/face protection). Such an analysis permits a determination of whether a respirator and hat are required for certain application scenarios. It should be noted however, that a respirator is required for all operations where exposure to a concentration of endosulfan in excess of 1% in end-use product is likely based on the acute inhalation toxicity of endosulfan. This is irrespective of dermal MOEs being in excess of 100 for these operations.

All study hand exposure data is assumed as being derived from use of protective gloves (ie, internal cotton glove dosimetry data). As such '*without glove*' exposure profiles could not be obtained from the available data.

### 9.3.1 End use acute exposure risk assessment

Endosulfan is of high acute oral, dermal and inhalation toxicity. It is an eye irritant and slight skin irritant in rabbits, but is not a skin sensitiser in guinea pigs.

At the concentration of endosulfan in all EC products, acute risks of dermal and inhalation toxicity and eye irritation are associated with mixing/loading activities.

Based on the following application rates, the concentrations of endosulfan in spray are as follows:

| | |
|---|---|
| Orchard: | 190mL/100mL = 0.067% |
| Nursery: | 2.1L/ha in 2000L water/ha = 0.037% |
| Broadacre (aerial): | 2.1L/ha in 20L water/ha = 3.675% |
| Broadacre (ground boom): | 2.1L/ha in 50L water/ha = 1.47% |

At these concentrations acute risks of inhalation toxicity (but not eye irritation or dermal toxicity) are associated with all broadacre spraying (ground and aerial).

### 9.3.2 End use repeated exposure risk assessment

The submitted exposure studies for endosulfan used the US EPA Occupational and Residential Exposure Test Guidelines OPPTS 875.1000 to estimate whole body exposure. In the calculations, head and face exposure was calculated from internal patches placed under the overalls on the external shoulder (dorsal side), chest, and back x 1300 $cm^2$.

According to US EPA Guidelines, head/face exposure should be estimated from patches placed on the outside (ie, externally) of garments at the back, chest and shoulders. In order to determine the

necessity for PPE for head/face exposure, and in the absence of external patch data, internal patch data (from the studies) were used to determine the need for a respirator and hat during application.

MOE were calculated for the various crops/situations and application methods from dermal exposure values determined from the studies conducted both with and without head/face exposure. These are presented in Tables 14 and 15.

MOE calculated for broadacre crops using ground application equipment were determined from PHED data. These are presented in Table 16.

***Risk for tree crop workers***

Tree crop workers handling 40 kg ai/day had acceptable MOE (when head/face exposure was included) for mixer/loaders (960), applicators using air-assist with no cabin (100), air assist with cabin (343), air shear with cabin (960), and oscillating boomspray (369). MOE for cleaners were acceptable (960). When mixer/loader activities were combined with application using air-assist without cabin, MOE was not acceptable (83). However, MOE for combined mixer/loader and applicators using air-assist with cabin (200), air shear with cabin (320) and oscillating boomspray equipment (209) were acceptable. All MOEs for scenarios (single and combined) were also acceptable when head/face exposure was excluded.

***Risk from ground application to nursery crops***

Nursery workers handling 0.5 kg ai/day had acceptable MOE (when head/face exposure was included)for mixer/loaders (8833), applicators (4698) and cleaners (15938). When all activities were combined the MOE was also acceptable (2572). Similar results were seen when head/face exposure was excluded.

***Risk from aerial application to broadacre crops***

Broadacre workers handling 1470 kg ai/day for aerial application had acceptable MOE (when head/face exposure was included) for mixer/loaders (107 & 120 for closed and open mixing), aerial applicators (480), vehicle support workers (988), ATV support workers (248) and cleaners (523). MOE for combined activities for broadacre crops (aerial) was not estimated as activities are usually undertaken by different workers. Similar results were seen when head/face exposure was excluded.

**Table 14: Margins of exposure (MOE) for workers mixing/loading (M/L) and applying (A) endosulfan to tree and nursery crops by ground application and aerial equipment, support workers (S) and cleaning down (C) operations using standardised label rates for all applications including head/face exposure (ie, without use of cotton hat and respirator)**

| Studies | MOE[1] | | | | |
|---|---|---|---|---|---|
| **Tree crops** (40 kg ai/30 ha/day) | **M/L** | **A** | **S[2]** | **C** | **M/L/A/S/C** |
| Mixing/loading (H1-1) | 960 | - | - | - | - |
| Spraying air-assist, no cabin (H-1-2-U) | - | 100 | - | - | 83 |
| Spraying air assist, with cabin (H-1-2-C) | - | 343 | - | - | 200 |
| Spraying air-shear, with cabin (H-2-2-C) | - | 960 | - | - | 320 |
| Oscillating boomspray (H-5-2-C) | - | 369 | - | - | 209 |
| Cleaning down (H-1-4) | - | - | - | 960 | - |
| **Nursery crops** (0.5 kg ai/2 hours/day) | | | | | |
| Mixing/loading (H-3-1) | 8833 | - | - | - | - |
| Spraying (H-3-2) | - | 4698 | - | - | - |
| Cleaning down (H-3-3) | - | - | - | 15938 | 2572 |
| **Broadacre crops (Aerial application)** (1470 kg ai/2000 ha/day) | | | | | |
| Mixing/loading, bulk and mini bulk, closed base (A1-1) | 107 | - | - | - | - |
| Mixing/loading, small containers, open/remote (A1-2) | 120 | - | - | - | - |
| Aerial application (A1-3) | - | 480 | - | - | - |
| Support workers, vehicles (A1-4) | - | - | 988 | - | - |
| Support workers, ATVs (A1-5) | - | - | 248 | - | - |
| Cleaning down (A1-6) | - | - | | 523 | NA [4] |

M/L= Mixer/Loader; A=Applicator; S =Support worker; C=Cleaner; M/L/A/S/C=Mixer/Loader/Applicator/Support workers/Cleaner.

[1] MOE= NOEL (1.92 mg/kg bw/day) ÷ mean dermal absorbed dose (mg ai/kg bw/day).

[2] only aerial application has support workers.

[3] exposure to workers performing all tasks.

[4] not applicable as each activity is usually undertaken by different workers

**Table 15: Margins of exposure (MOE) for workers mixing/loading (M/L) and applying (A) endosulfan to tree and nursery crops by ground application and aerial equipment, support workers (S) and cleaning down (C) operations using standardised label rates for all applications, excluding head exposure**

| Studies | MOE[1] | | | | |
|---|---|---|---|---|---|
| **Tree crops** (40 kg ai/30 ha/day) | **M/L** | **A** | **S[2]** | **C** | **M/L/A/S/C** |
| Mixing/loading (H1-1) | 960 | - | | - | - |
| Spraying air-assist, no cabin (H-1-2-U) | - | 253 | | - | 171 |
| Spraying air assist, with cabin (H-1-2-C) | - | 369 | | - | 218 |
| Spraying air-shear, with cabin (H-2-2-C) | - | 960 | | - | 343 |
| Oscillating boomspray (H-5-2-C) | - | 400 | | - | 229 |
| Cleaning down (H-1-4) | - | - | | 1200 | - |
| **Nursery crops** (0.5 kg ai/2 hours/day) | | | | | |
| Mixing/loading (H-3-1) | 9600 | - | - | - | - |
| Spraying (H-3-2) | - | 6400 | - | - | 3200 |
| Cleaning down (H-3-3) | - | - | - | 19200 | - |
| **Broadacre crops (Aerial application)** (1470 kg ai/2000 ha/day) | | | | | |
| Mixing/loading, bulk and mini bulk, closed base (A1-1) | 114 | - | - | - | |
| Mixing/loading, small containers, open/remote (A1-2) | 129 | - | - | - | - |
| Aerial application (A1-3) | | 518 | - | - | - |
| Support workers, vehicles (A1-4) | | - | 1054 | - | - |
| Support workers, ATVs (A1-5) | | - | 261 | | - |
| Cleaning down (A1-6) | | - | - | 523 | NA[4] |

M/L= Mixer/Loader; A=Applicator; S =Support worker; C=Cleaner; M/L/A/S/C; Mixer/Loader/Applicator/Support workers/Cleaner.
[1] MOE= NOEL (1.92 mg/kg bw/day) ÷ mean dermal absorbed dose (mg ai/kg bw/day).
[2] only aerial application has support workers.
[3] exposure to workers performing all tasks.
[4] not applicable as each activity is usually undertaken by different workers ND not determined

**Table 16: Margins of exposure (MOE) for workers mixing/loading and applying endosulfan to broadacre crops by ground application using PHED data**

| PHED Estimates | MOE[1] | | | | | Total |
|---|---|---|---|---|---|---|
| | *Dermal* | | | *Inhalation* | | |
| | *Gloves* | *Mixer/Loader* | *Applicator* | *Mixer/Loader* | *Applicator* | |
| **PHED Surrogate Scenario 3 and 13:** all liquid/open mixing/loading and ground boom application/open cab | N | 6 | 960 | 1920 | 1920 | 6 |
| | Y | 640 | 960 | 1920 | 1920 | 274 |
| **PHED Surrogate Scenario 28:** All liquids, open pour, ground boom, open cab | N | 45 | | 1920 | | 44 |
| | Y | 274 | | 1920 | | 240 |

[1] Based on a NOEL of 1.92 mg/kg bw/day

***Risk from ground application to broadacre crops (from PHED data)***

According to PHED estimates, workers handling 36.75 kg ai/day had acceptable MOE for open mixing/loading (640), and for applicators using open cab (960) while treating broadacre crops using ground equipment. Acceptable MOE were also determined for workers combining both activities (274). MOE were acceptable only when gloves where used.

### 9.3.3 Re-entry risk assessment

MOE were determined for workers conducting various re-entry activities (cotton chipping, crop checking and irrigating) determined for workers from DFR (using calculated and generic transfer coefficients) and from measured worker exposure data (dosimeters). These MOE were based on the dose derived from actual TC (i.e. amount transferred to workers' skin, on the assumption that 90% protection is provided to workers using PPE). These are presented in Table 17.

The DFR values obtained in the cotton study were extrapolated to other crops (citrus, pecans, fruit and nut trees, vegetables, some fruits, tomatoes, nursery crops, grapes, tobacco and broadacre crops) were extrapolated by considering relative application rates and generic transfer coefficients identified in the US Occupational Post-Application Risk Assessment Calculator (US EPA Policy 003.1). Application rates for the various crops were used (where provided). Where application rates were not provided, the rate/ha based on the dilution rates and spray volumes provided by the applicants were determined. Using the DFR data provided for cotton, the generic transfer coefficients of the various crops, and standardising the application rates, the dermal absorbed doses were determined, using the following formula:

Dermal absorbed dose = DFR cotton x application rate (crop) ÷ application rate (cotton) x TC (crop) x 8 hr working day x dermal absorption factor (0.1). The MOE were then determined using the dermal absorbed dose and NOEL of 1.92 mg/kg bw/day. These data are presented in Table 18.

