Australian Government

Australian Pesticides and Veterinary Medicines Authority

DICHLORVOS

OCCUPATIONAL HEALTH AND SAFETY ASSESSMENT

The reconsideration of approvals of the active constituent, registrations of products containing dichlorvos and approvals of their associated labels

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The Australian Pesticides & Veterinary Medicines Authority publishes this review report for oral, intramammary and injectable products, which contain dichlorvos and their associated approved labels. For further information about this review or the Chemical Review Program, contact:

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GLOSSARY OF TERMS AND ABBREVIATIONS

bw	body weight
g	gram
h	hour
ha	hectare
Iv	intravenous
kg	kilogram
L	litre
m	metre
m^2	square metre
m^3	cubic metre
µg	microgram
mg	milligram
mg/kg bw/day	mg/kg bodyweight/day
mL	millilitre
min	minute
mo	month
ng	nanogram
ppb	parts per billion
ppm	parts per million
s	second
te	Tonne
wk	week

ACPH	Advisory Committee on Pesticides and Health
APVMA	Australian Pesticides and Veterinary Medicines Authority
CalEPA	California Environmental Protection Agency
ChE	Cholinesterase
CRP	Chemical Review Program
CV	Coefficient of Variation
DDVP	2,2-dichlorovinyl dimethyl phosphate (dichlorvos)
DEFRA	UK Department for Environment, Food & Rural Affairs
DFR	Dislodgeable Foliar Residue
DMP	Dimethylphosphate
DoHA	Department of Health and Aging
EC	Emulsifiable Concentrate
GC	Gas Chromatography
GIT	Gastro-intestinal Tract
HG	Home Garden
IARC	International Agency for Research on Cancer
IPM	Integrated Pest Management
LD	Liquid
LOD	Limit of Detection
LOQ	Limit of Quantification
MOE	Margin of Exposure
MCL	Mononuclear cell leukaemia
NHMRC	National Health and Medical Research Council
NOEC	No Observed Effect Concentration
NOEL	No Observed Effect Level
NOHSC	National Occupational Health and Safety Commission

OCS	Office of Chemical Safety
OHS	Occupational Health and Safety
OP	Organophophorus pesticide
PA	Paste
PCO	Pest Control Operator
PQs	Performance Questionnaires
PHED	Pesticide Handlers Exposure Database
POEM	Predictive Operator Exposure Model
PPE	Personal Protective Equipment
PVC	Polyvinyl chloride
R	Correlation Coefficient
R^2	Regression Coefficient
RBC	Red blood cell
REI	Re-entry interval
RHI	Re-handling interval
S	Poisons Schedule
SCBA	Self Contained Breathing Apparatus
SD	Standard Deviation
SEE	Standard Error
SO	Solid (formulation type)
SR	Slow Release Generators (formulation type)
STEL	Short Term Exposure Limit
TWA	Time Weighted Average
UK	United Kingdom
USEPA	United States Environment Protection Agency
WHP	Withholding period

EXECUTIVE SUMMARY

Dichlorvos is an organophosphate chemical used in domestic, agricultural and veterinary situations. Due to its volatility, it is suitable for use as a fog, aerosol or mist for fumigation and disinfestation of machinery and confined areas, such as storage areas, warehouses, flour mills, silos, greenhouses and animal housing. Other applications for dichlorvos include grain protection and pest control in domestic, commercial and industrial areas. Dichlorvos also has use as an oral paste for horses.

Dichlorvos has caused severe or fatal anti-ChE poisoning in workers through dermal contact with concentrated products or spray mixture. Inhibition of plasma ChE activity is the most sensitive toxicological endpoint in humans following repeated exposure. The NOEL in humans following repeated oral dosing is 0.014 mg/kg bw/d. There are no repeat-dose studies with dichlorvos by the dermal or inhalation routes that are suitable for OHS assessment purposes. Based on studies in rats and pigs, respectively, dermal and inhalation absorption factors of 30% and 70% have been used for risk assessment purposes. Therefore, the dermal OHS NOEL has been set at 0.047 mg/kg bw/d and the inhalation OHS NOEL has been set at 0.02 mg/kg bw/d. Because these values were obtained using a pivotal NOEL from a study in humans, MOEs of 10 have been used in the risk assessment, to account for variation within the human population.

Due to its high acute toxicity, volatility and comparatively extensive dermal absorption, dichlorvos presents significant hazards and risks to persons who are occupationally exposed. This assessment suggests that mixing, loading and applying dichlorvos in most of its egistered situations of use is likely to cause toxicologically unacceptable levels of exposure and risk to operators. Based on exposure modelling, it appears that mixer/loaders can handle no more than approximately 1.4 kg of dichlorvos per day without eroding the MOE below the acceptable value of 10, even if enclosed mixing systems are used and gloves and chemical resistant clothing are worn. This amount of dichlorvos is insufficient to support the anticipated work rates associated with application of dichlorvos by indoor and outdoor fogging/misting, broadacre application to avocados and mechanical application to grain.

Operators applying dichlorvos are likely to be exposed extensively by the dermal and inhalation routes. Based on studies in PCOs and on appropriate exposure models, this assessment has shown that even with the highest level of PPE, it is not possible to assure adequate MOEs to protect persons applying dichlorvos indoors or outdoors by surface and space spray. Similarly, MOEs are inadequate in situations where the operator has to remain inside the structure under fumigation while using hand-held CO_2 pressure guns and portable fogging/misting equipment, or applying dichlorvos by watering can or paintbrush. There is insufficient information to predict the extent of operator exposure during indoor crack and crevice treatment. Consequently, these uses of dichlorvos can no longer be supported.

The situations in which operator exposure can be constrained within acceptable limits by use of appropriate PPE, are fumigation treatments in which dichlorvos is discharged from pressure cylinders into buildings, sealed plant fumigation chambers or other enclosed spaces using fixed installations, fumigation of the airspace within sealable silos, bins or other storage containers, where dichlorvos is discharged from manually released pressure cylinders by an operator remaining outside the space under treatment, fumigation of machinery and eradication of insect nests in outdoor settings, and administration of veterinary PA product by pre-loaded syringe. However, although operator safety can be assured in these situations, there is a hazard to persons re-occupying treated buildings, even after ventilation. An experimental study has shown that workers re-entering a treated industrial building will be exposed to toxicologically unacceptable airborne concentrations of dichlorvos for 3 days after application. A 4-day REI would be supportable, but compliance would be impractical in many situations. Therefore, the OCS considers that dichlorvos should not be applied within industrial or similar buildings which are to be re-occupied within four days of treatment. By contrast, dichlorvos is significantly less persistent when applied in glasshouses, and a REI of 4 hours after ventilation is suitable for these and similar structures. There is insufficient information upon which to set a REI for use in mushroom houses.

New and revised label Safety Directions including warning statements and PPE have been recommended for 50 g/kg LD products in pressure cylinders and veterinary PA preparations. To limit the inhalation exposure of workers involved in the manufacture of dichlorvos products to a toxicologically acceptable level, the OCS has recommended to the NOHSC that the Australian exposure standard for dichlorvos in the workplace atmosphere be revised from 0.9 mg/m^3 to a TWA concentration of 0.02 mg/m^3.

1. INTRODUCTION

Dichlorvos is an organophosphate chemical used in domestic, agricultural and veterinary situations. Due to its volatility, it is suitable for use as a fog, aerosol or mist for fumigation and disinfestation of machinery and confined areas, such as storage areas, warehouses, flour mills, silos, greenhouses and animal housing. Other applications for dichlorvos include crop protection and pest control in domestic, commercial and industrial areas. Dichlorvos also has limited veterinary use as an oral paste for horses.

This occupational health and safety review supersedes and replaces an interim report prepared by the NOHSC in 1999, and is based on information obtained from the following sources: data submitted by industry, APVMA performance questionnaires (initiated as part of the review of dichlorvos), the APVMA Agriculture Report on dichlorvos, published studies, and the Review of the Mammalian Toxicology and Metabolism/Toxicokinetics of Dichlorvos, prepared by the OCS in April 2004.

2. DICHLORVOS PRODUCTS AND THEIR USE PATTERNS

At the time this assessment was written, 18 dichlorvos products were registered in Australia. Of these, 7 were HG products, while the remainder were intended for use by the professional agricultural, pest control or veterinary sectors. Only products with the potential to cause occupational exposure were considered in this assessment, as the HG products were covered in the toxicology assessment report (http://www.apvma.gov.au/chemrev/dichlorvos.shtml). The professional/veterinary use products are shown in the following table:

APVMA Product Code	Product Name	Description	Dichlorvos Content
32082	Nufarm Dichlorvos 1140 Insecticide	EC; S7; grain disinfestant	1140 g/L
49203	Divap 1140 Insecticide	LD; S7; grain fumigant	500 g/L
48975	David Grays DDVP 500 Insecticide	EC; S6; also contains hydrocarbon solvent (455 g/L); commercial & domestic insect control	500 g/L
49362	Divap 500 EC Insecticide		
53320	Chemag Dichlorvos Insecticide		
55352	Garrards's ddvp 500 EC Insecticide		
55503	Barmac Dichlorvos 500 Insecticide		
49008	Permakill Insecticide	EC; S6; also contains chlorpyrifos (225 g/L) & hydrocarbon solvent (390 g/L); control of insect pests in residential, commercial & industrial settings	250 g/L
32939	Insectigas-D DDVP Insecticide	LD in compressed liquid CO_2; S6; pest control in domestic and commercial premises and storage facilities	50 g/kg
38847	Oximinth Plus Boticide Oral Worm and Bot Paste for Horses	PA; S6; veterinary medicine; also contains oxibendazole (5 g/25 mL)	2.5 g/25 mL
42496	Knock-Down Residual Spray Insecticide	LD; S6; also contains piperonyl butoxide (6 g/L), pyrethrins (1 g/L) & de-aromatised mineral solvent; control of crawling insects in houses, hospitals, factories and restaurants	7 g/L

EC = emulsifiable concentrate; S7 = Schedule 7 of the of SUSDP; S6 = Schedule 6 of the SUSDP; PA = paste; LD = liquid; SR = slow release generator; SO = solid

Product Labels

1140 g/L EC

Nufarm Dichlorvos 1140 Insecticide and Divap 1140 Insecticide are EC formulations containing 1140 g/L dichlorvos and 180 – 190 g/L emulsifying agent. The products are available in 500 mL – 20 L pack sizes (no further details available) and are intended for farm use for the control of insects infesting stored cereal grains. Grain is to be treated on the conveyor or at the auger when being moved into clean storage. The product labels do not give any further description of the application equipment used. The products are to be diluted to either 530 or 1050 mL/100 L water (6.0 or 12.0 g dichlorvos/L) and applied at 1 L mixture/te grain to yield final concentrations of 6 or 12 ppm. WHPs of 7 and 28 days are specified at the two respective treatment rates. Alternatively, the products can be diluted to 480 mL/100 L water (5.5 g dichlorvos/L) and applied at 1 L mixture/20 m^2 to the exposed top surface of bulk stored grain, as often as necessary to prevent infestation.

Both product labels comply with the current First Aid Instructions applying to 1140 g/L EC products ['**a**' (If poisoning occurs contact a doctor or poisons information centre.) and '**h**' (If swallowed, give one atropine tablet every 5 minutes until dryness of the mouth occurs - if poisoned by skin absorption or through lungs, remove any contaminated clothing, wash skin thoroughly and give atropine tablets as above. Get to a doctor or hospital quickly.)].

The labels also comply with the current Safety Directions for 1140 g/L or less EC products, which are as follows:

120 121 130 131 132 133 190 210 211 220 223 373 279 280 281 284 290 292 294 297 300 303 340 342 350 360 361 363 364 366	Product and spray are poisonous if absorbed by skin contact, inhaled or swallowed Repeated minor exposure may have a cumulative poisoning effect Avoid contact with eyes and skin Do not inhale spray mist Obtain an emergency supply of atropine tablets 0.6 mg When opening the container, preparing and using in enclosed areas, wear cotton overalls buttoned to the neck and wrist and a washable hat, elbow length PVC gloves, goggles, and half facepiece respirator with combined dust and gas cartridge If product on skin, immediately wash area with soap and water After use and before eating, drinking or smoking, wash hands, arms and face thoroughly with soap and water After each day's use, wash gloves, goggles, respirator and if rubber wash with detergent and warm water and contaminated clothing.