***Risks to re-entry workers (cotton crop)***

MOE for re-entry activities (cotton chipping, crop checking and irrigating) were determined for workers from DFR (using calculated and generic transfer coefficients) and from measured worker exposure data (dosimeters) (Table 17). No measured exposure data were provided for workers re-entering treated areas on day 0 and day 1. Data were only provided from day 2 onwards, with acceptable MOE being determined from day 2. Using the study TC and generic TC for low exposure activities for cotton chipping and crop checking, acceptable MOE were obtained from day 0 onwards. Therefore, as:

a) no measured data were provided for day 0 and day 1;
b) study exposure data provided acceptable MOE were determined on day 2; and
c) DFR data provided acceptable MOE on day 0;

a 2-day re-entry interval is considered suitable for workers entering treated areas for various crop activities for cotton.

**Table 17: Margins of exposure (MOE) for re-entry activities (cotton chipping, crop checking and irrigating) determined for workers from DFR (using calculated and generic transfer coefficients) and from measured worker exposure data (dosimeters).**

| Re-entry day | MOE[1] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cotton chipping | | | | Crop checking | | | | Irrigating | | | |
| | Calculated | | | Measured exposure [2] | Calculated | | | Measured exposure [2] | Calculated | | | Measured exposure [2] |
| | Study TC (average) (203) | Generic TC - low exposure (100) | Generic TC –medium exposure (1500) | | Study TC (average) (210) | Generic TC - low exposure (100) | Generic TC –medium exposure (1500) | | Study TC (average) ND | Generic TC - low exposure (100) | Generic TC –medium exposure (1500) | |
| **Ground rig (82 cm crop)** | | | | | | | | | | | | |
| 0 | 293 | 594 | 40 | ND | 753 | 1585 | 106 | ND | ND | ND | ND | ND |
| 1 | 168 | 341 | 23 | ND | 432 | 909 | 61 | ND | ND | ND | ND | ND |
| 2 | 327 | 665 | 44 | 256 | 843 | 1774 | 118 | 505 | ND | ND | ND | ND |
| 3 | 1862 | 3784 | 252 | 1200 | 4795 | 10090 | 673 | 1200 | ND | ND | ND | ND |
| 4 | 1723 | 3500 | 233 | 13714 | 4436 | 9333 | 622 | 1600 | ND | ND | ND | ND |
| 5 | 2974 | 6043 | 403 | 3840 | 7659 | 16115 | 1074 | 2742 | ND | ND | ND | ND |
| 7 | 2490 | 5060 | 337 | 3200 | 6413 | 13494 | 900 | 3200 | ND | ND | ND | ND |
| 13 | 5512 | 11200 | 747 | 9600 | 14194 | 29867 | 1991 | 6400 | ND | ND | ND | ND |
| **Aerial (26 cm crop)** | **(109)** | | | | **(99)** | | | | **(383)** | | | |
| 0 | 514 | 559 | 37 | ND | 1512 | 1492 | 99 | ND | 584 | 2238 | 149 | 138 |
| 1 | 453 | 493 | 33 | ND | 1333 | 1315 | 88 | ND | 514 | 1972 | 131 | 216 |
| 2 | 1662 | 1808 | 121 | 1829 | 4888 | 4822 | 321 | 1829 | 1887 | 7234 | 482 | 557 |
| 3 | 2652 | 2887 | 192 | 2743 | 7802 | 7698 | 513 | 2560 | 3011 | 11546 | 770 | ND |
| 4 | 4052 | 4409 | 294 | 4800 | 11917 | 11759 | 784 | 3840 | 4600 | 17638 | 1176 | ND |
| 5 | 5870 | 6388 | 426 | ND | 17264 | 17034 | 1136 | ND | 6664 | 25551 | 1703 | ND |

[1] MOE = NOEL (mg/kg bw/day) ÷ mean dermal absorbed dose (mg ai/kg bw/day)
[2] data from single study for ground application and two studies for aerial application
ND no data

**Table 18: MOE for various crops extrapolated from cotton DFR data, standardised to relevant application rates and TC for the various crops.**

| Re-entry day | MOE (Dermal absorbed dose/NOEL) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Citrus** | **Fruit and nut trees (Pecans)** | **Fruit and nut trees** | **Vegetables, some fruits, tomatoes & nursery crops** | **Grapes** | **Tobacco** | **Broadacre Crops (other than cotton)** |
| | *Generic TC: 3000 (high exposure)*** | *Generic TC: 3000 (high exposure)*** | *Generic TC: 3000 (high exposure)*** | *Generic TC: 5000 (high exposure)**** | *Generic TC: 5000 (high exposure)**** | *Generic TC: 1500** | *Generic TC: 1500** |
| | *Application rate: 1.4 L/ha* | *Application rate: 2.8 L/ha* | *Application rate: 2.1 L/ha* | *Application rate: 0.95 L/ha* | *Application rate: 1.52 L/ha* | *Application rate: 2.5 L/ha* | *Application rate: 2.1 L/ha* |
| 0 | 30 | 15 | 20 | 26 | 16 | 33 | 40 |
| 1 | 17 | 9 | 11 | 15 | 9 | 19 | 23 |
| 2 | 33 | 17 | 22 | 29 | 18 | 37 | 44 |
| **3** | **189** | **95** | **126** | **167** | **105** | **212** | **252** |
| 4 | 175 | 88 | 117 | 155 | 97 | 196 | 233 |
| 5 | 302 | 151 | 201 | 267 | 167 | 338 | 403 |
| 7 | 253 | 127 | 169 | 224 | 140 | 283 | 337 |
| 13 | 560 | 280 | 373 | 495 | 309 | 627 | 747 |

* irrigation, scouting, weeding mature/high foliage plants

**harvesting, pruning, training, tying

***hand harvesting resulting in the greatest re-entry exposure

***Risks to re-entry workers (other crops)***

The DFR data provided in the worker exposure studies for cotton were extrapolated to other orchard and broadacre crops. Based on the extrapolated data, acceptable MOE were obtained for workers conducting re-entry activities on day 3 for nursery, other broadacre and orchard crops, except pecans where a 5-day re-entry interval is indicate.

## 9.4 VALIDITY OF NEW OHS STUDIES

The Australian Centre for Agricultural Health and Safety (Moree) and the Centre for Pesticide Application Safety (Gatton) carried out and submitted worker exposure data for endosulfan for the following work practices:

- Mixer/loaders in ground and aerial applications
- Orchard ground spray applicators
- Broadacre aerial spray applicators including re-entry
- Broadacre ground spray (re-entry only)
- Workers using hand-directed spray applicators (nursery)

The study protocols (OHS Appendix 1) were adapted from the United States Environmental Protection Agency (US EPA) Occupational and Residential Exposure Test Guidelines and were approved by the APVMA, NOHSC and the New England Health Research Ethics Committee and the University of Sydney Research Ethics Committee. The EC formulation of endosulfan of 350 g ai/L was used in all the studies.

Generation of data on inhalation exposure was not included in the study protocols, since workers are required to wear respirators to protect against acute inhalation toxicity of endosulfan. In addition, data assessed in the interim report (APVMA 1998) indicated that dermal exposure represents >98% of exposure to endosulfan EC formulations during ground use (hand-held and mechanical spraying).

Overall, the studies were conducted according to the specifications of the protocol approved by NOHSC/APVMA, and in accordance with current label instructions, and use patterns, where deficient, in labels. The quality analysis for these studies including statistical analysis is presented in Appendices 2 and 3.

## 9.5 OHS REFERENCES

Clarke L and Churches T (1992) Pesticide Exposure in Cotton Chippers in the Gwydir Valley 1991-1992, Agricultural Health Unit, Moree District Hospital and NSW Health Department, December 1992.

Handbook of First Aid Instructions and Safety Directions, (1998) Commonwealth Department of Health and Family Services and National Occupational Health and Safety Commission, Australian Government Publishing Service, Canberra.

National Occupational Health and Safety Commission (1994) Control of Workplace Hazardous Substances [NOHSC: 1005(1994), 2007(1994)], Australian Government Publishing Service, Canberra.

National Registration Authority (1998) The NRA Review of Endosulfan, Existing Chemical Review Program, Canberra, Australia.

Worker exposure to endosulfan (EC) in the course of application in tree crops (Mixing/loading)– Lyn Fragar, Report No. H-1-1 (February, 2002).

Worker exposure to endosulfan (EC) in the course of application in tree crops (Spraying air-assist spray-tractor without cabin)– Lyn Fragar, Report No. H-1-2U (February, 2002).

Worker exposure to endosulfan (EC) in the course of application in tree crops (Spraying air-assist spray-tractor with cabin)– Lyn Fragar, Report No. H-1-2C (February, 2002).

Worker exposure to endosulfan (EC) in the course of application in tree crops (Air-shear, with cabin)– Lyn Fragar, Report No. H-2-2-C (February, 2002).

Worker exposure to endosulfan (EC) in the course of application in tree crops (Oscillating boomspray)– Lyn Fragar, Report No. H-5-2-C (February, 2002).

Worker exposure to endosulfan (EC) in the course of application in tree crops (Cleaning down)– Lyn Fragar, Report No. H-1-4 (February, 2002).

Worker exposure to endosulfan (EC) in the course of application to nursery crops (Mixing/loading)– Lyn Fragar, Report No. H-3-1 (February, 2002).

Worker exposure to endosulfan (EC) in the course of application to nursery crops (Spraying)– Lyn Fragar, Report No. H-3-2 (February, 2002).

Worker exposure to endosulfan (EC) in the course of application to nursery crops (Cleaning down)– Lyn Fragar, Report No. H-3-3 (February, 2002).

Worker exposure to endosulfan (EC) in the course of aerial application in broadacre cropping industries (Mixing/Loading Bulk and Mini Bulk – closed base)– Lyn Fragar, Report No. A1-1 (February, 2002).

Worker exposure to endosulfan (EC) in the course of aerial application in broadacre cropping industries (Mixing/Loading small containers-open/remote)– Lyn Fragar, Report No. A1-2 (February, 2002).

Worker exposure to endosulfan (EC) in the course of aerial application in broadacre cropping industries (Aerial applicators)– Lyn Fragar, Report No. A1-3 (February, 2002).

Worker exposure to endosulfan (EC) in the course of aerial application in broadacre cropping industries (Support workers - vehicles)– Lyn Fragar, Report No. A1-4 (February, 2002).

Worker exposure to endosulfan (EC) in the course of aerial application in broadacre cropping industries (Support workers - ATVs)– Lyn Fragar, Report No. A1-5 (February, 2002).

Worker exposure to endosulfan (EC) in the course of aerial application in broadacre cropping industries (Cleaning down)– Lyn Fragar, Report No. A1-6 (February, 2002).

Worker exposure to endosulfan (EC) in the course of re-entry in broadacre cropping industries (Cotton chipping)– Lyn Fragar, Report No. RC 1-1 (February, 2002).

Worker exposure to endosulfan (EC) in the course of re-entry in broadacre cropping industries (Crop checking)– Lyn Fragar, Report No. RC 1-2 (February, 2002).

Worker exposure to endosulfan (EC) in the course of re-entry in broadacre cropping industries (Foliar Residue)– Lyn Fragar, Report No. RC 1-5 (February, 2002).

## OHS APPENDIX 1

### Studies used in the OHS Exposure Assessment of Endosulfan

The following end use and re-entry studies provided adequate data in order to conduct an OHS risk assessment for endosulfan and to provide recommendations for the safe use of endosulfan for the various activities assessed.

Worker exposure to endosulfan (EC) in the course of application in tree crops (Mixing/loading)– Lyn Fragar, Report No. H-1-1 (February, 2002).

Worker exposure to endosulfan (EC) in the course of application in tree crops (Spraying air-assist spray-tractor without cabin)– Lyn Fragar, Report No. H-1-2U (February, 2002).

Worker exposure to endosulfan (EC) in the course of application in tree crops (Spraying air-assist spray-tractor with cabin)– Lyn Fragar, Report No. H-1-2C (February, 2002).

Worker exposure to endosulfan (EC) in the course of application in tree crops (Air-shear, with cabin)– Lyn Fragar, Report No. H-2-2-C (February, 2002).

Worker exposure to endosulfan (EC) in the course of application in tree crops (Oscillating boomspray)– Lyn Fragar, Report No. H-5-2-C (February, 2002).

Worker exposure to endosulfan (EC) in the course of application in tree crops (Cleaning down)– Lyn Fragar, Report No. H-1-4 (February, 2002).

Worker exposure to endosulfan (EC) in the course of application to nursery crops (Mixing/loading)– Lyn Fragar, Report No. H-3-1 (February, 2002).

Worker exposure to endosulfan (EC) in the course of application to nursery crops (Spraying)– Lyn Fragar, Report No. H-3-2 (February, 2002).

Worker exposure to endosulfan (EC) in the course of application to nursery crops (Cleaning down)– Lyn Fragar, Report No. H-3-2 (February, 2002).

Worker exposure to endosulfan (EC) in the course of aerial application in broadacre cropping industries (Mixing/Loading Bulk and Mini Bulk – closed base)– Lyn Fragar, Report No. A1-1 (February, 2002).

Worker exposure to endosulfan (EC) in the course of aerial application in broadacre cropping industries (Mixing/Loading small containers-open/remote)– Lyn Fragar, Report No. A1-2 (February, 2002).

Worker exposure to endosulfan (EC) in the course of aerial application in broadacre cropping industries (Aerial applicators)– Lyn Fragar, Report No. A1-3 (February, 2002).

Worker exposure to endosulfan (EC) in the course of aerial application in broadacre cropping industries (Support workers - vehicles)– Lyn Fragar, Report No. A1-4 (February, 2002).

Worker exposure to endosulfan (EC) in the course of aerial application in broadacre cropping industries (Support workers - ATVs)– Lyn Fragar, Report No. A1-5 (February, 2002).

Worker exposure to endosulfan (EC) in the course of aerial application in broadacre cropping industries (Cleaning down)– Lyn Fragar, Report No. A1-6 (February, 2002).

Worker exposure to endosulfan (EC) in the course of re-entry in broadacre cropping industries (Cotton chipping)– Lyn Fragar, Report No. RC 1-1 (February, 2002).

Worker exposure to endosulfan (EC) in the course of re-entry in broadacre cropping industries (Crop checking)– Lyn Fragar, Report No. RC 1-2 (February, 2002).

Worker exposure to endosulfan (EC) in the course of re-entry in broadacre cropping industries (Irrigating)– Lyn Fragar, Report No. RC 1-3 (February, 2002).

Worker exposure to endosulfan (EC) in the course of re-entry in broadacre cropping industries (Siphon Residue)– Lyn Fragar, Report No. RC 1-4 (February, 2002).

## OHS APPENDIX 2

### Quality analysis of the endosulfan worker exposure studies

Study guidelines

The endosulfan worker exposure studies were conducted by the Australian Centre for Agricultural Health and Safety (Moree) with funding from the Cotton Research & Development Corporation, and in horticultural industries in collaboration with the Centre for Pesticide Application Safety (Gatton) with funding from the Horticulture Research and Development Corporation. The studies were based on a protocol approved by the APVMA and NOHSC, and in accordance with standards prescribed by the New England Health Research and University of Sydney Research ethics committees. All studies used the same formulation of endosulfan containing 350 g ai/L, which was considered representative of each of the products under review.

For the purposes of measuring dermal exposure, the US EPA Occupational and Residential Exposure Test Guidelines were adopted to assess worker exposure to endosulfan, which includes guidance on estimating total body deposition for workers.

General reporting of data

The applicator raw data had many values with "nd" (not detected), but there was no mention of the limit of detection or the limit of quantification. It is usual practice that levels below the limit of detection are included in the data at half the LOQ**.**

No explanation was provided by the study authors for the high field blank values for aerial applicators. The location of the field blank patches appear to be the same for all studies, ie 3 internal patches (2 on shoulders one on back below neck). The authors did not say how the field blanks were conducted for aerial applicators.

The re-entry raw data had many values with "nd" (not detected), but there was no mention of the limit of detection or the limit of quantification. It is usual practice that levels below the limit of detection are included in the data at half the LOQ.

The field blanks for re-entry workers were based on 3 patches only and extrapolated to all body parts. The positioning of the field blank patches gave an overestimate of contamination for body parts which were better protected from exposure. The variability between field blanks conducted on different days and also on the same day suggested poor sample handling, and it was unclear whether the field blanks represented 'background' contamination rather than handler error. Therefore the raw data uncorrected for field blanks was used in the OHS assessment. It was also noted that field blank levels were often far greater than test sample levels. Furthermore, field blanks were not available for all re-entry days and on these occasions the study authors used inappropriately high surrogate field blanks to correct the raw data.

When a sample was lost or not obtained, the authors used an average of the other samples for that body part as a surrogate. On the whole this was considered acceptable, however the authors also used surrogate data to replace 'high' values. In study RC-1-3-A Day 0 subject DV, the authors replaced the entire glove reading (alpha + beta-endosulfan + endosulfan sulphate) by a surrogate total glove reading. In this case the alpha-endosulfan and the endosulfan sulfate values were not

excessive in comparison to other readings for this worker group, only the beta-endosulfan reading was excessive (approximately 80 times that for alpha-endosulfan). For this particular reading it was considered more appropriate to use the alpha endosulfan value reading as a surrogate for the beta value.

No field blanks or field fortification data were reported for the siphon residues or the foliar residue s studies.

Number of replicates

The number of replicates used in the studies were generally in accordance with US EPA recommendations, except in certain instances when they were reduced (eg, air-shear with cabin for tree crops, cleaning down for nursery crops etc).

Positioning/type of dosimeters

The positioning of the dosimeters was unclear and not consistent. From information provided in the studies, "chromatographic patches were fixed either on the singlet or overall or fixed on the cloth pads which were stitched with Velcro adhesive straps. These straps attached with chromatographic papers by pins on the cloth pads were placed on the forearms, thighs and knees of the workers". Explanations for the varied positioning of dosimeters were later provided, but were still not consistent.

The PPE worn by the workers was generally similar for all studies, applicator and re-entry, ie in relation to cotton coveralls. However, the re-entry workers did not wear coveralls, they wore their own clothing. It was assumed that dosimeters which would have been internal dosimeters had the workers worn coveralls would also be internal dosimeters for workers wearing shirts and pants.

Cotton gloves were used as dosimeters, however the authors did not state whether they were worn with PVC gloves and if so, whether they were worn outside or inside the PVC gloves. It was assumed that cotton gloves were worn inside protective gloves for the purpose of the exposure estimates.

In the study, head and face exposure was calculated from internal patches placed under the overalls on the external shoulder (dorsal side), chest, and back x 1300cm2. However, according to US EPA Guidelines, head and face exposure is estimated from patches placed on the outside (ie, externally) of the garments at the back, chest and shoulders. In order to determine the necessity for PPE for head and face exposure, and in the absence of external patch data, internal patch data (from the studies) were used to determine the need for a respirator and hat during mixing/loading/application.

Duration of monitoring

A range of monitoring times was provided for all mixer/loader, and applicator studies. Although the US EPA recommends a minimum of 4 hours per activity, the exposure and risk assessments were based on the amount of active ingredient handled per day and standardised for local use conditions.

Sample Recovery

Field fortification data for applicator studies were not used to adjust the sample values. Field recovery rates ranged from just over 50% to over 120%. The authors did not adjust the sample

values for field recovery rates, nor did they present method sensitivity data or sample chromatograms (as required according to the US EPA guidelines).

Field fortification data for re-entry studies were not reported. Field recovery rates were reported to be greater than 50%. The authors did not adjust the sample values for field recovery rates, nor did they present method sensitivity data or sample chromatograms (as required according to the US EPA guidelines).

Statistical analysis

The data presented in the studies in some instances appeared to be skewed (higher or lower than expected). Explanations for these "outliers" were provided by the study authors. However, when the data were plotted on a log-normal distribution, the so-called "outliers" were determined as acceptable values, with the geometric mean the most appropriate statistical technique for averaging the data. These are provided in Appendices 3 and 4.