500 g/L EC

There are 5 EC products containing 500 g/L dichlorvos as the active constituent and 455 g/L hydrocarbon solvent. With the exception of Garrard's DDVP 500 EC Insecticide, the products in this category also contain surfactants and/or emulsifying agents. Pack sizes range from 1 to 200 L, but no further information is available on the type of containers used. Some labels warn that the product is too hazardous to be recommended for HG use.

These products are intended for control of spiders, silverfish and insect pests in a wide variety of situations, and can be used undiluted or diluted in water (as an emulsion), kerosene (as a solution) or in a recommended fogging diluent. All information on application methods included on the labels is summarised below.

Indoor uses include:

- domestic households, against flying and crawling insects, spiders and silverfish, when diluted to 12 mL product/L (6 g dichlorvos/L) and sprayed or sprinkled with a watering can where pests occur,

dairies and cattle sheds, diluted to 2.5 g dichlorvos/L and applied as a coarse spray at a rate of 600 mL (1.5 g dichlorvos)/50 m^2 ,

stables and piggeries, applied as a space spray using a sprayer with a fine nozzle, or as a mist via a mister or atomiser. The dilution rate is 2.5 g dichlorvos/L and an application rate of 14 L (35 g dichlorvos)/1000 m^3 is specified.

animal houses and pens and meat works (non-product areas), against flies and mosquitoes, diluted to 20 mL product (10 g dichlorvos)/10 L water and applied to walls and other surfaces as a coarse spray using 15 L (15 g dichlorvos)/100 m^2, or into the air as a mist (no further details provided).

abattoirs and wineries, against flies and vinegar flies, diluted to 1 - 2.5 g dichlorvos/L and applied as a coarse spray onto the floor and around doorways and windows at 5.3 - 10 g dichlorvos/50 m^2 , or diluted to 2.5 g dichlorvos/L for application by fogging at 14 L (35 g dichlorvos)/1000 m^3. Some labels also recommend application by space spray at 140 mL product (70 g dichlorvos)/1000 m^3 in a "convenient" volume of water.

factories, stores, mills and food warehouses against flies, cockroaches, beetles and moths, diluted to 2.5 g dichlorvos/L and applied as a liquid bait. Liquid baits are made by dissolving 50 g sugar/L spray mixture and applied as a coarse spray, or painted on in strips or patches where insects harbour. Alternatively, for fogging, labels recommend dilution rates of 2.5 - 5 g dichlorvos/L diluent (kerosene, dieseline of other suitable carrier). Fogging is performed at 17.5 - 35 g dichlorvos/1000 m^3 or 3 – 3.5 g dichlorvos/50 m^2, using a stationary fogging machine. Some labels advise that the fogger be set up to fill the building through a door or window on the windward side. For application by space spray, some labels recommend a use rate of 35 - 150 mL product (17.5 - 75 g dichlorvos)/1000 m^3 in a "convenient" volume of water. Treatment is repeated as necessary, although some labels recommend 2 treatments/wk against beetles and moths.

Some labels further advise that when used indoors, the product should be applied away from cooking and eating utensils and foodstuffs. All doors and windows are to be closed before application and the site cleared of bystanders and animals. Operators are advised to start application at a point furthest from a door and work towards the door. Some (but not all) labels advise that indoor sites are to be kept closed for at least 4 h following treatment and ventilated thoroughly before re-occupation.

Additional indoor uses of 500 g/L EC products comprise:

- poultry houses, against maggots, diluted to 60 mL product/10 L water (3 g dichlorvos/L) and applied by spray at 10 L spraymix per 12 m manure under cages, repeated at 3-wk intervals,

- empty grain silos, diluted to 100 mL product/10 L water (5 g dichlorvos/L) and sprayed onto the inside walls and exit chutes until run-off,

tobacco stores, warehouses, greenhouses, glasshouses and mushroom houses, against insects including flies, aphids and thrips, applied undiluted by the "wooden board method". This entails sprinkling the undiluted product onto wooden boards at the rate of 20 mL (10 g dichlorvos)/150 m^3 volume. To enhance effectiveness, a fan may be set up to blow over each board. The treated area should remain closed overnight and be ventilated thoroughly before re-entry. After use, boards are hosed down and stored outdoors. Some labels recommend that gloves be worn when applying the product and handling boards. Other labels specify application as a spray or fog at 15 mL product (7.5 g dichlorvos)/100 m^3 in these situations, and recommend twice-weekly treatment for control of cigarette beetle, tobacco moth, other moth species and sawtoothed grain beetle. A 2-day WHP applies to edible crops.

Outdoor uses cover:

- garbage dumps, beach, picnic and recreation areas applied at an unspecified dilution rate as a space spray at 300 mL/ha (150 g dichlorvos/ha,), or undiluted through a portable or stationary fogger at 300 mL/ha (150 g dichlorvos/ha), or by misting machine at 30 L of 0.5% product/ha (75 g dichlorvos/ha), and

- destruction of bee and wasp nests in trees, uncultivated ground, rockeries and buildings. For this use, the product is mixed at 12 - 20 mL/L water (6 - 10 g dichlorvos/L) and up to 1 L of the mixture is sprayed into each nest.

There are also several uses on crops and foodstuffs, as follows:

stored grain, against moths, grain borers and beetles, when diluted to 100 mL product/10 L water (5 g dichlorvos/L), applied by spray at a rate of 5 L spraymix/100 m^2 grain surface. Some labels specify mechanised spray equipment for this purpose. A 7-day WHP applies to stored grain.

- infested grain held by flour millers, diluted to 120 mL product/10 L water (6 g dichlorvos/L) and applied at the elevator via specially designed and calibrated spray equipment at 1 L spraymix per tonne grain, yielding a final concentration of 6 ppm,

- bagged and stored potatoes, against tuber moths, when diluted to 50 mL product/5 L water (5 g dichlorvos/L) and applied by spray to bag surfaces, shed walls and surrounds at 5 L spraymix/16 bags,

- avocados, against leaf rollers, applied at 1 L product (500 g dichlorvos)/ha together with 1 kg chlorpyrifos/ha. Application is performed at the first signs of pest activity and repeated as required. No application equipment is specified but airblast would be the most probable method in an orchard situation. A 7-day WHP applies to avocados.

Users of David Gray's DDVP 500 Insecticide and Barmac Dichlorvos 500 Insecticide are also advised to open, decant and mix the product only in well ventilated outdoor areas. The required amount of product is to be added to the required amount of water in the mixing vessel or spray tank and thoroughly agitated.

Labels of 500 g/L EC products should display the same First Aid Instructions and Safety Directions applying to 1140 g/L EC products (see previous section), with the addition of First Aid Instruction '**c**' (If swallowed, do **NOT** induce vomiting. Give a glass of water) due to the presence of liquid hydrocarbons in the formulations. All labels of the 500 g/L EC products bear the recommended Safety Directions and First Aid Instructions '**a**' and '**h**', but omit '**c**'.

250 g/L EC with 225 g/L chlorpyrifos

There is a single EC product, Permakill Insecticide, which contains 250 g/L dichlorvos in combination with 225 g/L chlorpyrifos in hydrocarbon solvent at 390 g/L. It is available in 5 L packs only, and is intended for the control of insect pests in residential, commercial and industrial situations by professional pest control operators. The label warns that the product is too hazardous for use by householders. The dichlorvos provides fumigant action, while the chlorpyrifos acts as a residual contact insecticide.

Directions for use specify the product is to be diluted to 240 mL (60 g dichlorvos, 54 g chlorpyrifos)/10 L water and applied as a low pressure spray to the point of run-off to cracks, crevices, harbourages and places where pests may occur. For use against ants, the preferred technique is direct injection into the nest. The label bears a precaution against application inside buildings except as a crack and crevice treatment, and warns against application to surface areas such as interior floors and walls. Application equipment is not specified, but would most probably comprise a knapsack sprayer or hand-held sprayer used in conjunction with a vehicle-mounted tank and pump.

The label directs users to open, decant and mix the product only in well-ventilated outdoor areas. The required amount of Permakill Insecticide is to be added to the spray tank when half full of water. The balance of the water is then added under agitation. Knapsack sprayers should be shaken gently before use. For indoor use, operators are advised to close windows and doors, clear the area of people, animals and unpacked foodstuffs, and to commence application at the furthermost area from entry and work back. The label warns that the product should not be applied to cooking and eating utensils or on food application areas. When used outdoors, the label states that it is preferable to apply the product when the air is reasonably still and dry and the treatment site will be clear of people and animals for at least 4 h after treatment. Re-entry is not permitted until treated areas are completely dry (normally 4 h). If prior entry is required, the duration of entry should be limited and protective clothing and equipment worn (see below).

Following use, the spray tank is to be thoroughly washed with a pressure hose, and drained. Spray equipment and lines are then to be washed by quarter filling the tank with clean water and circulating through the pump, lines and nozzles. The apparatus is then to be drained and the procedure repeated twice.

There is no FAISD Handbook entry to cover this combination product. The label for Permakill Insecticide bears the First Aid Instructions recommended for chlorpyrifos: '**a**', '**h**' (see above) and '**s**' (If in eyes, hold eyes open, flood with water for at least 15 minutes and see a doctor). Due to the presence of liquid hydrocarbons in the formulation, the product label should also carry First Aid Instruction '**c**' (If swallowed, do **NOT** induce vomiting. Give a glass of water). The Safety Directions shown on the product label are those currently recommended for dichlorvos 1140 g/L EC products, with the addition of statements 161 162 164 (Will irritate the eyes and skin).

50 g/kg LD in compressed liquid CO_2

There is a single pressurised LD product, Insectigas-D DDVP Insecticide, containing 50 g dichlorvos/kg in carbon dioxide. It is available in 6 and 31 kg cylinders for control of flies, mosquitoes, moths, cockroaches, ants and silverfish in industrial and domestic premises, moths and beetles in stored product facilities (including farm machinery and silos), plant pests in greenhouses, and wasps in nests. The product is for professional use only, and is usually applied as a space spray using a manual pressure gun or via a fixed installation, which may be operated using a manual or programmed time release. However, there is a label restraint against installing an automatic time release system in food preparation areas or offices.

Indoor areas are to be closed and air movement minimised for 4 h during treatment. Re-entry must not take place within 4 h of treatment. Licensed or authorised personnel must thoroughly ventilate treated premises for 30 min prior to re-occupation. The product label advises that warning notices be placed on all door entries to treated areas, and that warning lights and an audible alarm system should be fitted in treatment areas where there are fixed systems.

No mixing is required prior to use. When applying Insectigas-D manually as a space spray in enclosed spaces, operators are directed to work away from spray drift and towards the exit when using the pressure gun, and avoid wetting any surfaces with the spray produced. Wasp nests are treated by directing the nozzle into the cavity or nest. Empty cylinders are returned to BOC Gases for refilling. A single application rate of 200 g product (10 g dichlorvos)/300 m^3 is recommended for all situations. This amount of product is discharged in 70 sec when using BOC Gases kit 416651 and 736685 nozzle.

The First Aid Instructions currently recommended in the FAISD Handbook for dichlorvos in compressed liquid carbon dioxide are '**a**' and '**x**' (If poisoned by skin absorption or through lungs, remove any contaminated clothing, wash skin thoroughly and give one atropine tablet every 5 minutes until dryness of the mouth occurs. Get to a doctor or hospital quickly.) The label for Insectigas-D bears both Instructions, but also states, "If swallowed, induce vomiting, preferably using Ipecac Syrup APF and give one atropine tablet every 15 minutes until dryness of the mouth occurs. If poisoned by skin absorption or through lungs, remove contaminated clothing and wash skin thoroughly and give atropine tablets as above. Get to a doctor or hospital quickly". Following recommendations from a review of First Aid Instructions by a Working Party of the NDPSC, statements relating to the induction of vomiting have been deleted from the FAISD Handbook due to the risk of aspirating the vomitus. Therefore, the presence of such a First Aid Instruction on this particular dichlorvos product is considered inappropriate.