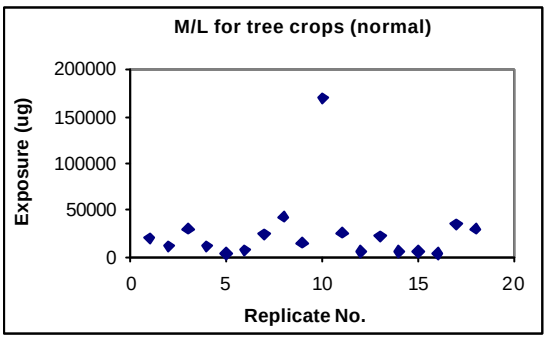
Summary and conclusions

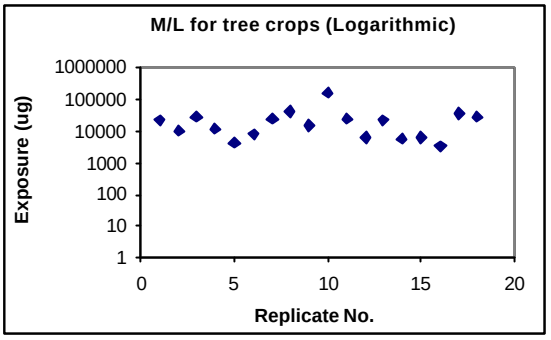
The studies covered a range of use pattern scenarios and application methods. However, data presentation was not clear and consistent in some studies, with reasons for missing data or high and low exposure values not justifiable due to lack of accurate reporting. In the case of support workers it was unclear whether enclosed ATV / vehicles were used, or in some instances whether the workers were outside the ATV / vehicles. Sample values were not adjusted for field recovery rates. The field blanks for re-entry workers were based on 3 patches only and extrapolated to all body parts. In some instances, the positioning of the field blank patches gave an overestimate of contamination for body parts which were better protected from exposure.

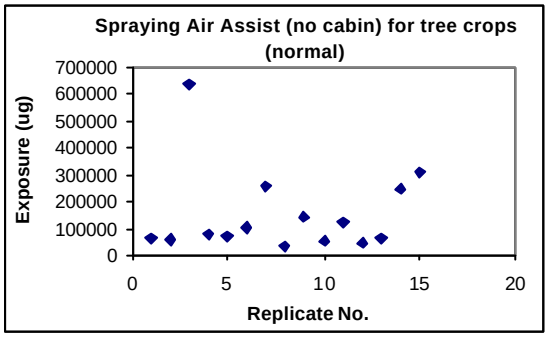
To overcome the deficiencies in data presentation, surrogate (minimal) values for missing data were used to estimate exposure, adjusting for high and low exposure values by log transformation of data, and standardising to local conditions.

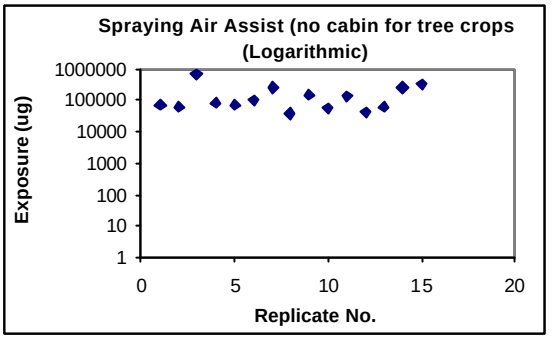
## OHS APPENDIX 3

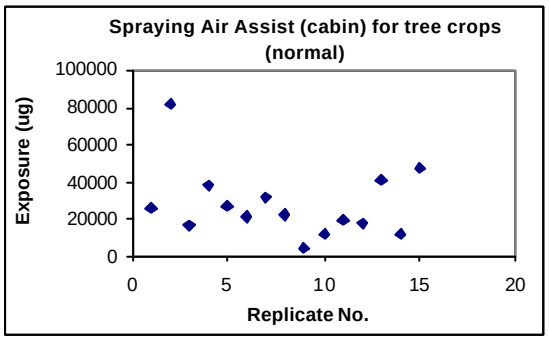
### Comparison of normal and logarithmic distribution of mixer / loader / applicator / cleaner / support worker data for tree, nursery and broadacre crops

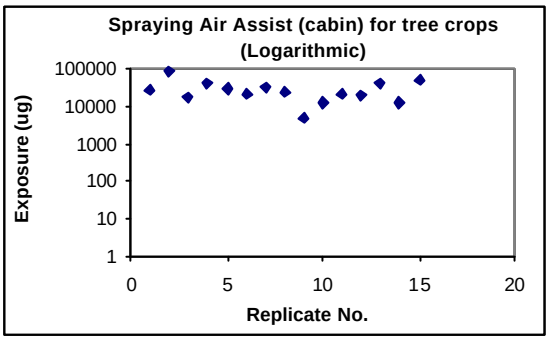


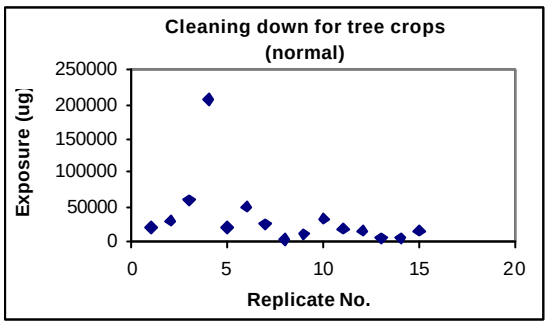



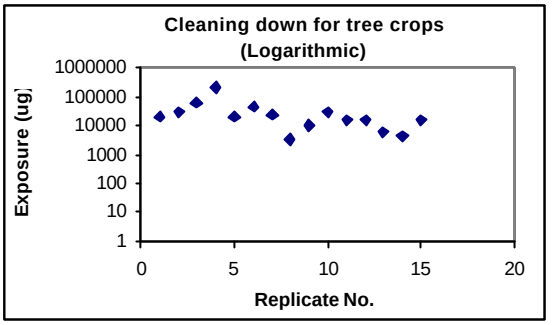



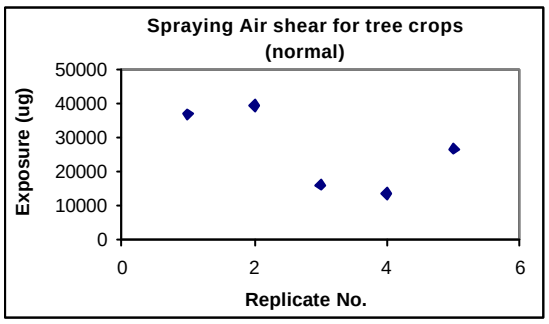



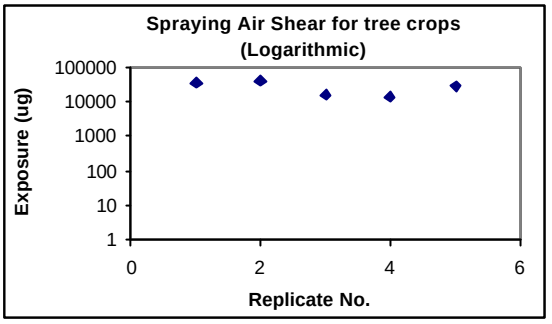



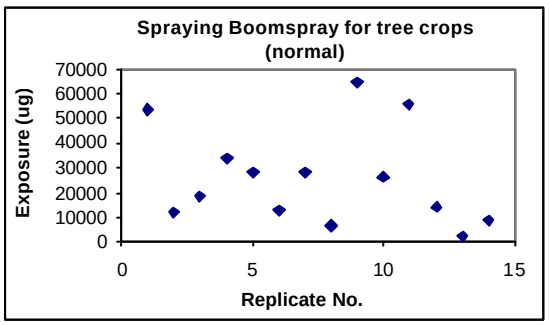



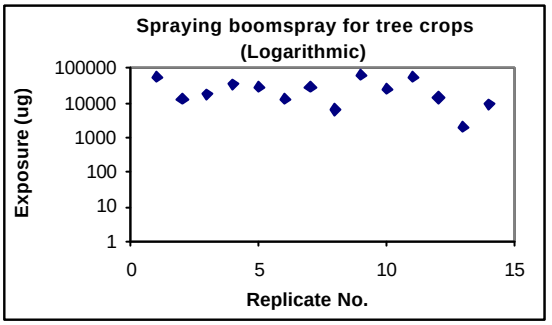

Cleaning down for tree crops
(normal)
Exposure (ug)
250000
200000
150000
100000
50000
0
0
5
10
15
20
Replicate No.

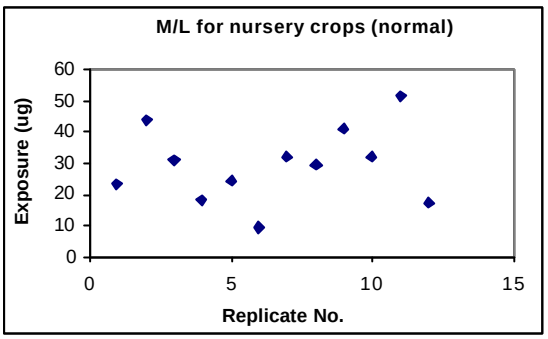

Cleaning down for tree crops
(Logarithmic)
Exposure (ug)
1000000
100000
10000
1000
100
10
1
0
5
10
15
20
Replicate No.

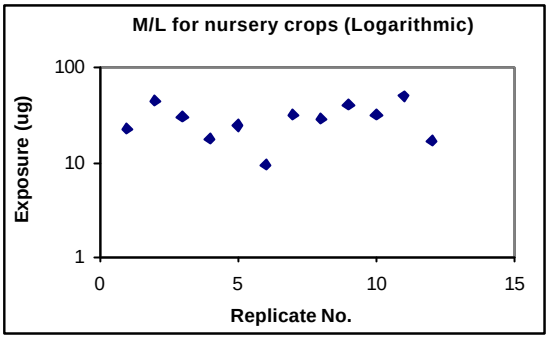

Spraying Air shear for tree crops
(normal)
Exposure (ug)
50000
40000
30000
20000
10000
0
0
2
4
6
Replicate No.

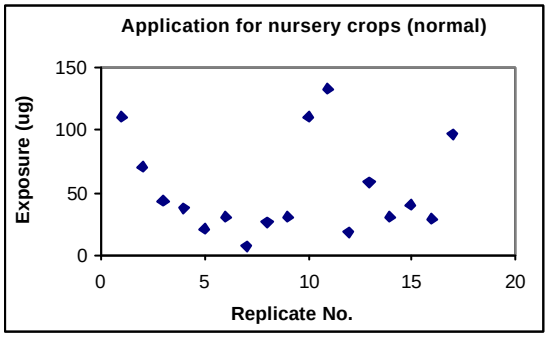

Spraying Air Shear for tree crops
(Logarithmic)
Exposure (ug)
100000
10000
1000
100
10
1
0
2
4
6
Replicate No.

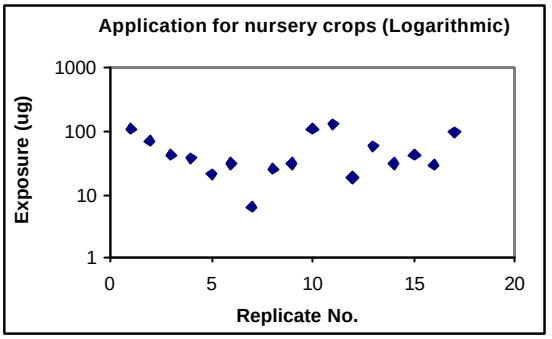

Spraying Boomspray for tree crops
(normal)
Exposure (ug)
70000
60000
50000
40000
30000
20000
10000
0
0
5
10
15
Replicate No.

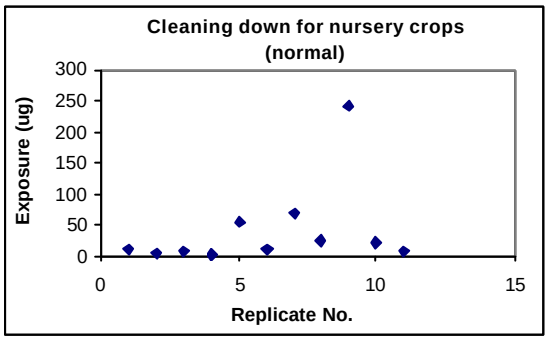

Spraying boomspray for tree crops
(Logarithmic)
Exposure (ug)
100000
10000
1000
100
10
1
0
5
10
15
Replicate No.

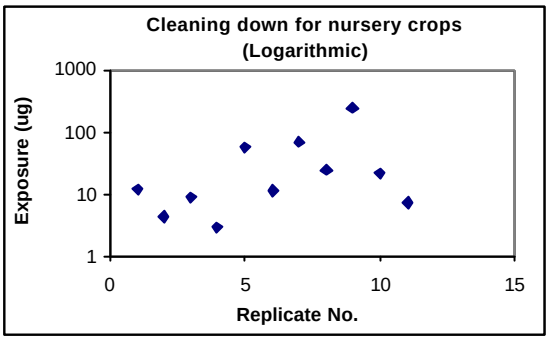

M/L for nursery crops (normal)
Exposure (ug)
60
50
40
30
20
10
0
0
5
10
15
Replicate No.

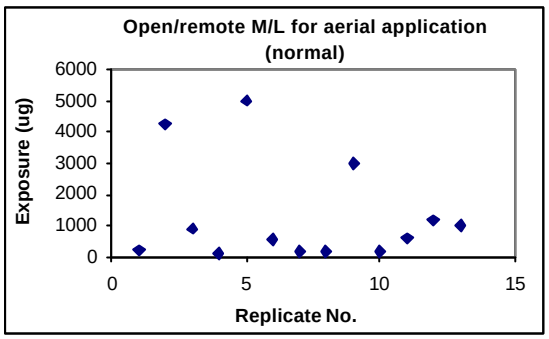

M/L for nursery crops (Logarithmic)
Exposure (ug)
100
10
1
0
5
10
15
Replicate No.

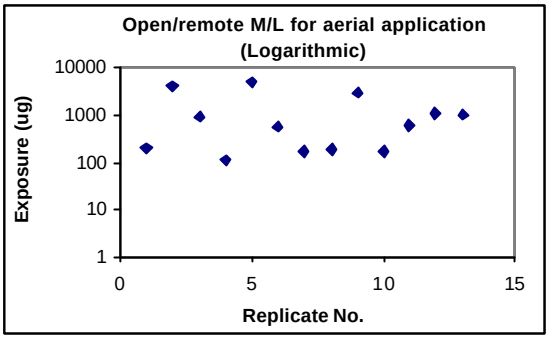

Application for nursery crops (normal)
Exposure (ug)
150
100
50
0
0
5
10
15
20
Replicate No.

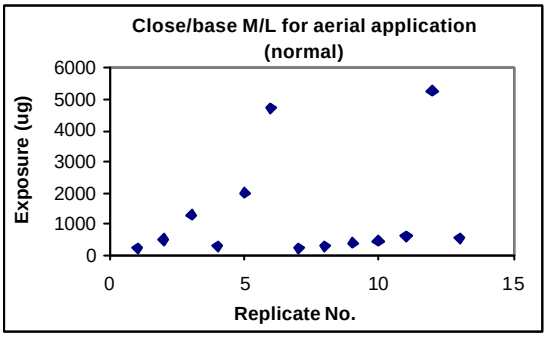

Application for nursery crops (Logarithmic)
Exposure (ug)
1000
100
10
1
0
5
10
15
20
Replicate No.

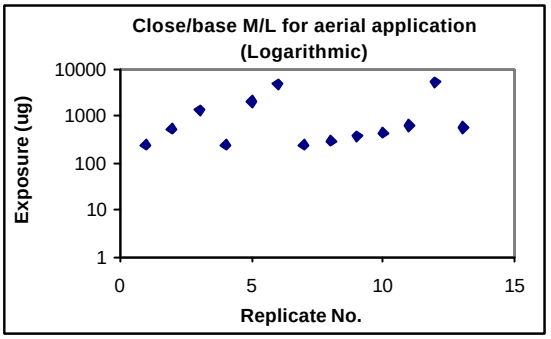

Cleaning down for nursery crops (normal)
Exposure (ug)
300
250
200
150
100
50
0
0
5
10
15
Replicate No.

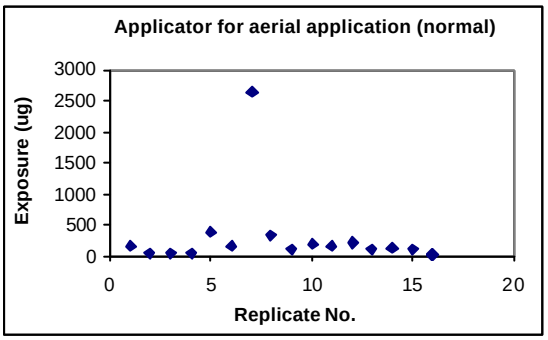

Cleaning down for nursery crops (Logarithmic)
Exposure (ug)
1000
100
10
1
0
5
10
15
Replicate No.

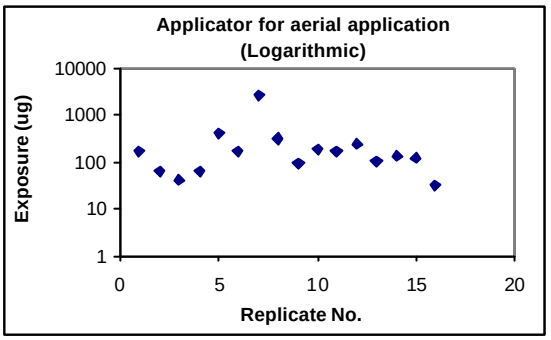

Open/remote M/L for aerial application (normal)
Exposure (ug)
6000
5000
4000
3000
2000
1000
0
0
5
10
15
Replicate No.

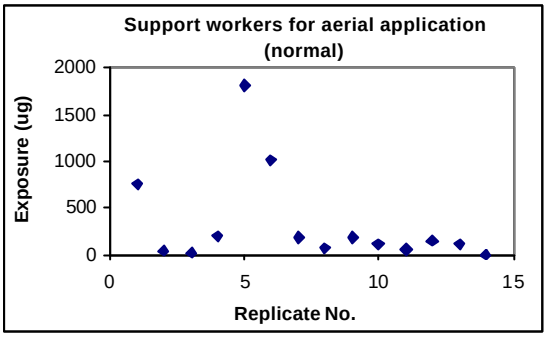

Open/remote M/L for aerial application (Logarithmic)
Exposure (ug)
10000
1000
100
10
1
0
5
10
15
Replicate No.

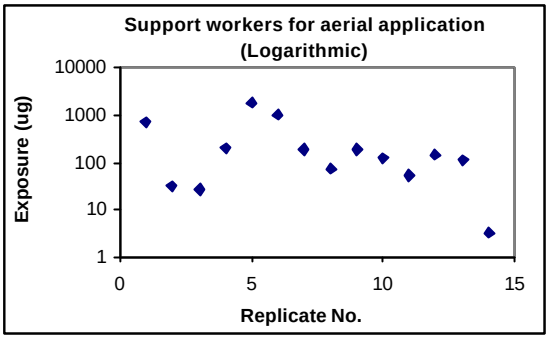

Close/base M/L for aerial application (normal)
Exposure (ug)
6000
5000
4000
3000
2000
1000
0
0
5
10
15
Replicate No.

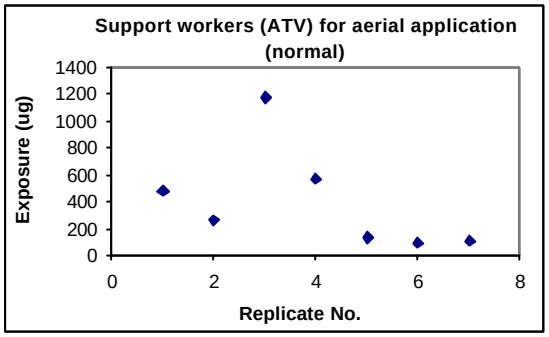

Close/base M/L for aerial application (Logarithmic)
Exposure (ug)
10000
1000
100
10
1
0
5
10
15
Replicate No.

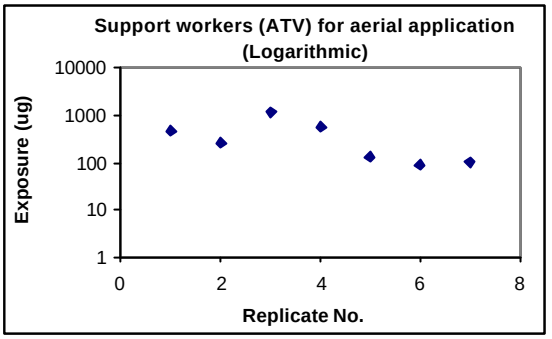

Applicator for aerial application (normal)
Exposure (ug)
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
Replicate No.

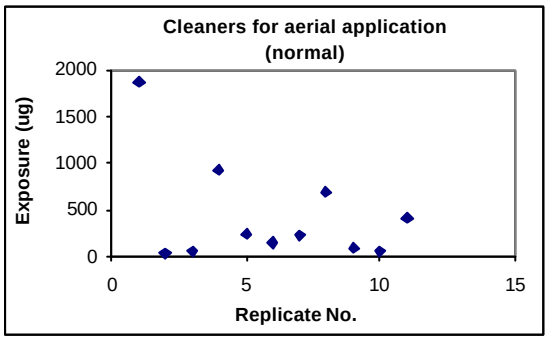

Applicator for aerial application (Logarithmic)
Exposure (ug)
10000
1000
100
10
1
0
5
10
15
20
Replicate No.