Insectigas-D is covered by a FAISD Handbook entry for LD 50 g/kg or less in compressed liquid carbon dioxide, as follows:

130 131 132 190 210 211 220 223 279 280 290 292 294 301 303 320 349 350 360 361 364 366	Poisonous if absorbed by skin contact and inhaled Repeated minor exposure may have a cumulative poisoning effect Avoid contact with eyes and skin Do not inhale spray mist When opening the container, wear cotton overalls buttoned to the neck and wrist and a washable hat, elbow length PVC gloves, and a full facepiece respirator with combined dust and gas cartridge or canister Thoroughly ventilate treated areas before reoccupying Avoid re-entry for (time to be inserted by registering authority) after use in glass houses or other confined spaces. If re-entering, wear all protective clothing including respirator After use and before eating, drinking or smoking, wash hands, arms and face thoroughly with soap and water After each days use, wash gloves, respirator and if rubber wash with detergent and warm water and contaminated clothing.

The product label differs from the recommended statements in several respects. Statement 284 (Using in enclosed areas) is shown in place of statement 280 (Opening the container); the former is considered more appropriate and the FAISD Handbook should be amended accordingly. Statement 320 is omitted from the Safety Directions but an equivalent re-entry statement appears elsewhere on the label. In the final after use statement, the label states 363 (Goggles) instead of 364 (Respirator and if rubber wash with detergent and warm water), and should be corrected.

7 g/L LD with 1 g/L pyrethrins and 6 g/L piperonyl butoxide

There is a single LD product, Knock-Down Residual Spray Insecticide, which contains dichlorvos (7 g/L), piperonyl butoxide (6 g/L) and pyrethrins (1 g/L) in de-aromatised mineral solvent (780 g/L). It is available in 25 and 205 L packs, and is intended for residual control of crawling insects, spiders and silverfish in houses, hospitals, factories and restaurants. The product is sprayed undiluted directly onto infested areas or insect hiding places. Inaccessible areas may be treated by application of a barrier spray around the opening. No further information appears on the product label.

The label advises that the product should not be sprayed directly on humans, pets or clothing, and bears First Aid Instruction ‘**a**’. However, the label does not carry the required First Aid Instruction ‘**h**’. Due to the presence of liquid hydrocarbons in the formulation, the product label should also carry First Aid Instruction ‘**c**’ (If swallowed, do **NOT** induce vomiting. Give a glass of water). The label advises against induction of vomiting and to “give plenty of water or milk”.

There is currently no entry in the FAISD handbook to cover the Safety Directions for this particular product. Commercial products containing pyrethrins should carry Safety Directions 180 181 210 211 220 (221 or 222 or 223) 351 (Repeated exposure may cause allergic disorders. Sensitive workers should use protective clothing. Avoid contact with eyes and skin. Do not inhale dust [or vapour or spray mist]. Wash hands after use). The only Safety Directions appearing on the product label are statements 219 223 and 351 (Avoid inhaling spray mist. Wash hands after use).

100 g/kg PA with 200 g/kg oxibendazole

There is a single PA formulation used for the treatment of adult roundworms, blood worms, red worms, pin worms and bots in horses (Oximinth Plus Boticide Oral Worm and Bot Paste for Horses). This product contains 2.5 g/25 mL dichlorvos (ie. 100 g/L) and 5 g/25 mL oxibendazole as the active constituents. It is supplied in a 25 mL syringe (for the treatment of a 500 kg horse), which is placed on the horse’s tongue and the plunger pressed to administer the required dose. The label directions indicate that the horse’s mouth should be kept closed until the paste has been swallowed. Adult horses are treated twice per year or as required. A meat WHP of 28 days applies.

The label for Oximinth Plus bears statements '**a**' and '**h**', which are the recommended First Aid Instructions for this type of veterinary preparation. However, there is no FAISD Handbook entry to cover dichlorvos PA formulations, and no Safety Directions appear on the product label. Appropriate Safety Directions should therefore be prepared and the label amended accordingly.

APVMA Agriculture Report and Surveys of Users

Additional information on the use pattern of dichlorvos is available from the APVMA Agriculture Report, based in part on advice received from registrants and on performance questionnaires covering large- and small-scale users and State Chemical Co-ordinators. Use of dichlorvos is confined to comparatively narrow sectors of Australian agriculture, where its fumigant action and knock-down capacity are most valuable. During 1996 – 1997, about 33.5 te of technical grade dichlorvos were imported by the approval holders.

By far the largest user of dichlorvos is the grains industry. Some 55% of the total quantity of dichlorvos used is expended against pests of stored products. Major sectors include on-farm storage and stockfeed merchants. Currently, GrainCorp is the only bulk handling authority utilising dichlorvos for grain treatment[1]. Dichlorvos is most commonly used as a disinfestant, rather than a protectant. It may be applied to lightly infested grain as it enters or leaves the storage facility, or to grain that has become infested during storage. In these situations, the most common application method is as a coarse spray via mechanical equipment directly onto grain on the auger/conveyor. Up to 10 000 tonnes of grain may be treated per day. Grain applicator equipment operators may work for up to 12 h/d, 7 d/wk over the harvest period. Mixing times during this period may occupy up to 1 h/d. Under normal operating conditions, workers are exposed to the chemical only during mixing/loading of spray tanks (which is done by open pour), as they do not need to be present continuously to supervise spray application.

Dichlorvos may also be applied by hand as a gas or surface spray on storage structures, equipment and machinery to prevent re-infestation of grain entering storage. The NSW and Queensland State agricultural authorities recommend the use of dichlorvos in spray programs for structural hygiene. According to the GrainCorp submission, dichlorvos is required for control of insect species that are not easily managed using other products and pest control techniques. Storage infrastructure includes silos, sheds and bunker storage. Silos have a grain storage capacity from 300 - 10,000 tonnes and sheds hold from 3,000 - 100,000 tonnes. Grain storage bunkers are constructed from low walls (up to 1.8 metres high), placed in parallel on prepared ground. Grain is loaded onto the ground between the walls and tarpaulins are placed over the grain surface and secured to the walls with clamps.

Internal floor areas of silos and walls and floors of sheds and bunkers are treated once per year prior to intake of grain at harvest. Other internal/enclosed areas including surfaces of under-storage tunnels and elevator pits may be treated up to three times per year. Under-storage tunnels and elevator pits are not normally accessed by personnel other than for brief periods (usually less than 15 minutes) to check operation of equipment. External surfaces of grain stores may also be treated up to three times per year. Due to improved control of moths through use of grain protectants including phosphine, bulk handling facilities now seldom spray dichlorvos onto the surface of stored grain.[2] However, Clamp and Gazzard (2000) describe the fortnightly use of fogging to fumigate critical areas of a large grain shipping terminal against psocids, an activity performed at night when the pests are most active and there are few personnel within the plant.

The APVMA Agriculture Report and the GrainCorp submission stress the lack of alternatives to dichlorvos in grain protection, where the chemical is essential in situations where infestations cannot be fumigated because of the age of storage infrastructure. Similarly, dichlorvos is effective in treating machinery, equipment and structures which cannot be fumigated satisfactorily by other chemicals. The APVMA report states that dichlorvos is used for moth control at 1 g/1000 m^3 daily into storage headspace, a use which does not appear on product labels.

[1] Submission by GrainCorp to the OCS, February 2005.
[2] Mr Bill Murray, consultant to grains industry, personal communication.

The second largest use of dichlorvos is for pest control in industrial, commercial and domestic situations, including non-product areas of abattoirs, warehouses and other storage facilities including flour mills. Approximately 26% of dichlorvos is used in this role, in which the chemical is considered as pivotal. The NSW and Victorian State agricultural authorities have nominated dichlorvos as being important for pest control strategies in these situations. Fogging, misting and aerosol discharge of Insectigas-D are the main methods employed. Almost all flour mills use Insectigas-D as a space and structural treatment of the mill itself, warehouses, machinery and sometimes infested wheat, reliance on dichlorvos having increased due to the phasing out of methyl bromide. The NT State Chemical Co-ordinator noted that three people had been hospitalised in Katherine after a building was fumigated by a PCO, but did not provide any further details.

Household vapour strip products account for a further 15% of dichlorvos use. Minor uses of dichlorvos comprise animal housing (1.8%), greenhouses/glasshouses (1.7%) and veterinary applications (0.6%). According to the APVMA Agriculture Report, the principal use in greenhouses/glasshouses is for control of thrips on ornamentals, with dichlorvos being recommended as part of a resistance management strategy by the NSW State agricultural authorities. There are further limited uses on a range of crops including tomatoes, cucumbers, and capsicums. Dichlorvos is also used to fumigate vegetable seedlings and cut flowers prior to export. One survey respondent described use of Insectigas-D in a chamber/enclosed fumigant bed at 64 mg dichlorvos/m^3 with pyrethrin at 5.2 mg/m^3. Dichlorvos is also used under permit in fruit fly traps in conjunction with pheromone lures for monitoring programs in SA, Queensland and Victoria.

Dichlorvos aerosols are considered essential for IPM in mushroom cultivation. Mushroom growers use dichlorvos for control of small flies and midges, usually during the spawning phase of production, when inoculated compost is held within purpose-built rooms under controlled atmosphere. Dichlorvos cylinders or fogging equipment are located outside the rooms and the chemical is introduced through the walls to eliminate any adult flies that have gained entry while the spawning rooms are being filled. Spawning rooms remain sealed for 10 days after being treated. If dichlorvos has to be applied during the growing or picking phases of production, which take place in different rooms, the growing rooms are left overnight and ventilated before re-entry. However, pyrethrins are the preferred option for use in growing rooms. One grower indicated that dichlorvos may also be applied at the end of cropping, with re-entry occurring at least 15 hours post-treatment and after at least 12 hours' ventilation. Each holding has 2 – 3 growing rooms, with a total of 800 – 1200 m^2 growing surface. The grower indicated that he used only 5 – 10 L of 500 g/L EC product annually. The APVMA observes that Insectigas-D is used by the mushroom industry even though the product label does not contain directions for use in mushroom production.

Foliar spray treatment of avocados to control leaf roller is the only direct crop use identified for dichlorvos. This use is very minor and only 500 g/L EC formulations are employed. The APVMA have advised that leaf roller is a significant but sporadic pest of avocados, with growers needing to treat it only once every 2 - 3 seasons, usually with a single application of dichlorvos made with chlorpyrifos, tank mixed together. Dichlorvos is used for its action as a fumigant, flushing out the pest, while chlorpyrifos is used as the control agent. To ensure optimal fumigant activity, spraying is conducted on warm days.

According to the NSW Department of Agriculture, dichlorvos has been part of a resistance management strategy for fly control in poultry houses, but its use in this situation is expected to decrease because of pest resistance. Although significant quantities of dichlorvos have been used in the past for protection of potatoes against tuber moths, chemical usage in this situation is declining due to improved management practices. Therefore, the APVMA has concluded that there may be little need for dichlorvos to be used for control of tuber moths in the future.

3. TOXICOLOGICAL HAZARDS OF DICHLORVOS

Acute toxicity

Dichlorvos acts by inhibiting cholinesterase (ChE) enzymes in the blood and central and peripheral nervous systems. In lethal-dose studies, the oral LD_{50} for dichlorvos in rats ranged from 46-108 mg/kg bw (moderate to high toxicity), and the dermal LD_{50} ranged from 75-210 mg/kg bw (high toxicity). In rats, the inhalational LC_{50} was >200 mg/m^3 (limit test) for vapour exposures, and in the range 340-523 mg/m^3 for aerosol exposures (moderate toxicity). The effects of acute dichlorvos intoxication were consistent with those seen for other organophosphate insecticides, and included exophthalmia, prostration, lacrimation, salivation, tremors, spasms, altered gait, and death. However, recovery from non-lethal doses was rapid. Dichlorvos was slightly irritating to rabbit skin and a moderate eye irritant in rabbits, and is a skin sensitiser in guinea pigs and humans. No acute toxicity studies have been performed with any of the Australian products containing dichlorvos (with registrations current at the time this assessment was written).