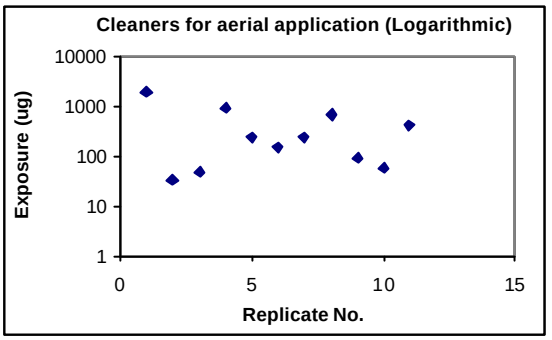

Support workers for aerial application (normal)
Exposure (ug)
2000
1500
1000
500
0
0
5
10
15
Replicate No.


Support workers for aerial application (Logarithmic)
Exposure (ug)
10000
1000
100
10
1
0
5
10
15
Replicate No.


Support workers (ATV) for aerial application (normal)
Exposure (ug)
1400
1200
1000
800
600
400
200
0
0
2
4
6
8
Replicate No.


Support workers (ATV) for aerial application (Logarithmic)
Exposure (ug)
10000
1000
100
10
1
0
2
4
6
8
Replicate No.


Cleaners for aerial application (normal)
Exposure (ug)
2000
1500
1000
500
0
0
5
10
15
Replicate No.


Cleaners for aerial application (Logarithmic)
Exposure (ug)
10000
1000
100
10
1
0
5
10
15
Replicate No.

## OHS APPENDIX 4

### RAW EXPOSURE DATA DETERMINED FROM THE WORKER EXPOSURE STUDIES FOR WORKERS TREATING TREE CROPS, NURSERY CROPS AND BROADACRE CROPS (INCLUDING AND EXCLUDING HEAD/FACE EXPOSURE).

**Including head/face exposure**

**Tree crops: (H-1-1) Mixing/loading; (H-1-2-U) Air-assist spraying, no cabin; (H-1-2-C) Air-assist spraying, with cabin; (H-2-2-C) Air shear spraying; (H-5-2-C) Oscillating Boomspray; (H-1-4) Cleaning down**

| Replicate No. | Endosulfan handled (kg ai) | Total exposure (µg) | Exposure (mg/kg bw/kg ai)* |
|---|---|---|---|
| **Mixing/Loading** | | | |
| 1 | 0.385 | 20.96 | 0.0008 |
| 2 | 0.385 | 10.41 | 0.0004 |
| 3 | 0.385 | 30.15 | 0.0011 |
| 4 | 0.385 | 11.33 | 0.0004 |
| 5 | 0.385 | 4.41 | 0.0002 |
| 6 | 1.050 | 8.27 | 0.0001 |
| 7 | 0.525 | 24.62 | 0.0007 |
| 8 | 1.575 | 42.19 | 0.0004 |
| 9 | 1.575 | 14.78 | 0.0001 |
| 10 | 1.575 | 169.95 | 0.0015 |
| 11 | 1.103 | 26.82 | 0.0003 |
| 12 | 0.210 | 6.30 | 0.0004 |
| 13 | 0.210 | 21.38 | 0.0015 |
| 14 | 0.131 | 5.83 | 0.0006 |
| 15 | 0.315 | 6.41 | 0.0003 |
| 16 | 0.315 | 3.23 | 0.0001 |
| 17 | 0.315 | 35.24 | 0.0016 |
| 18 | 0.315 | 29.44 | 0.0013 |
| **Geomean** | | | **0.0005** |
| | | | |
| **Air-assist spraying, no cabin** | | | |
| 1 | 0.385 | 67.37 | 0.0025 |
| 2 | 0.385 | 60.00 | 0.0022 |
| 3 | 0.385 | 642.42 | 0.0238 |
| 4 | 0.385 | 75.02 | 0.0028 |
| 5 | 0.385 | 71.10 | 0.0026 |
| 6 | 0.7875 | 104.68 | 0.0019 |
| 7 | 0.7875 | 260.92 | 0.0047 |
| 8 | 0.525 | 35.11 | 0.0010 |
| 9 | 0.525 | 142.74 | 0.0039 |
| 10 | 0.525 | 51.62 | 0.0014 |
| 11 | 0.525 | 125.40 | 0.0034 |
| 12 | 0.525 | 44.56 | 0.0012 |
| 13 | 0.0525 | 64.89 | 0.0177 |
| 14 | 0.0525 | 246.02 | 0.0669 |
| 15 | 0.0525 | 310.61 | 0.0845 |

| | | | |
|---|---|---|---|
| **Geomean** | | | **0.0048** |
| | | | |
| **Air Assist Spraying, with cabin** | | | |
| 1 | 0.8458 | 26.14 | 0.0004 |
| 2 | 0.8458 | 81.03 | 0.0014 |
| 3 | 0.8458 | 17.07 | 0.0003 |
| 4 | 0.3938 | 37.83 | 0.0014 |
| 5 | 0.6563 | 26.80 | 0.0006 |
| 6 | 0.525 | 21.14 | 0.0006 |
| 7 | 1.1025 | 31.70 | 0.0004 |
| 8 | 1.1025 | 21.82 | 0.0003 |
| 9 | 0.0525 | 4.53 | 0.0012 |
| 10 | 0.0525 | 12.09 | 0.0033 |
| 11 | 0.0525 | 19.74 | 0.0054 |
| 12 | 0.0525 | 17.69 | 0.0048 |
| 13 | 0.0525 | 40.46 | 0.0110 |
| 14 | 0.0525 | 12.27 | 0.0033 |
| 15 | 0.1313 | 46.90 | 0.0051 |
| **Geomean** | | | **0.0014** |
| | | | |
| **Air shear spraying, with cabin** | | | |
| 1 | 1.26 | 37.01 | 0.0004 |
| 2 | 0.63 | 39.45 | 0.0009 |
| 3 | 0.63 | 16.22 | 0.0004 |
| 4 | 0.525 | 13.68 | 0.0004 |
| 5 | 0.525 | 26.80 | 0.0007 |
| **Geomean** | | | **0.0005** |
| | | | |
| **Oscillating boomspray, with cabin** | | | |
| 1 | 0.16 | 53.46 | 0.0048 |
| 2 | 0.16 | 12.29 | 0.0011 |
| 3 | 0.16 | 18.16 | 0.0016 |
| 4 | 0.16 | 33.79 | 0.0030 |
| 5 | 0.16 | 28.36 | 0.0025 |
| 6 | 0.16 | 12.79 | 0.0011 |
| 7 | 0.16 | 28.23 | 0.0025 |
| 8 | 0.16 | 6.63 | 0.0006 |
| 9 | 0.16 | 65.29 | 0.0058 |
| 10 | 0.16 | 26.14 | 0.0023 |
| 11 | 0.51 | 55.55 | 0.0016 |
| 12 | 0.51 | 14.36 | 0.0004 |
| 13* | 0.39 | 2.08 | 0.00008 |
| 14 | 0.39 | 8.73 | 0.0003 |
| **Geomean** | | | **0.0013** |
| | | | |
| **Cleaning Down** | | | |
| 1 | 1.925 | 19.53 | 0.0001 |
| 2 | 2.3625 | 30.17 | 0.0002 |
| 3 | 0.7875 | 60.37 | 0.0011 |
| 4 | 1.05 | 207.47 | 0.0028 |
| 5 | 2.3625 | 20.44 | 0.0001 |

| | | | |
|---|---|---|---|
| 6 | 1.54875 | 49.98 | 0.0005 |
| 7 | 2.205 | 25.54 | 0.0002 |
| 8 | 0.105 | 3.61 | 0.0005 |
| 9 | 0.13125 | 10.01 | 0.0011 |
| 10 | 0.7875 | 31.97 | 0.0006 |
| 11 | 0.5075 | 16.67 | 0.0005 |
| 12 | 1.015 | 16.14 | 0.0002 |
| 13 | 0.777 | 5.83 | 0.0001 |
| 14 | 0.0525 | 4.40 | 0.0012 |
| 15 | 0.105 | 14.93 | 0.0020 |
| **Geomean** | | | **0.0005** |

*based on 70 kg person

**Nursery crops: (H-3-1) Mixing/loading; (H-3-2) Spraying; (H-3-3) Cleaning down**

| Replicate No. | Endosulfan handled (kg ai) | Total exposure (µg) | Exposure (mg/kg bw/kg ai)* |
|---|---|---|---|
| **Mixing/Loading** | | | |
| 1 | 0.133 | 23.23 | 0.0025 |
| 2 | 0.133 | 43.92 | 0.0047 |
| 3 | 0.133 | 30.99 | 0.0033 |
| 4 | 0.200 | 18.06 | 0.0013 |
| 5 | 0.200 | 24.59 | 0.0018 |
| 6 | 0.200 | 9.53 | 0.0007 |
| 7 | 0.067 | 32.36 | 0.0070 |
| 8 | 0.067 | 29.44 | 0.0063 |
| 9 | 0.033 | 41.09 | 0.0177 |
| 10 | 0.035 | 32.04 | 0.0131 |
| 11 | 0.035 | 51.55 | 0.0210 |
| 12 | 0.070 | 17.18 | 0.0035 |
| **Geomean** | | | **0.0043** |
| | | | |
| **Spraying** | | | |
| 1 | 0.133 | 111.38 | 0.0120 |
| 2 | 0.133 | 71.28 | 0.0077 |
| 3 | 0.133 | 42.46 | 0.0046 |
| 4 | 0.100 | 37.25 | 0.0053 |
| 5 | 0.100 | 21.23 | 0.0030 |
| 6 | 0.100 | 30.98 | 0.0044 |
| 7 | 0.100 | 6.28 | 0.0009 |
| 8 | 0.100 | 25.73 | 0.0037 |
| 9 | 0.100 | 30.89 | 0.0044 |
| 10 | 0.067 | 110.87 | 0.0238 |
| 11 | 0.033 | 133.87 | 0.0575 |
| 12 | 0.067 | 18.52 | 0.0040 |
| 13 | 0.035 | 58.88 | 0.0240 |
| 14 | 0.035 | 31.16 | 0.0127 |
| 15 | 0.033 | 40.82 | 0.0175 |
| 16 | 0.033 | 29.67 | 0.0127 |

| | | | |
|---|---|---|---|
| 17 | 0.070 | 96.93 | 0.0198 |
| **Geomean** | | | **0.0082** |
| | | | |
| **Cleaning Down** | | | |
| 1 | 0.133 | 12.19 | 0.0013 |
| 2 | 0.133 | 4.40 | 0.0005 |
| 3 | 0.133 | 8.88 | 0.0010 |
| 4 | 0.200 | 3.02 | 0.0002 |
| 5 | 0.200 | 54.68 | 0.0039 |
| 6 | 0.200 | 11.69 | 0.0008 |
| 7 | 0.067 | 69.44 | 0.0148 |
| 8 | 0.067 | 25.24 | 0.0054 |
| 9 | 0.033 | 242.18 | 0.1048 |
| 10 | 0.100 | 21.66 | 0.0031 |
| 11 | 0.070 | 7.24 | 0.0015 |
| **Geomean** | | | **0.0024** |