Repeat-dose toxicity

Dose-related inhibition of plasma, RBC and brain ChE activities was the most common manifestation of dichlorvos toxicity in short-term, subchronic and chronic studies in mice, rats and dogs. Cholinergic signs and occasional mortalities occurred in rats and dogs at the same doses as the inhibition of brain ChE activity. Plasma and RBC ChE activities were also inhibited following chronic inhalational exposure in rats (LOEC = 0.5 mg/m^3). Nevertheless, there is no experimental evidence that dichlorvos causes delayed neuropathy. There was little indication that repeated oral or inhalational exposure had any effect on haematology, clinical chemistry or urinary parameters, or on organ weights or gross pathology, but in some rat and dog studies, histopathology revealed cytoplasmic vacuolisation of the liver.

Dichlorvos is mutagenic and/or clastogenic in bacteria and other micro-organisms and in mammalian cells and tissues exposed directly to high concentrations of un-metabolised dichlorvos, including the skin of mice. However, findings in *in vivo* genotoxicity studies have been consistently negative and there is no evidence that dichlorvos has any systemic genotoxic potential. Although causing oesophageal and forestomach tumours in mice, these are likely to have resulted from repeated exposure to localised, high concentrations associated with dietary administration, and are not directly relevant to occupational exposure of humans. There was no carcinogenic activity in a long-term inhalational study in rats, which simulated a highly relevant route of occupational exposure. Based on studies in rats and rabbits, dichlorvos is considered not to pose a reproductive or developmental toxicity hazard to humans.

Toxicity to Humans

Information summarised from the OCS Review of Mammalian Toxicology

Like other mammals, the inhibition of plasma ChE activity is the most sensitive toxicological endpoint in humans following repeated exposure. The NOEL following repeated oral dosing is 0.014 mg/kg bw/d (Rider 1967). For acute or short-term exposures, the inhibition of RBC ChE activity is the most sensitive toxicological endpoint. The NOEL following a single oral dose is 1 mg/kg bw/d (Gledhill 1996; Morris 1996a; Gledhill 1997a).

In studies investigating the inhalational exposure of humans in residential and public premises, exaggerated exposure (10 or 17 strips per room) caused the inhibition of plasma but not RBC ChE activity in adult males (Ueda & Nishimura 1967). Air levels of dichlorvos in this study were up to 2.2 and 7.1 mg/m^3, respectively. Newborn babies exposed to air levels of 0.095 - 0.25 mg/m^3 for 18 h/d showed no effects on plasma or RBC ChE activities (Cavagna et al 1970). Two studies by Hunter (1970a & b) examined the effect of dichlorvos vapour on laboratory staff following exposure for up to 7.5 hours. There was no treatment related effect on RBC ChE activity, while plasma ChE was inhibited (>20%) at and above approximately 200 - 2000 mg/min/m^3.

Few studies have examined the dermal toxicity of dichlorvos in humans. Repeated dermal exposure to resin strips for 5 days failed to perturb plasma or RBC ChE activities, but plasma ChE was reportedly inhibited in two commercial pesticide applicators following the spraying of up to 20 residences (Gold & Holcslaw 1984). In this study, the level of dermal exposure was estimated to be 0.028 mg/kg bw/h.

Reports of Toxicity Following Occupational or Accidental Exposure

Hayes (1982) has described several cases of accidental occupational poisoning with dichlorvos. Two workers died after splashing a concentrated formulation on their bare arms and failing to wash it off promptly. In a serious but non-fatal case following dermal exposure, the victim developed slurred speech and drowsiness slightly more than 1.5 hours after the accident. He collapsed suddenly after reaching a hospital but was saved by administration of oxygen, artificial respiration, 15 mg atropine sulfate (mostly iv) and other supportive treatment. Spillage of a 3% dichlorvos solution in oil onto a man's lap resulted in severe poisoning. There was no effort to remove the poison for about 30 minutes after the accident, when a superficial wash was performed, followed by a bath at 90 minutes post-exposure. The estimated dose of dichlorvos in this incident was 72 mg/kg bw. In another case, a man spilled a smaller amount of the same product onto his arm. He removed his shirt immediately and washed with soap and water about 15 minutes later, but developed dizziness and nausea.

Bisby JA & Simpson GR (1975) An unusual presentation of systemic organophosphate poisoning. Med J Australia 2; 394 – 395.

A PCO was accidentally exposed to dichlorvos (1% solution in mineral spirit) whilst using a gasoline engine-powered knapsack mister. He was fumigating a commercial premises and was wearing a singlet and overalls and a cartridge-type respirator. After 10 minutes he noticed a leak onto his left shoulder from a faulty seal and changed his overalls, but not undergarments, and placed a plastic sheet under the sprayer. During the day, he noticed increasing local irritation and burning in the contaminated skin area. By the end of the shift he reported excessive tiredness, weakness, dizziness and breathing difficulties. After showering, the symptoms improved although rapid shallow breathing lasted for 2 hours. He developed skin irritation, consisting of extensive areas of erythema and bulla. When whole blood ChE was measured 3 days after exposure, it was 36% of normal but reached 51% after 5 days and 78% after a month.

Mathias CGT (1983) Persistent contact dermatitis from the insecticide dichlorvos. Contact Dermatitis 9; 217 – 218.

A truck driver was exposed dermally to a liquid product containing 5% dichlorvos in 15% petroleum distillate and 80% trichloroethane, which became spilled in vehicle. The next day he awoke with dermatitis of his neck, anterior chest, dorsal hands and forearms. He also experienced a frontal headache, mild rhinorrhea, burning of the tongue and a bitter taste in his mouth. Initial blood ChE activity level was in the "low normal range". A repeat assay 2 weeks later revealed activity in the "high normal range". The dermatitis resolved approximately 10 weeks after onset. Patch tests with dichlorvos in petrolatum were negative, so the cause of irritation was presumed to be irritation rather than sensitisation.

Comment: These incidents clearly illustrate the potential for dichlorvos to cause toxicity via the dermal route. Dermal absorption may have been enhanced by the mineral spirits/organic solvents in which the dichlorvos was diluted. Given that dichlorvos is a slight skin irritant and was present at only 1 or 5%, the dermal reactions were probably caused by the solvents

4. TOXICOLOGICAL ENDPOINTS FOR OHS RISK ASSESSMENT

Dermal absorption factor

The level of percutaneous absorption in rats was 22-30% when dichlorvos was applied to 12 cm^2 of skin at 3.6, 36 or 360 μg in a total volume of 100 μL (equal to 0.5, 3 or 30 $\mu g/cm^2$) (Jeffcoat, 1990). Absorption occurred within the first 10 hours of exposure and a substantial proportion (38-55%) of dichlorvos was found to evaporate from the skin surface following application. In the absence of such evaporation, it is plausible that close to 100% of the applied dose would have been absorbed. However, this scenario is unlikely under actual use conditions. The concentration range tested of 0.0036 - 0.36% is representative of the working concentration of the 8 EC products for use (0.1 - 1%). No *in vitro* dermal penetration studies with dichlorvos are available. However, in a biomonitoring study (McDonald, 1991) in volunteers, approximately 19% of the estimated dermal load of dichlorvos was absorbed over a 5-hour period. Taken together, the results of Jeffcoat (1990) and McDonald (1991) suggest that a dermal absorption factor of 30% over an 8 hour workday is an appropriate figure for use in the occupational health and safety assessment for dichlorvos.

Inhalation absorption factor

A study (Kirkland, 1971) evaluated by the WHO (1988) demonstrated that at dichlorvos concentrations of 0.1 – 2.0 mg/m^3, pigs retained 15 – 70% of the inhaled dichlorvos. A 70% inhalation absorption factor will therefore be used for risk assessment purposes.

NOELs for Occupational Health & Safety Assessment

Dichlorvos products intended for professional use are most likely to be applied by PCOs, horticulturalists and operators of grain storage facilities and flour mills. Depending on pest activity, PCOs may use dichlorvos products on several days or daily during the working week. Repeated use of dichlorvos for treatment of commercial and industrial buildings could result in daily exposure of building occupants, given that dichlorvos has been detected in workplace atmospheres for up to a fortnight after application (Schofield, 1993). Grain storage operators and avocado growers are more likely to be exposed on a seasonal basis, but also may be exposed on several days in succession. Exposure of horticulturalists would be dictated by the growth cycle of mushrooms or plants under cultivation, and could occur regularly on single days but with several days or more between uses. The most likely potential routes of exposure would be by dermal contact with the undiluted products or spray mixture, and by inhalation of dichlorvos vapour or aerosols.

Dermal NOEL for Occupational Exposure Assessment

Short-term repeat-dose toxicity studies of up to 28 days' duration are considered to be the most appropriate for derivation of NOELs for occupational health and safety assessment of product users who are exposed repeatedly. The most relevant toxicological end-point for occupational exposure to dichlorvos is plasma ChE inhibition, as in a repeated exposure scenario, there would be scope for progressively increasing inhibition of plasma ChE activity if the (less sensitive) RBC ChE inhibition were used as the pivotal end-point. Although repeat-dose studies via the dermal route would be optimal for derivation of occupational health and safety NOELs, no such studies with dichlorvos are available. The assessment therefore must be performed using studies undertaken by oral administration. A summary of NOELs determined in oral studies considered adequate for regulatory purposes is shown in the following table:

Dichlorvos: Summary of oral NOELs relevant for OH & S assessment

Species	NOEL (mg/kg bw/d)	LOEL (mg/kg bw/d)	Toxicological Endpoint	Reference
Acute Studies				
Rat po gavage	0.1	0.5	Clinical signs (exophthalmus, absent hindlimb and reduced forelimb grasp) within 15-45 min of dosing.	Lamb (1992) [GLP]
Developmental studies				
Rat po gavage	3.0	21.0	Dams: cholinergic signs (within 10-60 min of dosing) & reduced food consumption.	Tyl et al (1990a) [QA, GLP]
	21.0	-	Foetuses: no toxicity	
	21.0	-	Developmental toxicity: none	
Rabbit po gavage	0.1	7.0	Dams: mortalities	Tyl et al (1990b) [QA, GLP]
	7.0	-	Foetuses: no toxicity	
	7.0	-	Developmental toxicity: none	

Acute Neurotoxicity studies				
Rat po gavage	0.5	35	Clinical signs of neurotoxicity.	Lamb (1993a) [QA, GLP]
Human studies				
Single-dose, po gelatine capsules	1	-	Inhibition of RBC ChE activity.	Gledhill (1996), Morris (1996a), Gledhill (1997a) [QA, GLP]
21-d po, gelatine capsules	-	0.1	Inhibition of RBC ChE activity.	Gledhill (1997b, c) Morris (1996b) [QA, GLP]
28-d po, gelatine capsules	0.014	0.021	Inhibition of plasma ChE activity.	Rider (1967)
	0.036	-	Inhibition of RBC ChE activity.	

QA = quality assured study; GLP = statement of compliance with principles of good laboratory practice

It is considered that the most suitable endpoint for estimation of occupational risks for dermal exposures is an oral NOEL of 0.014 mg/kg bw/d, established in the 28-d oral study in humans by Rider (1967). The study is highly suitable because it demonstrated a NOEL and a LOEL for plasma ChE inhibition and was performed with human subjects, thereby eliminating uncertainty associated with inter-species extrapolation. Adjusting for a dermal absorption factor of 30%, the resulting dermal NOEL becomes 0.047 mg/kg bw/d. The acceptable margin of exposure (MOE) is $\geq$ 10, resulting from application of a 10-fold uncertainty factor for intra-species variability. No correction for an internal dose is required since absorption from the GIT is almost complete (93 – 96%).

Inhalational NOEL for Occupational Exposure Assessment

Due to the volatile nature of dichlorvos, there is highly significant potential for product users to be exposed via inhalation, especially during spray application. For product users, the frequency of inhalation exposure in an occupational setting would be the same as for dermal exposure, as discussed above. Persons exposed occupationally in treated buildings are likely to be exposed by inhalation repeatedly on successive days.

Several short-term studies have been undertaken in which ChE activity was measured in humans exposed to dichlorvos by inhalation. However, their usefulness is limited by uncertainty concerning the NOECs and/or the airborne concentrations of dichlorvos to which the subjects were exposed. It is therefore necessary to perform the assessment using studies carried out by oral administration. As discussed previously, the most suitable study for estimation of occupational risks is that of Rider (1967), in which the NOEL was 0.014 mg/kg bw/d. Adjusting for the inhalation absorption factor of 70%, the resulting NOEL becomes 0.02 mg/kg bw/d. This value should be used for risk assessment of professional users during application and on re-entry into treated areas. The acceptable margin of inhalation exposure (MOE) is $\geq$ 10, resulting from application of a 10-fold uncertainty factor for intra-species variability.

NOEL for Health & Safety Assessment of Building Occupants

The use of dichlorvos within domestic residences, stores, other commercial premises and enclosed structures used for grain storage and plant or mushroom production will cause exposure of the occupants. This is notwithstanding the 4-h re-entry period and instructions to thoroughly ventilate treated premises before re-occupation which appear on some (but not all) product labels. Given the volatility of dichlorvos, the predominant route of exposure would be via inhalation in most circumstances but there would also be scope for exposure via the dermal route, especially if dichlorvos is applied within a domestic residence.

Current label directions indicate that some structures such as factories and warehouses are fumigated twice per week. Studies by Durham et al (1959), Gold and Holcslaw (1984) and Schofield (1993a,b) have demonstrated that dichlorvos persists within the atmosphere for up to 14 days after a single application in industrial or domestic environments, even when ventilated. Indeed, McDonald (1991) detected airborne dichlorvos in a hotel room treated by aerosol fogging a month previously. Hence, irrespective of whether a building is treated once or repeatedly, its occupants are likely to be exposed for several successive days. This precludes use of a NOEL derived from a single-dose (acute) study for risk assessment of persons re-entering treated premises.

Therefore, it is necessary to use the same pivotal NOEL adopted for risk assessment of persons applying dichlorvos, i.e., 0.014 mg/kg bw/d, established in the 28-d oral study in humans by Rider (1967). Adjusting for a dermal absorption factor of 30%, the resulting dermal NOEL becomes 0.047 mg/kg bw/d. Adjusting for the inhalation absorption factor of 70%, the resulting inhalation NOEL becomes 0.02 mg/kg bw/d. The acceptable margin of dermal and inhalation exposure (MOE) is $\geq$ 10, resulting from application of a 10-fold uncertainty factor for intra-species variability.

To ensure that the MOE for building occupants does not fall below 10, the maximum TWA concentration of dichlorvos in the workplace atmosphere should be 0.02 mg/m^3. This value is derived on the assumption of 8 h exposure/day, an inhalation rate of 1 m^3/h, 70% absorption of inhaled dichlorvos and 70 kg bodyweight.

5. ASSESSMENT OF OCCUPATIONAL EXPOSURE DURING PRODUCTION

Evaluation of exposure studies

Jian T & Zhiying F (1990) Chronotoxicological studies on dichlorvos in mice and humans. Environ Sci 2; 83 -89.

A study was performed on blood cholinesterase levels in groups of 30 workers in a plant in China that produced dichlorvos. Age and sex matched controls (20) were also examined. Blood samples were taken at 09:00, 13:00, 17:00 and 21:00 h on a single day. The airborne dichlorvos level in the plant was 7.6 mg/m^3. The average blood cholinesterase activity was always significantly depressed in exposed workers to 67-75% of the control value. *(UK DEFRA assessment,* 1995*)*

Menz M et al (1974) Long-term exposure of factory workers to dichlorvos (DDVP) insecticide. Arch Environ Health 28; 72 – 76.

Thirteen Swiss workers aged between 20 and 67 years involved in the production and processing of dichlorvos-releasing vaporizers were exposed to an average of 0.7 mg dichlorvos/m^3 for 8 months (mean levels at the production and processing sites ranged from 0.3 to 0.9 mg/m^3, with the highest single measurement being 3 mg/m^3). Employees worked for between 18 and 144 h/mo in the production plant and 72 and 210 h/mo in the processing plant. The employees wore a rubber apron and rubber boots with disposable gloves and were subjected to regular haematology, serum biochemistry and urinalysis. Plasma and RBC ChE activities were measured prior to exposure, weekly during exposure and monthly thereafter by the method of Voss and Sachsse (1970). During the exposure period, the plasma and RBC ChE activities of the workers were 35% and 60% of pre-exposure levels, respectively. Medical examinations were normal and there were no effects on haematology, blood chemistry or urinalysis for any of the workers. ChE activity levels returned to normal within one month after cessation of exposure.

6. ASSESSMENT OF OCCUPATIONAL EXPOSURE AND RISK DURING APPLICATION

6.1 Evaluation of exposure studies

Das YT et al (1983) Exposure of professional pest control operator to dichlorvos (DDVP) and residue on house structures. Toxicol Lett 17; 95 – 99.

Materials and methods

Thirteen volunteers participated in this study, in which their exposure to dichlorvos was measured during application of the pesticide to homes. Each volunteer treated 4 homes in accordance with label instructions, wearing PPE comprising goggles, cap, respirator, coat, gloves and shoes. The applicators used 10 – 14 cans of Vapona aerosol insecticide (65 g dichlorvos/L and 4.9 g "related compounds"/L); 220 - 330 g dichlorvos was applied using aerosol cans. In addition, with a 3.8 L sprayer, they applied 8.5 – 10.4 L of spray mixture containing 5 g dichlorvos/L (43 – 52 g dichlorvos). The product used was Vaponite-2 emulsifiable insecticide (228 g dichlorvos/L and 17 g "related compounds"/L). Each volunteer therefore applied a total of 263 – 382 g dichlorvos, while each house would have been treated with approximately 66 – 96 g. Assuming an average house size of 100 m^2, the application rate would have been 0.7 – 1.0 g/m^2. No further information on the application procedure was provided.

Six 10 cm^2 gauze dosimeters were attached on each applicator's back and another 6 on the chest. The study authors did not state whether the dosimeters were on the inside or the exterior of the protective coat. A filter (size unspecified) was placed within the respirator to collect airborne dichlorvos. Dichlorvos residue on the dosimeters and respirator filter was "immediately" extracted in n-hexane and analysed by GC. The LOD was not given.

Blood was drawn from each volunteer before treatment, at the end of the day's work and on the following morning. Analysis of haematology and serum biochemistry (including ChE activity, by the pH method of Lee & Serat [1977]) was performed. Urine was collected overnight before treatment, throughout the day of treatment, and overnight after treatment. Urinalysis including assay for DMP (LOD: 25 ng/L) was carried out.

Results

At the end of the day's work, the mean dichlorvos residue level on the back dosimeters was 0.082 $\mu g/cm^2$ (Range: 0.021 – 0.181 $\mu g/cm^2$), while the corresponding level on the chest dosimeters was 0.044 $\mu g/cm^2$ (Range: 0.017 – 0.092 $\mu g/cm^2$). The mean dichlorvos residue level on the respirator filters was 1.088 $\mu g/cm^2$ (Range: 0.286 – 2.922 $\mu g/cm^2$).

"No appreciable changes" were seen in serum biochemistry (including ChE) or clinical urinalysis. One applicator excreted 1.39 µg DMP in the urine up to 3 hours post-treatment and a further 0.74 µg between 3 and 6 hours post-treatment. No data were obtained subsequently. Two further volunteers excreted 0.40 and 0.32 µg, respectively, by 3 h post-treatment. In one of these latter cases, no further DMP was detected in urine voided between 3 and 6 hours post-treatment, while no data were obtained from the second.

Comment: The estimated application rates in this study are 3 - 5 times higher than those recorded in a similar study by Gold and Holcslaw (1984; see below). It is unclear whether the dichlorvos products were applied as a space spray, surface spray, or both techniques. It is also unknown whether dosimeters were changed after each house was treated or were left attached until the after the final house was treated. If the pads were placed on the exterior of the coat and the total surface area of the volunteers' clothing was 1.9 m^2, and dichlorvos residue levels averaged 0.06 $\mu g/cm^2$ across the entire body, an average of $(190)^2$ X 0.06 = 2166 µg dichlorvos would have been deposited. Based on the top-of-range data, assuming that the concentration of dichlorvos averaged 0.137 $\mu g/cm^2$, a worst-case estimate would be $(190)^2$ X 0.137 = 4928 µg total deposit. Therefore, the worst-case rate of dermal exposure would have been 4928 ÷ 0.263 = 18 736 µg dichlorvos/kg applied. However, these values may be underestimates because dosimeters were not placed on the hands, arms and legs. These areas may have been more heavily contaminated than the chest and back, depending on the application methods used. Furthermore, the study authors appear not to have corrected their results for losses of dichlorvos from dosimeters through volatility or other causes.

Since the area of the respirator filters is unknown, the results presented do not give any direct indication of the potential inhalation exposure of the volunteers to dichlorvos. Using a conservative estimate of 100 cm^2 filter size, and assuming 100% capture efficiency with no subsequent loss of dichlorvos, the average potential inhalation exposure would have been approximately 109 µg, with a worst-case estimate of 292 ug, based on top-of-range data. Therefore, the rate of inhalation exposure would have been approximately 292 ÷ 0.263 = 1110 µg dichlorvos/kg applied.

Gold RE & Holcslaw (1984) Dermal and respiratory exposure of applicators and residents to dichlorvos-treated residences. In: Dermal exposure related to pesticide use: discussion of risk assessment (RC Honeycutt, G Zwerg & N Ragsdoleet eds). American Chemical Society Symposium Series No. 273.

And

Gold RE et al (1984) Dermal and respiratory exposure to applicators and occupants of residences treated with dichlorvos (DDVP). J Econ Entomol 77; 430 – 436

Materials and Methods

Two applicators were monitored for their exposure to dichlorvos during the treatment of 20 single-family residences in Nebraska, USA with a 0.5% (5 g/L) water-emulsion spray prepared from Vaponite 2EC (24.7% or approximately 250 g dichlorvos/L). The spray mixture was applied with a 3.8 L hand sprayer fitted with a multitip nozzle set to deliver a fine fan spray. The application rate was 0.19 g dichlorvos/m^2 (38.7 mL spray mixture/m^2) and the average residence size was 103$\pm$33 m^2. Therefore, the average amount of dichlorvos applied to each residence was 19.6 g. The mean time taken to treat each residence was 26 minutes. Temperature and humidity were 26.1°C and 82%, respectively. The spray was applied as a continuous band along the baseboards, doorways, windows, all entrances, under the sink, stove and refrigerator, shelves, cabinets and around plumbing and utility installations.

Applicator one treated 7 houses over a 7 hour period, while applicator two treated the remaining 13 over a period of 56 hours (approximately 3 working days). Both applicators wore a long-sleeved polyester jumpsuit, hard hat, respirator and rubber gloves. Dermal exposure pads were fitted on the clothing and the skin beneath the clothing at the following sites: head (under the top of the hard hat), forearm (above the wrists), leg (above the ankle), upper chest and back. Following pesticide application, exposure pads were removed and stored frozen to reduce volatilisation and degradation of dichlorvos. Each applicator washed their hands in ethanol:water (50:50), with this wash kept for analysis. Inhalational exposure was monitored using a personal air pump fitted with an impinger filled with water:ethylene glycol (5:15). Data from respiratory monitoring were expressed in terms of µg/L air, calculated by dividing the amount of dichlorvos in the impinger by the length of application time and pumping rate.

Blood and urine samples were collected from the applicators prior to treatment and then at 7 and 30 h for applicator one, and at 8, 24, 30, 48 and 56 h for applicator two. Following acetone extraction (dermal exposure pads), dichloromethane extraction (personal air pump and hand wash samples) or hexane extraction (urine), dichlorvos was analysed by GC. Plasma and RBC ChE activities were measured in blood samples. Following derivatisation and extraction, dichloroacetic acid (a metabolite of dichlorvos) was measured in urine by GC.

Results

Average dermal exposure was 0.499$\pm$0.274 µg/cm^2/h (Range: 0.110 – 0.988) according to the exposure pads fitted to the clothing, 0.102$\pm$0.062 µg/cm^2/h (Range: 0.026 – 0.125) for the exposure pads fitted to the skin under the clothing and 0.024$\pm$0.021 µg/cm^2/h for the hands (Range: 0.004 – 0.064). These findings indicate approximately 20% penetration of dichlorvos through the clothing. Exposure was heaviest on the legs, feet, thighs and trunk (front and back). Although it is apparent that dichlorvos also penetrated through the rubber gloves, the extent is unknown as the amount of dichlorvos on the outside of the gloves was not measured. However, dichlorvos was detected on the applicators' hands after each of the 20 applications. Dichlorvos was detected in the applicators' breathing zone atmosphere at a mean concentration of 21±19 $\mu g/m^3$ (Range: 4.0 – 64 $\mu g/m^3$).