*based on 70 kg person

**Aerial application: (A1-1) Mixing/Loading bulk and mini bulk (closed base); (A1-2) Mixing/Loading small containers (open/remote); (A1-3) Aerial applicators; (A1-4) Support workers (vehicles); (A1-5) Support workers (ATVs); (A1-6) Cleaning down**

| Replicate No. | Endosulfan handled (kg ai) | Total exposure (µg) | Exposure (mg/kg bw/kg ai)* |
|---|---|---|---|
| **Open/remote M/L for aerial application** | | | |
| 1 | 71.95 | 197.9 | 0.00004 |
| 2 | 71.95 | 4265.5 | 0.00085 |
| 3 | 163.49 | 902.6 | 0.00008 |
| 4 | 32.17 | 115.9 | 0.00005 |
| 5 | 353.87 | 4997.0 | 0.00020 |
| 6 | 41.53 | 545.6 | 0.00019 |
| 7 | 110.99 | 167.9 | 0.00002 |
| 8 | 36.75 | 186.7 | 0.00007 |
| 9 | 73.5 | 2988.1 | 0.00058 |
| 10 | 102.21 | 169.3 | 0.00002 |
| 11 | 73.5 | 609.9 | 0.00012 |
| 12 | 73.5 | 1143.4 | 0.00022 |
| 13 | 220.03 | 1017.4 | 0.00007 |
| **Geomean** | | | **0.00011** |
| | | | |
| **Close/base M/L for aerial application** | | | |
| 1 | 337.9 | 241.9 | 0.00001 |
| 2 | 84.48 | 502.6 | 0.00008 |
| 3 | 27.69 | 1264.0 | 0.00065 |
| 4 | 49 | 250.8 | 0.00007 |
| 5 | 35.81 | 2003.7 | 0.00080 |
| 6 | 107.42 | 4694.9 | 0.00062 |
| 7 | 35.11 | 233.4 | 0.00009 |
| 8 | 103.12 | 285.6 | 0.00004 |
| 9 | 103.12 | 365.7 | 0.00005 |

| | | | |
|---|---|---|---|
| 10 | 103.12 | 448.3 | 0.00006 |
| 11 | 103.12 | 596.0 | 0.00008 |
| 12 | 84.67 | 5281.2 | 0.00089 |
| 13 | 138.23 | 567.5 | 0.00006 |
| **Geomean** | | | **0.00012** |

| | | | |
|---|---|---|---|
| **Applicator** | | | |
| 1 | 71.95 | 176.4 | 0.00004 |
| 2 | 196.82 | 61.3 | 0.00000 |
| 3 | 337.9 | 42.0 | 0.00000 |
| 4 | 84.48 | 61.0 | 0.00001 |
| 5 | 160.86 | 390.9 | 0.00003 |
| 6 | 160.86 | 168.6 | 0.00001 |
| 7 | 27.69 | 2630.2 | 0.00136 |
| 8 | 49.21 | 319.8 | 0.00009 |
| 9 | 59.5 | 99.3 | 0.00002 |
| 10 | 35.81 | 191.4 | 0.00008 |
| 11 | 107.42 | 173.4 | 0.00002 |
| 12 | 35.11 | 236.1 | 0.00010 |
| 13 | 103.12 | 103.6 | 0.00001 |
| 14 | 103.12 | 132.2 | 0.00002 |
| 15 | 92.11 | 122.1 | 0.00002 |
| 16 | 28.28 | 33.0 | 0.00002 |
| **Geomean** | | | **0.00003** |

| | | | |
|---|---|---|---|
| **Support Workers (vehicles)** | | | |
| 1 | 196.18 | 756.6 | 0.00006 |
| 2 | 84.48 | 32.5 | 0.00001 |
| 3 | 337.9 | 27.0 | 0.00000 |
| 4 | 289.55 | 209.5 | 0.00001 |
| 5 | 143.22 | 1815.7 | 0.00018 |
| 6 | 35.11 | 1021.4 | 0.00042 |
| 7 | 103.12 | 188.6 | 0.00003 |
| 8 | 28.28 | 76.4 | 0.00004 |
| 9 | 204.42 | 193.3 | 0.00001 |
| 10 | 103.12 | 120.0 | 0.00002 |
| 11 | 83.06 | 52.7 | 0.00001 |
| 12 | 127.01 | 143.7 | 0.00002 |
| 13 | 364.68 | 109.6 | 0.00000 |
| 14 | 364.68 | 3.3 | 0.00000 |
| **Geomean** | | | **0.00001** |

| | | | |
|---|---|---|---|
| **Support Workers (ATVs)** | | | |
| 1 | 289.55 | 479.6 | 0.00002 |
| 2 | 49.21 | 265.6 | 0.00008 |
| 3 | 49.21 | 1179.3 | 0.00034 |
| 4 | 35.11 | 570.9 | 0.00023 |
| 5 | 28.28 | 131.4 | 0.00007 |
| 6 | 204.42 | 90.3 | 0.00001 |
| 7 | 83.06 | 108.4 | 0.00002 |
| **Geomean** | | | **0.00005** |

| | | | |
|---|---|---|---|
| **Cleaners** | | | |
| 1 | 457.76 | 1877.25 | 0.00006 |
| 2 | 845.25 | 32.62 | 0.00000 |
| 3 | 49.25 | 49.75 | 0.00001 |
| 4 | 59.54 | 920.85 | 0.00022 |
| 5 | 582.86 | 238.18 | 0.00001 |
| 6 | 35.11 | 152.63 | 0.00006 |
| 7 | 111.79 | 230.22 | 0.00003 |
| 8 | 184.52 | 677.79 | 0.00005 |
| 9 | 36.75 | 93.5 | 0.00004 |
| 10 | 36.75 | 57.37 | 0.00002 |
| 11 | 115.75 | 405.22 | 0.00005 |
| **Geomean** | | | **0.00002** |

*based on 70 kg person

**Excluding head/face exposure**

**Tree crops: (H-1-1) Mixing/loading; (H-1-2-U) Air-assist spraying, no cabin; (H-1-2-C) Air-assist spraying, with cabin; (H-2-2-C) Air shear spraying; (H-5-2-C) Oscillating Boomspray; (H-1-4) Cleaning down**

| Replicate No. | Endosulfan handled (kg ai) | Total exposure (µg) | Exposure (mg/kg bw/kg ai)* |
|---|---|---|---|
| **Mixing/Loading** | | | |
| 1 | 0.385 | 19.32 | 0.0007 |
| 2 | 0.385 | 9.89 | 0.0004 |
| 3 | 0.385 | 27.94 | 0.0010 |
| 4 | 0.385 | 11.03 | 0.0004 |
| 5 | 0.385 | 4.20 | 0.0002 |
| 6 | 1.050 | 7.68 | 0.0001 |
| 7 | 0.525 | 22.51 | 0.0006 |
| 8 | 1.575 | 39.53 | 0.0003 |
| 9 | 1.575 | 14.06 | 0.0001 |
| 10 | 1.575 | 167.31 | 0.0015 |
| 11 | 1.103 | 25.08 | 0.0003 |
| 12 | 0.210 | 6.06 | 0.0004 |
| 13 | 0.210 | 20.08 | 0.0014 |
| 14 | 0.131 | 5.60 | 0.0006 |
| 15 | 0.315 | 6.15 | 0.0003 |
| 16 | 0.315 | 3.01 | 0.0001 |
| 17 | 0.315 | 32.50 | 0.0015 |
| 18 | 0.315 | 28.76 | 0.0013 |
| **Geomean** | | | **0.0005** |
| | | | |
| **Air-Assist spraying, no cabin** | | | |
| 1 | 0.385 | 9.08 | 0.0003 |
| 2 | 0.385 | 23.99 | 0.0009 |
| 3 | 0.385 | 31.11 | 0.0012 |
| 4 | 0.385 | 57.03 | 0.0021 |

| | | | |
|---|---|---|---|
| 5 | 0.385 | 52.04 | 0.0019 |
| 6 | 0.7875 | 97.23 | 0.0018 |
| 7 | 0.7875 | 230.71 | 0.0042 |
| 8 | 0.525 | 26.25 | 0.0007 |
| 9 | 0.525 | 127.04 | 0.0035 |
| 10 | 0.525 | 41.15 | 0.0011 |
| 11 | 0.525 | 114.34 | 0.0031 |
| 12 | 0.525 | 36.87 | 0.0010 |
| 13 | 0.0525 | 17.65 | 0.0048 |
| 14 | 0.0525 | 18.45 | 0.0050 |
| 15 | 0.0525 | 17.39 | 0.0047 |
| **Geomean** | | | **0.0019** |
| | | | |
| **Air-Assist spraying, with cabin** | | | |
| 1 | 0.8458 | 23.56 | 0.0004 |
| 2 | 0.8458 | 80.23 | 0.0014 |
| 3 | 0.8458 | 16.20 | 0.0003 |
| 4 | 0.3938 | 35.00 | 0.0013 |
| 5 | 0.6563 | 24.84 | 0.0005 |
| 6 | 0.525 | 19.68 | 0.0005 |
| 7 | 1.1025 | 29.81 | 0.0004 |
| 8 | 1.1025 | 20.87 | 0.0003 |
| 9 | 0.0525 | 4.35 | 0.0012 |
| 10 | 0.0525 | 11.92 | 0.0032 |
| 11 | 0.0525 | 18.08 | 0.0049 |
| 12 | 0.0525 | 16.69 | 0.0045 |
| 13 | 0.0525 | 38.39 | 0.0104 |
| 14 | 0.0525 | 12.15 | 0.0033 |
| 15 | 0.1313 | 43.23 | 0.0047 |
| **Geomean** | | | **0.0013** |
| | | | |
| **Cleaning Down** | | | |
| 1 | 1.925 | 17.58 | 0.0001 |
| 2 | 2.3625 | 21.72 | 0.0001 |
| 3 | 0.7875 | 56.36 | 0.0010 |
| 4 | 1.05 | 205.58 | 0.0028 |
| 5 | 2.3625 | 19.03 | 0.0001 |
| 6 | 1.54875 | 47.54 | 0.0004 |
| 7 | 2.205 | 23.86 | 0.0002 |
| 8 | 0.105 | 3.40 | 0.0005 |
| 9 | 0.13125 | 9.54 | 0.0010 |
| 10 | 0.7875 | 29.42 | 0.0005 |
| 11 | 0.5075 | 15.55 | 0.0004 |
| 12 | 1.015 | 15.20 | 0.0002 |
| 13 | 0.777 | 5.63 | 0.0001 |
| 14 | 0.0525 | 4.14 | 0.0011 |
| 15 | 0.105 | 12.97 | 0.0018 |
| **Geomean** | | | **0.0004** |
| | | | |
| **Air-shear spraying, with cabin** | | | |
| 1 | 1.26 | 36.00 | 0.0004 |