Detailed data from one of the applicators were provided, and are summarised below. His total dermal exposure was 2.354 mg/h (or 0.028 mg/kg bw/h, adjusting for his bodyweight of 84 kg). Inhalation exposure was estimated at 0.037 mg/h or 0.0004 mg/kg bw/h.

Exposure of pest control operator during hand spray application of dichlorvos

Body part	Exposure rate (mg/h)	Exposure (mg) assuming 3.5 h spraying time
Head (includes face + throat + back of neck)	0.561	1.964
Body (under overalls)	1.771	6.199
Hands (under gloves)	0.022	0.077
Total dermal exposure	2.354	8.239
Inhalation exposure	0.037	0.129
Total dermal + inhalation exposure	2.391	8.369

Applicator one was reportedly forced to stop applying dichlorvos after 7 hours due to illness, with the nature of this illness unconfirmed although "pesticide poisoning" could not be discounted. He had a 59% reduction in plasma ChE activity at 7 hours post-treatment and an 18% reduction at 30 hours. However, by comparison with the pre-exposure value, his RBC ChE activity was increased by 55 and 37% at 7 and 30 hours, respectively. Applicator two had a 21% reduction in plasma ChE activity at 8 hours, no inhibition at 24 hours and 5.5% reduction at 30 hours, after which activity returned to the baseline level. His RBC ChE activity declined progressively by 15% over the 56-hour study period. No dichloroacetic acid was detected in the urine of either applicator.

Conclusions: This study suggests that toxicologically significant exposure of applicators can occur during the mixing/loading and application of dichlorvos by surface spray in enclosed spaces. Although this study has only a limited number of observations, it provides fairly detailed information on the use of and exposure to dichlorvos in a typical PCO situation, and may be used for risk assessment purposes.

Comment: Applicator one was exposed for approximately 3.5 hours over a single day, during which he would have applied 137 g dichlorvos in 27.9 L spray mixture, requiring 7 tank mixes to be performed. Based on the study authors' estimates, his dermal dose of dichlorvos would have been approximately 0.098 mg/kg bw. Applicator two was exposed for approximately 5.6 hours over 3 days, applied 254 g dichlorvos in 51.8 L spray mixture (13 – 14 tank mixes), and would have received a mean dermal dose of approximately 0.05 mg/kg bw/d.

The rate of whole-body dermal exposure for the operator who treated 7 houses would have been approximately 2.354 X 3.5 ÷ 0.137 = 60.1 mg dichlorvos/kg applied. The rate of head exposure would have been 0.561 X 3.5 ÷ 0.137 = 14.3 mg dichlorvos/kg applied. For the hands, the rate of exposure would have been 0.022 X 3.5 ÷ 0.137 = 0.56 mg dichlorvos/kg applied. Therefore, the rate of body exposure would have been 60.1 – 14.3 – 0.56 = 45.3 μg dichlorvos/kg applied. The study authors appear not to have corrected their results for losses of dichlorvos from the dosimeters through volatility or other causes. Hence, dermal exposure may have been underestimated, albeit to an unknown extent.

In the absence of any respiratory protection, the operator would have been exposed at a rate of 37 X 3.5 ÷ 0.137 = 945 μg dichlorvos/kg applied. At the highest measured concentration of 64 $\mu g/m^3$, the potential inhalation exposure rate would have been 64 X 3.5 ÷ 0.137 = 1635 μg dichlorvos/kg applied, assuming a ventilation rate of 1.0 m^3/h.

Hayes AL et al (1980) Assessment of occupational exposure to organophosphates in pest control operators. Am Ind Hyg Assoc 41; 568 - 575

Materials and methods

A study was conducted on the occupational exposure of pest control company employees to three OP pesticides: dichlorvos, diazinon and chlorpyrifos. The company was located in Houston, TX, USA and consisted of 22 male PCOs, 3 female secretaries, and a supervisor, salesman and a manager. The PCOs normally worked with a spray emulsion prepared from Dursban-E2 (23.5% active) and Vaponite E-2 (23% active), containing 4.4 g chlorpyrifos and 2.6 g dichlorvos/L water. The spraymix was applied to cracks, crevices and baseboards in and around structures. Structures having attics were dusted mechanically with Diazinon 2D dust (2% active). No further information on the use pattern was provided. Treatment rates per unit area were not given and it was not stated whether the PCOs wore PPE.

Breathing zone air samples were collected from 14 of the PCOs throughout their 8-hour work shift. The PCOs wore a calibrated battery-operated pump drawing air through a Sep-Pak C_{18} cartridge which had been primed before use with 10 mL 1:1 acetone:hexane and 5 mL pentane and then purged with nitrogen. After sampling, the cartridges were stored at -20 ^{o}C and assayed by GC. Cartridges “spiked” with known quantities of each pesticide were also assayed. The mean recoveries were 89% for dichlorvos, 84% for diazinon and 88% for chlorpyrifos. The LOD was stated to be 30 µg OP/L. Air samples were also obtained from 3 office staff, 2 control offices at the study laboratory, and 2 treated houses, where stationary pumps were run for 8 hours in places where pesticide application was concentrated. However, no further details were provided. Two or 3 air samples were obtained from each PCO or office staff member who participated in the study. Only data on dichlorvos will be presented in this evaluation.

The study group was also monitored for plasma and RBC ChE activity and urinary excretion of the OP metabolites 0,0-dimethyl,0-amyl phosphate (DMP; a metabolite of dichlorvos and diazinon), 0,0-dimethyl,0-amyl phosphorothionate (DMTP; a metabolite of diazinon) and 0,0-dimethyl,0-amyl phosphate and 0,0-diethyl,0-amyl amyl phosphorothionate (metabolites of chlorpyrifos). However, given that none of these metabolites was unique to dichlorvos, and that ChE inhibition would have occurred in response to all the OPs applied, these aspects of the study will not be considered further.

Results

Over the 8-hour workday, the mean concentration of dichlorvos in the PCOs’ breathing zone air ranged between 4.1 and 131 µg/m^3, and the average mean concentration was 34.8 µg/m^3. The supervisor was exposed to a mean of 15.8 µg dichlorvos/m^3, while the corresponding values for a secretary and the manager were 10.8 and 12.4 µg/m^3, respectively. Environmental sampling conducted in the treated homes showed an average airborne dichlorvos concentration of 124 µg/m^3, while levels in the control locations were below the LOD. Four of the PCOs reported headaches and most stated that they experienced aggravation of nasal or respiratory problems, which they attributed to exposure to the pesticides.

Comment: In the absence of any respiratory protection, the potential dichlorvos intake via inhalation at the average mean atmospheric concentration would have been 34.8 µg/m^3 X 1.0 X 0.7 = 0.024 mg/h, assuming a ventilation rate of 1.0 m^3/h and 70% absorption. At the highest mean concentration measured, the potential intake would have been 131 µg/m^3 X 1.0 X 0.7 = 0.091 mg/h. An adult exposed for 8 h to the mean dichlorvos level detected in the air of the treated homes would have a respiratory intake of 124 µg/m^3 X 8 X 1.0 X 0.7 = 0.69 mg, or a dose of 0.010 mg/kg bw.

6.2 Estimation occupational exposure and risk

Estimates of occupational exposure to and of risk from dichlorvos have been prepared utilising the results of the exposure studies evaluated in Section 6.1, together with exposure modelling to cover situations for which no experimental data are available. Appropriate adjustments are made for the dilution rates, application rates and use patterns specified by the labels of Australian products. The following assumptions have been applied:

List of assumptions used in exposure and risk assessment

Bodyweight	70 kg	US EPA (1996)
Body surface area (adult)	1.94 m^2	Derelanko (2000)
Ventilation rate (light activities)	1.0 m^3/h	US EPA (1996)
Normal workday	8 h with an application period of 6 h	
Average size of house	Area 170 m^2 Volume 430 m^3	
Average size of greenhouse	Area 150 m^2 Volume 375 m^3	
Average industrial building	Area 2500 m^2 Volume 12 500 m^3	
Average office building	Area 7500 m^2 Volume 18 000 m^3	
Penetration through overalls	20%	Gold & Holsclaw (1984)
Penetration through chemical-resistant full body clothing	5%	Thongsinthusak et al (1993)
Penetration through chemical-resistant gloves	10%	Thongsinthusak et al (1993)
Protection afforded by half face-piece respirator with gas/dust cartridges	90%	Thongsinthusak et al (1993)
Protection afforded by full face-piece respirator with gas/dust cartridges	98%	Thongsinthusak et al (1993)
Protection afforded by supplied air respirator (air-hose respirator or SCBA)	100%	
Container neck width	Narrow	

The situations of use for which exposure and risk estimates have been prepared are as follows:

Scenario (1) Application of 50 LD/CO_2 formulation as a space spray
Scenario (2) Mixing and loading 1140 & 500 EC formulations and mechanical application to grain
Scenario (3) Application of 500 EC formulation as a surface spray
Scenario (4) Indoor application of 500 EC formulation as a space spray
Scenario (5) Indoor application of 500 EC formulation as a fog or mist
Scenario (6) Outdoor application of 500 EC formulation by space spray, fog or mist
Scenario (7) Application of 500 EC formulation by the wooden board method
Scenario (8) Application of 500 EC formulation by watering can
Scenario (9) Application of 500 EC formulation as a liquid bait
Scenario (10) Application of 500 EC formulation to wasp & bee nests
Scenario (11) Application of 500 EC formulation to avocados
Scenario (12) Application of 250 EC formulation with 225 g/L chlorpyrifos
Scenario (13) Application of 7 LD formulation with 1 g/L pyrethrins as a surface spray
Scenario (14) Veterinary administration of 100 PA with 200 g/kg oxibendazole

Scenario 1: Application of 50 LD/CO_2 formulation as a space spray

There is a single pressurised gas product, Insectigas-D DDVP Insecticide, containing 50 g dichlorvos/kg in carbon dioxide. It is available in 6 and 31 kg cylinders for control of arthropod pests in industrial and domestic premises, stored product facilities (including farm machinery and silos), greenhouses, farm machinery, storage bins and wasp nests. Insectigas-D is also used in mushroom houses and in plant fumigation chambers, although these uses are not included on the product label. The product is for professional use only, and is applied as a space spray using a manual pressure gun or via a fixed installation, which may be operated using a manual or programmed time release. Indoor areas are to be closed and air movement minimised for 4 hours during treatment. No mixing is required prior to use. An application rate of 200 g product/300 m^3 [equivalent to 10 g dichlorvos/300 m^3 or 33 mg/m^3] is recommended for all situations. This amount of product is discharged in 70 seconds when using the manual BOC Gases kit 416651 and 736685 nozzle. Discharging an entire 6 kg cylinder would take 35 minutes and would be sufficient to treat a volume of 9000 m^3. A 31 kg cylinder would treat 46 000 m^3. When using the manual pressure gun, operators are directed to work away from spray drift and towards the exit, and avoid wetting any surfaces with the spray produced. Wasp nests are treated by directing the nozzle into the cavity or nest. According to a survey respondent, Insectigas-D is used at a higher application rate of 64 mg/m^3 in plant fumigation chambers, in conjunction with pyrethrin at 5.2 mg/m^3.

Indoor application using manual pressure gun

Operators are expected to use a 6 kg cylinder in conjunction with a pressure regulator and nozzle, which would probably be held at chest or head height as the operator moves through the treated building. Once ejected from the nozzle, volatilisation of dichlorvos would be almost instantaneous and complete. It is anticipated that operator exposure would arise principally from inhalation, with some additional exposure via the dermal route.

Dermal exposure: No studies measuring the exposure of persons applying dichlorvos by manual CO_2 pressure gun are available for evaluation. Because there is no need to handle and dilute a liquid concentrate, the presentation of dichlorvos in pressure cylinders reduces the potential for dermal exposure. Nevertheless, dermal exposure may occur through precipitation of dichlorvos from the effluxive stream or the vapour phase onto the operator's body or clothing, particularly if the building design requires the operator to traverse areas already treated. In the absence of exposure data, the POEM and PHED exposure models were examined to ascertain whether they could assist in estimating dermal exposures in this situation. POEM is unsuitable, as its exposure estimates are derived from the volume of spray mixture contaminating the skin and clothing. However, PHED may be used, as it provides estimates of dermal exposure from hand-held apparatus, expressed in terms of mg exposure/unit mass of active constituent handled. High pressure handwand application caused the lowest exposure. The respective amounts on the head/neck, exterior of clothing and hands were 0.184, 26.8 and 2.55 mg/kg active handled, for a total of 29.5 mg/kg active handled.

The efflux from a manual pressure gun is expected to be significantly less diffuse and more directional than from a high pressure handwand sprayer. Hence, dermal exposure while using a pressure gun is expected to be lower than using a high pressure handwand. The following estimates of dermal exposure have been prepared assuming that exposure from a pressure gun is 10% of that from a high pressure handwand (ie. 0.018, 2.68 and 0.26 mg/kg active handled, for a total of 2.95 mg/kg active handled). It is assumed that dichlorvos penetration is 20% through overalls (based on experimental data from Gold & Holcslaw, 1984) and 10% through gloves (a value higher than the PHED estimate has been used because the physico-chemical properties of dichlorvos suggest it will penetrate through gloves more readily than will most other pesticides). The exposure estimates are based on an operator treating 8 domestic residences, 10 greenhouses, 2 industrial buildings or 2 office buildings. These work rates have been chosen to represent the greatest number of fumigation operations likely to be performed in a single day. Unacceptable MOEs are highlighted. It is apparent that overalls alone would limit dermal exposure from treatment of several small buildings to acceptable levels. However, chemical resistant clothing and gloves would be necessary to assure adequate protection of operators treating larger structures.

Application of dichlorvos 50 LD/CO_2 – dermal exposure from manual pressure gun

Structures treated	**Total volume (m^3)**	**Active applied (kg)**	**Exposure (mg)**	**Dose (mg/kg bw) MOE relative to 0.047 mg/kg bw**			
				Protective clothing			
				None	**Overalls**	**Overalls + Gloves**	**Chem resistant clothes + gloves**
8 Houses	3440	0.115	0.34	0.00486 MOE= 9.7	0.00134 MOE= 35	0.00095 MOE= 49	0.00029 MOE= 160
10 Green-houses	3750	0.126	0.37	0.00529 MOE= 8.9	0.00147 MOE=32	0.00104 MOE= 45	0.00032 MOE= 150
2 Industrial buildings	25 000	0.838	2.47	0.0353 MOE= 1.3	0.00976 MOE= 4.8	0.00692 MOE= 6.8	0.0021 MOE= 22
2 Office buildings	36 000	1.21	3.58	0.0512 MOE= 0	0.0147 MOE= 3.2	0.0104 MOE= 4.5	0.0032 MOE= 15

Operators may also be exposed to dichlorvos when changing cylinders, through contact with small amounts of liquid dichlorvos deposited in the connector fittings or on the nozzle. Even if exposure from this source was limited to 0.001 mL/cylinder used (equivalent to 0.0014 g, as the relative density of dichlorvos is 1.425), it would be significant from a toxicological viewpoint without hand protection or where multiple cylinder changes are required. This is illustrated in the following table (a single cylinder change when treating multiple houses/greenhouses has been assumed).

Application of dichlorvos 50 LD/CO_2 – hand exposure from cylinder changing

Structures treated	Cylinders used	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.047 mg/kg bw	
			Hand protection	
			None	Gloves
8 Houses	1	1.4	0.020 MOE= 2.4	0.002 MOE= 24
10 Green-houses	1	1.4	0.020 MOE= 2.4	0.002 MOE= 24
2 Industrial buildings	3	4.2	0.060 MOE= 0	0.006 MOE= 7.8
2 Office buildings	4	5.6	0.08 MOE= 0	0.008 MOE= 5.9

Inhalation exposure: Neither POEM nor PHED provide a suitable model for estimating inhalation exposure during use of a manual pressure gun because of the high volatility of dichlorvos. Nevertheless, it is possible to infer the potential for inhalation exposure from the recommended application rate and the length of time it would take an operator to treat the types of premises in which use of the product is registered.

Operators would probably hold the nozzle at chest or head height as they move through the treated building. Once ejected from the nozzle, volatilisation of dichlorvos would be almost instantaneous and complete, and the atmospheric concentration of dichlorvos would increase rapidly. Provided the operator did not walk through the effluxive stream, the highest airborne concentration of dichlorvos to which they would be exposed would be 33 mg/m^3. However, this concentration would be attained only at end of application. When treatment commenced, the airborne concentration of dichlorvos would be zero. Therefore, operators would probably be exposed to dichlorvos at a TWA concentration of 16.5 mg/m^3 while fumigating an enclosed space. The duration of exposure may be estimated by using the manufacturer's specification for the manual pressure gun (70 sec/300 m^3) except for domestic residences, for which a duration of 5 min/structure is probably more realistic, given their more complex layout.

In the following table, estimates of inhalation exposure have been prepared for an operator treating 8 domestic residences, 10 greenhouses, 2 industrial buildings or 2 office buildings. These work rates have been chosen to represent the greatest number of fumigation operations likely to be performed in a day. The scenarios for which the estimated inhalation MOE is unacceptable (< 10) are highlighted (for clarity, MOE values < 1.0 are shown as zero). For all scenarios except greenhouse fumigation, inhalation MOEs are unacceptable even with a full facepiece respirator. Otherwise, acceptable MOEs would only be achieved by use of an air-hose respirator or SCBA, which would entirely prevent inhalation exposure.

Indoor application of dichlorvos 50 LD/CO_2 – inhalation exposure

Structures treated	Total volume (m^3)	Total duration (h)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.02 mg/kg bw			
				Respiratory protection			
				None	Half face	Full face	Air-hose
8 Houses	3440	0.67	11.1	0.158 MOE= 0	0.016 MOE= 1.3	0.003 MOE = 6.7	Nil MOE > 10000
10 Greenhouses	3750	0.25	4.13	0.059 MOE= 0	0.006 MOE=	0.001 MOE= 17	Nil MOE >

					3.3		10000
2 Industrial buildings	25 000	1.67	27.6	0.394 MOE= 0	0.039 MOE= 0	0.008 MOE= 2.5	Nil MOE > 10000
2 Office buildings	36 000	2.42	39.9	0.570 MOE= 0	0.057 MOE= 0	0.011 MOE= 1.8	Nil MOE > 10000

Aggregate exposure: The following table shows the aggregate MOEs for an operator wearing chemical resistant clothing, gloves and an air-hose respirator, calculated by the formula

1 ÷ (1/MOE inhalation + 1/MOE dermal [cylinder change] + 1/MOE dermal [application]).

The table also displays the maximum volume that could be fumigated without eroding the aggregate MOE below 10. It can be seen that although the MOEs for fumigation of domestic houses and greenhouses are acceptable and would support a higher work rate than has been assumed, the MOEs when treating large structures are unacceptable. Operators could treat up to approximately 15 000 m^3 of industrial or office space or 7000 m^3 of domestic housing or greenhouses. The maximum permissible volumes of domestic housing and greenhouse space are markedly lower than for other applications because of the number of cylinder changes assumed in the exposure estimates. It should be noted that the MOEs for all situations would decrease to unacceptable levels (1.3 - 9.3) if respiratory protection were downgraded from an air-hose respirator/SCBA to a full facepiece respirator (data not shown).

Indoor application of dichlorvos 50 LD/CO_2 – aggregate dermal and inhalation exposure

Structures treated	Total volume (m^3)	Total duration (h)	Active applied (kg)	Aggregate MOE	Maximum treatment volume (m^3) for MOE $\geq$ 10
8 Houses	3440	0.67	0.115	21	6880
10 Greenhouses	3750	0.25	0.126	21	7500
2 Industrial buildings	25 000	1.67	0.838	5.8	14 250
2 Office buildings	36 000	2.42	1.21	4.2	15 120

Conclusions: There is scope for toxicologically significant dermal and inhalation exposure to dichlorvos when applying the 50 LD/CO_2 product with a manual pressure gun in enclosed spaces, even with PPE comprising elbow length butyl rubber gloves, chemical resistant clothing and an air-hose respirator/SCBA. Although several comparatively small structures could be treated without eroding the MOE to unacceptable levels, the maximum volume treated would be limited to about 15 000 m^3. However, it is considered impractical to impose any such limit on users. Therefore, indoor manual application of dichlorvos 50 LD/CO_2 products to buildings and other structures should be discontinued.

Indoor treatment using fixed installations

Dermal exposure: Application of Insectigas-D through fixed installations will cause markedly less dermal exposure than manual application. Under most reasonably foreseeable circumstances, the operator would not need to enter the space during fumigation, and exposure would be limited to manual contact with dichlorvos when changing cylinders. As 31 kg cylinders (sufficient to treat 46 000 m^3) would probably be used for fixed installations, it is unlikely that PCOs would need to change more than 1 or 2 cyliners/day. Operators of fumigation chambers may need to perform only a few cylinder changes per year. However, it is important to note that despite the relevant FAISD Handbook entry stating that gloves and overalls should be worn "when opening the container", the safety directions shown on the label for this product specify PPE only "when using in enclosed areas". Operators following these directions are unlikely to wear gloves when changing cylinders, and could be exposed at the unacceptable margin of 2.4 when performing a single change. If gloves were worn, the dermal MOEs would be and 24 and 12 for 1 or 2 changes, respectively. In practice, the MOEs may be higher if the gloves were worn for only a short time during cylinder changes, limiting the opportunity for dichlorvos to penetrate through the material to the skin.

Inhalation exposure: Specialised fumigation chambers are gas tight and rooms within mushroom houses are sealed. Under normal conditions of use, there would be no inhalation exposure to dichlorvos when the cylinders are discharged into these spaces. Although it is improbable that completely gas tight entrances would be fitted to warehouses, mills, silos and other structures where fixed installations are present, operators are unlikely to remain in the vicinity for any significant time after releasing dichlorvos from the pressure cylinder. There would be no opportunity for exposure in situations where an automatic release system was employed.

As discussed previously, a small amount of liquid dichlorvos may be present within the cylinder fittings and connections. If so, it would evaporate into the atmosphere when a cylinder is removed. If a 0.005 mL quantity of dichlorvos (weighing 7.1 mg) evaporated into the 1 m^3 personal air space around an operator's breathing zone, and the operator was exposed for 1 minute, they would inhale 0.12 mg dichlorvos. The inhalation dose would therefore be 0.0017 mg/kg bw. Relative to the inhalation NOEL of 0.02 mg/kg bw, the MOE would be 11.8 for an unprotected person and 118 if a half facepiece respirator was worn.

Aggregate exposure: The aggregate dermal and inhalation exposure for operators has been based on the assumption that other than changing cylinders, there is no exposure when applying dichlorvos via fixed installations. For a single cylinder change, the aggregate MOE for an operator wearing gloves but no respiratory protection is 8.0, and is unacceptable. If gloves and a half facepiece respirator were worn, the MOE would increase to 19.9. This is sufficiently high to support 2 cylinder changes/day, for which the MOE would be 10.

Conclusions: Application of dichlorvos 50 LD/CO_2 products via fixed installations is supported, provided operators wear PPE comprising elbow length butyl rubber gloves, overalls and a half facepiece respirator with combined gas/dust cartridge when changing cylinders.

Manual treatment of grain storage containers

Registered uses for Dichlorvos 50 LD/CO_2 products include fumigation of grain storage silos and bins. Grain storage containers may be treated on a regular basis to prevent infestation, or sporadically in response to a pest outbreak. To treat bins and small on-farm silos, operators would probably use a 6 kg cylinder in conjunction with a manual pressure gun, which would be discharged into the opened silo valve or bin for sufficient time to achieve the target concentration of 33 mg dichlorvos/m^3 air space. Treated containers would then be closed immediately. There is little information upon which to base an estimated daily work rate for this activity, as the volume of air space requiring treatment would depend on the size, design and number of silos or bins fumigated and the volume of grain they contained. Treated air space volumes could range from a few hundred to several thousand m^3. Consequently, the OCS has based exposure estimates on a very high work rate of 9000 m^3/day with different combinations of PPE, and estimated the maximum volumes that could be treated to maintain acceptable levels of exposure.