| | | | |
|---|---|---|---|
| 2 | 0.63 | 38.73 | 0.0009 |
| 3 | 0.63 | 15.20 | 0.0004 |
| 4 | 0.525 | 12.64 | 0.0003 |
| 5 | 0.525 | 24.84 | 0.0007 |
| **Geomean** | | | **0.0005** |
| | | | |
| **Oscillating boomspray, with cabin** | | | |
| 1 | 0.16 | 49.44 | 0.0044 |
| 2 | 0.16 | 12.10 | 0.0011 |
| 3 | 0.16 | 17.19 | 0.0015 |
| 4 | 0.16 | 30.75 | 0.0027 |
| 5 | 0.16 | 25.93 | 0.0023 |
| 6 | 0.16 | 11.89 | 0.0011 |
| 7 | 0.16 | 26.55 | 0.0023 |
| 8 | 0.16 | 6.54 | 0.0006 |
| 9 | 0.16 | 61.37 | 0.0055 |
| 10 | 0.16 | 24.84 | 0.0022 |
| 11 | 0.51 | 49.98 | 0.0014 |
| 12 | 0.51 | 13.40 | 0.0004 |
| 13* | 0.39 | 1.92 | 0.0001 |
| 14 | 0.39 | 8.46 | 0.0003 |
| **Geomean** | | | **0.0012** |

*Based on 70 kg person

**Nursery crops: (H-3-1) Mixing/loading; (H-3-2) Spraying; (H-3-3) Cleaning down**

| Replicate No. | Endosulfan handled (kg ai) | Total exposure (µg) | Exposure (mg/kg bw/kg ai)* |
|---|---|---|---|
| **Mixing/Loading** | | | |
| 1 | 0.133 | 22.71 | 0.0024 |
| 2 | 0.133 | 43.88 | 0.0047 |
| 3 | 0.133 | 30.38 | 0.0033 |
| 4 | 0.200 | 17.63 | 0.0013 |
| 5 | 0.200 | 21.68 | 0.0016 |
| 6 | 0.200 | 8.88 | 0.0006 |
| 7 | 0.067 | 31.06 | 0.0067 |
| 8 | 0.067 | 27.34 | 0.0059 |
| 9 | 0.033 | 39.28 | 0.0169 |
| 10 | 0.035 | 30.08 | 0.0123 |
| 11 | 0.035 | 49.12 | 0.0201 |
| 12 | 0.070 | 16.57 | 0.0034 |
| **Geomean** | | | **0.0041** |
| | | | |
| **Spraying** | | | |
| 1 | 0.133 | 105.22 | 0.0113 |
| 2 | 0.133 | 63.87 | 0.0069 |
| 3 | 0.133 | 32.80 | 0.0035 |
| 4 | 0.100 | 32.65 | 0.0047 |
| 5 | 0.100 | 8.53 | 0.0012 |
| 6 | 0.100 | 27.82 | 0.0040 |

| | | | |
|---|---|---|---|
| 7 | 0.100 | 4.16 | 0.0006 |
| 8 | 0.100 | 24.43 | 0.0035 |
| 9 | 0.100 | 29.37 | 0.0042 |
| 10 | 0.067 | 98.63 | 0.0212 |
| 11 | 0.033 | 87.60 | 0.0376 |
| 12 | 0.067 | 16.20 | 0.0035 |
| 13 | 0.035 | 53.83 | 0.0220 |
| 14 | 0.035 | 28.83 | 0.0118 |
| 15 | 0.033 | 39.20 | 0.0168 |
| 16 | 0.033 | 28.62 | 0.0123 |
| 17 | 0.070 | 90.16 | 0.0184 |
| **Geomean** | | | **0.0068** |
| | | | |
| **Cleaning Down** | | | |
| 1 | 0.133 | 11.93 | 0.0013 |
| 2 | 0.133 | 4.10 | 0.0004 |
| 3 | 0.133 | 8.27 | 0.0009 |
| 4 | 0.200 | 1.94 | 0.0001 |
| 5 | 0.200 | 37.83 | 0.0027 |
| 6 | 0.200 | 4.06 | 0.0003 |
| 7 | 0.067 | 68.55 | 0.0146 |
| 8 | 0.067 | 24.42 | 0.0052 |
| 9 | 0.033 | 222.11 | 0.0961 |
| 10 | 0.100 | 20.55 | 0.0029 |
| 11 | 0.070 | 6.95 | 0.0014 |
| **Geomean** | | | **0.0020** |

*Based on 70 kg person

**Aerial application: (A1-1) Mixing/Loading bulk and mini bulk (closed base); (A1-2) Mixing/Loading small containers (open/remote); (A1-3) Aerial applicators; (A1-4) Support workers (vehicles); (A1-5) Support workers (ATVs); (A1-6) Cleaning down**

| Replicate No. | Endosulfan handled (kg ai) | Total exposure (µg) | Exposure (mg/kg bw/kg ai)* |
|---|---|---|---|
| **Open/remote M/L for aerial application** | | | |
| 1 | 71.95 | 191.5 | 0.00004 |
| 2 | 71.95 | 4245.5 | 0.00084 |
| 3 | 163.49 | 886.9 | 0.00008 |
| 4 | 32.17 | 109.5 | 0.00005 |
| 5 | 353.87 | 4891.7 | 0.00020 |
| 6 | 41.53 | 529.7 | 0.00018 |
| 7 | 110.99 | 153.8 | 0.00002 |
| 8 | 36.75 | 174.2 | 0.00007 |
| 9 | 73.5 | 2975.6 | 0.00058 |
| 10 | 102.21 | 157.5 | 0.00002 |
| 11 | 73.5 | 587.7 | 0.00011 |
| 12 | 73.5 | 1133.8 | 0.00022 |
| 13 | 220.03 | 999.0 | 0.00006 |
| **Geomean** | | | **0.00010** |
| | | | |
| **Close/base M/L for Aerial application** | | | |

| | | | |
|---|---|---|---|
| 1 | 337.9 | 229.1 | 0.00001 |
| 2 | 84.48 | 480.8 | 0.00008 |
| 3 | 27.69 | 1156.1 | 0.00060 |
| 4 | 49 | 231.6 | 0.00007 |
| 5 | 35.81 | 1884.7 | 0.00075 |
| 6 | 107.42 | 4686.0 | 0.00062 |
| 7 | 35.11 | 215.0 | 0.00009 |
| 8 | 103.12 | 279.3 | 0.00004 |
| 9 | 103.12 | 355.7 | 0.00005 |
| 10 | 103.12 | 429.2 | 0.00006 |
| 11 | 103.12 | 567.5 | 0.00008 |
| 12 | 84.67 | 5255.8 | 0.00089 |
| 13 | 138.23 | 552.7 | 0.00006 |
| **Geomean** | | | **0.00011** |
| | | | |
| **Applicator** | | | |
| 1 | 71.95 | 173.0 | 0.00003 |
| 2 | 196.82 | 59.0 | 0.00000 |
| 3 | 337.9 | 39.8 | 0.00000 |
| 4 | 84.48 | 59.5 | 0.00001 |
| 5 | 160.86 | 368.7 | 0.00003 |
| 6 | 160.86 | 149.7 | 0.00001 |
| 7 | 27.69 | 2443.0 | 0.00126 |
| 8 | 49.21 | 300.1 | 0.00009 |
| 9 | 59.5 | 97.3 | 0.00002 |
| 10 | 35.81 | 187.4 | 0.00007 |
| 11 | 107.42 | 168.0 | 0.00002 |
| 12 | 35.11 | 216.8 | 0.00009 |
| 13 | 103.12 | 98.5 | 0.00001 |
| 14 | 103.12 | 125.4 | 0.00002 |
| 15 | 92.11 | 115.3 | 0.00002 |
| 16 | 28.28 | 30.7 | 0.00002 |
| **Geomean** | | | **0.00003** |
| | | | |
| **Support Workers (vehicles)** | | | |
| 1 | 196.18 | 742.5 | 0.00005 |
| 2 | 84.48 | 31.6 | 0.00001 |
| 3 | 337.9 | 26.1 | 0.00000 |
| 4 | 289.55 | 201.1 | 0.00001 |
| 5 | 143.22 | 1649.3 | 0.00016 |
| 6 | 35.11 | 927.5 | 0.00038 |
| 7 | 103.12 | 169.6 | 0.00002 |
| 8 | 28.28 | 73.5 | 0.00004 |
| 9 | 204.42 | 178.1 | 0.00001 |
| 10 | 103.12 | 107.2 | 0.00001 |
| 11 | 83.06 | 48.7 | 0.00001 |
| 12 | 127.01 | 123.7 | 0.00001 |
| 13 | 364.68 | 108.4 | 0.00000 |
| 14 | 364.68 | 3.3 | 0.00000 |
| **Geomean** | | | **0.00001** |

| | | | |
|---|---|---|---|
| **Support Workers (ATVs)** | | | |
| 1 | 289.55 | 466.9 | 0.00002 |
| 2 | 49.21 | 249.3 | 0.00007 |
| 3 | 49.21 | 1148.8 | 0.00033 |
| 4 | 35.11 | 546.8 | 0.00022 |
| 5 | 28.28 | 126.8 | 0.00006 |
| 6 | 204.42 | 78.6 | 0.00001 |
| 7 | 83.06 | 103.8 | 0.00002 |
| **Geomean** | | | **0.00005** |
| | | | |
| **Cleaners** | | | |
| 1 | 457.76 | 1877.25 | 0.00006 |
| 2 | 845.25 | 32.62 | 0.00000 |
| 3 | 49.25 | 49.75 | 0.00001 |
| 4 | 59.54 | 920.85 | 0.00022 |
| 5 | 582.86 | 238.18 | 0.00001 |
| 6 | 35.11 | 152.63 | 0.00006 |
| 7 | 111.79 | 230.22 | 0.00003 |
| 8 | 184.52 | 677.79 | 0.00005 |
| 9 | 36.75 | 93.5 | 0.00004 |
| 10 | 36.75 | 57.37 | 0.00002 |
| 11 | 115.75 | 405.22 | 0.00005 |
| **Geomean** | | | **0.00002** |

*based on 70 kg person