Dermal exposure: The extent of dermal exposure while discharging the pressure gun would be similar to the value estimated for indoor manual application, ie. 0.018, 2.68 and 0.26 mg/kg active handled for the head/neck, body and hands, respectively, for a total of 2.95 mg/kg active handled. The extent of dermal exposure when changing cylinders will remain at 1.4 mg/operation, which is assumed to contaminate only the hands. Exposure estimates for an operator treating 9000 m^3 air space with 300 g dichlorvos and performing 1 cylinder change are shown in the following table. To achieve an acceptable MOE, a minimum of overalls and gloves would be required.

Manual application of dichlorvos - grain container treatment – dermal exposure

Source of dermal exposure	Exposure (mg)	Dose (mg/kg bw)			
		Protective clothing			
		None	Overalls	Overalls + Gloves	Chem resistant clothes + gloves
Application	0.89	0.0126	0.00378	0.00251	0.00079
Cylinder change	1.4	0.020	0.020	0.002	0.002
Total dermal dose (mg/kg bw)	-	0.0326	0.02378	0.00451	0.00279
MOE relative to 0.047 mg/kg bw		1.4	2	10	17

Inhalation exposure: If an operator discharging Insectigas-D into a grain bin or on-farm silo would not have to enter the fumigated air space, inhalation exposure would be significantly less than estimated for indoor application. Even if grain bins were located within a building (such as a bulk handling facility or mill), the concentration of dichlorvos in the operator's breathing zone is unlikely to exceed 3.3 mg/m^3, ie. 10% of the target concentration within the treated container. The table below shows exposure estimates for an operator treating 9000 m^3 of container air space with 300 g dichlorvos, an activity which would take 35 minutes. It can be seen that the MOEs without respiratory protection or with a half-facepiece respirator are unacceptable. To achieve a MOE $\geq$ 10, a full facepiece respirator would be required.

Manual application of dichlorvos – grain container treatment – inhalation exposure

Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.02 mg/kg bw			
	Respiratory protection			
	None	Half face	Full face	Air-hose
1.92	0.0275 MOE = 0	0.00275 MOE = 7.3	0.00055 MOE = 36	Nil MOE > 10000

Aggregate exposure: From the above tables, the MOE for an operator treating 9000 m^3 of air space wearing PPE comprising a full facepiece respirator, gloves and overalls would be 7.8. A maximum of 7000 m^3 air space volume could be fumigated to ensure the MOE did not fall below the acceptable value of 10. If a full facepiece respirator and gloves were combined with chemical resistant clothing, the MOE after treating 9000 m^3 air space would be 12. Up to approximately 11 000 m^3 air space could be treated before the MOE declined below 10.

Conclusions: Provided that operators do not enter the spaces being treated, manual application of dichlorvos 50 LD/CO_2 products to air space within grain bins, silos and similar sealed storage containers is supported provided operators wear PPE comprising elbow length butyl rubber gloves, chemical resistant clothing and a full facepiece respirator. It is important to note that this conclusion does not apply to fumigation of bulk storage silos or other situations which would require entry into the structure under fumigation.

Miscellaneous outdoor uses

Dichlorvos 50 LD/CO_2 products may be used to fumigate farm machinery and eradicate wasp nests in defined or confined spaces. These activities would probably occur outdoors on an *ad hoc* basis, and are unlikely to take longer than 30 minutes in any single day. The extent of operator exposure per unit mass of dichlorvos applied would be similar to exposure when treating storage containers. Hence, farm machinery and insect nest fumigation are supported, provided operators wear PPE comprising elbow length butyl rubber gloves, chemical resistant clothing and a full facepiece respirator.

Scenario 2: Mixing and loading 1140 & 500 EC formulations and mechanical application to grain

Bulk grain storage/handling facilities and millers use dichlorvos for disinfesting lightly infested grain, which may be treated as it arrives at the storage facility, during storage, or at outturn. Treatment usually occurs during the second half of the storage period, some weeks or months after harvest. One State grain handling authority anticipated that 550 000 tonnes of grain would be treated with dichlorvos annually, although this would constitute only a minor proportion of the total volume grain stored or handled. The usual application method is as a coarse spray via mechanical equipment directly onto grain on the auger/conveyor. Grain applicator equipment operators may work for up to 12 h/d, 7 d/wk over the harvest period of about 2 months. Mixing times during this period may occupy up to 1 h/d. Under normal operating conditions, workers are exposed to the chemical only during mixing and loading of spray tanks (which is done by open pour), because they do not need to be present during spray application and are unlikely to make contact with treated grain.

There is wide variation in estimates of how much grain would be treated with dichlorvos per day. Some large facilities may use up to 50 L of the concentrate in a single day, for between 1 and 10 individual days each year[3]. (A 50 L volume of the 1140 EC product is sufficient to treat 5000 – 10 000 tonnes of grain, depending on application rate.) However, other operators use equipment with markedly less capacity. One survey respondent indicated that their auger uptake of grain is 60 te/h, but in practice lower amounts of grain would actually require treatment. Their total use of dichlorvos was less than 1 L/y. If an 1140 EC product was involved, a 1 L volume would be sufficient to treat approximately 100 tonnes of grain at the highest label rate of 12 g dichlorvos/te.

Based on information from product labels, the APVMA Agriculture Report and information received from the grain handling industry, estimates of exposure have been prepared on the assumption that operators are exposed only during the mixing/loading phases of disinfestation procedures, and treat grain at the highest label rate of 12 g dichlorvos/te.

Dermal exposure: None of the available studies on operators using dichlorvos provides data on exposure through mixing/loading, as distinct from exposure through application. The POEM model is optimised for broadacre spraying scenarios, and is unsuitable for predicting mixer/loader exposure where the daily work rate is not expressed in hectares. However, PHED has algorithms for predicting exposure of mixer/loaders handling liquids by open pour and closed pour methods. PHED model 3 (open pour) predicts a total dermal exposure of 6.92 mg/kg active handled, of which head, body and hand contamination comprise 0.0116, 0.6622 and 6.248 mg/kg active handled. Dermal exposure levels, doses and MOEs at work rates of 10 – 1000 te grain/d are shown in the following table. It is noteworthy that at work rates of 100 or 1000 te/d, the MOEs would be unacceptable even if the operator wore chemical resistant clothing and gloves. A minimum of overalls and gloves would be required to protect an operator preparing sufficient spraymix to treat 10 tonnes of grain.

Grain treatment - open pour mixing/loading dichlorvos 1140 & 550 EC – dermal exposure

Tonnage of grain treated	Active applied (kg)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.047 mg/kg bw			
			Protective clothing			
			None	Overalls	Overalls + Gloves	Chem resistant clothes + gloves
10	0.12	0.8306	0.0119 MOE= 3.9	0.0110 MOE= 4.3	0.0013 MOE= 36	0.0012 MOE= 41
100	1.2	8.3062	0.1187 MOE = 0	0.1096 MOE = 0	0.0132 MOE = 3.6	0.0115 MOE = 4.1
1000	12	83.062	1.1866 MOE = 0	1.0958 MOE = 0	0.1318 MOE = 0	0.1148 MOE = 0

[3] GrainCorp submission to the OCS, February 2005.

According to PHED model 6, use of closed mixing/loading systems will reduce dermal exposure/kg handled by a factor of 2.7 relative to open pour methods. While a 2.7-fold reduction in dermal exposure would permit an unprotected operator to treat 10 te grain/d, the MOEs associated with treatment of 100 tonnes are unacceptable unless chemical resistant clothing and gloves were worn. Even with this level of PPE, the MOE would decline to 1.1 if 1000 tonnes were treated.

Grain treatment – closed mixing/loading dichlorvos 1140 & 550 EC – dermal exposure

Tonnage of grain treated	Active applied (kg)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.047 mg/kg bw			
			Protective clothing			
			None	Overalls	Overalls + Gloves	Chem resistant clothes + gloves
10	0.12	0.3076	0.0044 MOE= 11	0.0041 MOE= 12	0.00049 MOE= 97	0.00042 MOE= 111
100	1.2	3.0763	0.0439 MOE = 1.1	0.0406 MOE = 1.2	0.0049 MOE = 9.6	0.0042 MOE = 11
1000	12	30.763	0.4395 MOE = 0	0.4058 MOE = 0	0.0488 MOE = 0	0.0425 MOE = 1.1

Inhalation exposure: In the absence of relevant data, the POEM and PHED exposure models were examined for their suitability for predicting inhalation exposure of mixer/loaders. POEM does not enable such an estimate to be performed. PHED (model 3) predicts an inhalation exposure rate of 2.64 µg/kg active handled during mixing/loading by open pour. In practice, this rate will be significantly less than the rate of inhalation exposure to dichlorvos, due to its high volatility. The approximate magnitude of the underestimate can be gauged by comparing the top-of-range inhalation exposure rate measured by Gold and Holcslaw (1984) with the corresponding PHED value. The experimentally demonstrated exposure rate was 1635 µg/kg dichlorvos handled when operators mixed, loaded and applied a liquid product using low pressure hand sprayers. By contrast, PHED (models 32 and 34) predicts an inhalation exposure rate of 66 µg/kg active handled for operators mixing by open pour and applying with backpack or low pressure handwand sprayers. The experimentally derived exposure rate is therefore 25-fold higher than the PHED prediction for exposure using the same mixing and application methods. Given that the experimental data are derived from a single study, a conservative 50-fold factor will be applied to the PHED model 3 estimate of 2.64 µg inhaled/kg active applied, yielding a value of 132 µg/kg dichlorvos applied.

The following table displays estimated inhalation exposures from mixing/loading dichlorvos by open pour methods. MOEs at a work rate of 10 te/d are adequate in the absence of respiratory protection, but a half-facepiece respirator would be required to support treatment of 100 te/d, and treatment of 1000 te/d would be possible only if the operator wore a full facepiece respirator.

Grain treatment – open mixing/loading dichlorvos 1140 & 550 EC – inhalation exposure

Tonnage of grain treated	Active applied (kg)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.02 mg/kg bw			
			Respiratory protection			
			None	Half face	Full face	Air-hose
10	0.12	0.0158	0.00023 MOE= 88	0.00002 MOE= 880	0.000005 MOE= 4419	Nil MOE > 10 000
100	1.2	0.1584	0.00226 MOE = 8.8	0.00023 MOE = 88	0.000045 MOE = 442	Nil MOE > 10 000
1000	12	1.5840	0.0226 MOE = 0	0.00226 MOE = 8.8	0.000453 MOE = 44	Nil MOE > 10 000

The extent of inhalation exposure when using closed pour mixing/loading systems can be estimated from PHED model 6, which predicts an exposure of 0.1826 µg/kg active handled. This value is 14-fold lower than the corresponding exposure rate (from model 3) of 2.64 µg/kg active handled during mixing/loading by open pour. Inhalation exposure to dichlorvos when pouring and mixing in closed systems is therefore estimated at 132 ÷ 14 = 9.429 µg/kg active handled. Inhalation exposure estimates for an operator using closed mixing systems are shown in the following table. Even in the absence of respiratory protection, the MOEs are acceptable for work rates up to 1000 te/d, although a respirator would be required to support higher work rates.

Grain treatment – closed mixing/loading dichlorvos 1140 & 550 EC – inhalation exposure

Tonnage of grain treated	Active applied (kg)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.02 mg/kg bw			
			Respiratory protection			
			None	Half face	Full face	Air-hose
10	0.12	0.0011	0.000016 MOE= 1250	0.000002 MOE > 10000	0.0000003 MOE > 10000	Nil MOE > 10000
100	1.2	0.0113	0.00016 MOE = 125	0.000016 MOE = 1250	0.000003 MOE = 6250	Nil MOE > 10000
1000	12	0.1131	0.0016 MOE = 13	0.00016 MOE = 125	0.000032 MOE = 625	Nil MOE > 10000

Aggregate exposure: The following table displays the aggregate exposure for a mixer/loader treating 100 tonnes of grain at the high treatment rate of 12 g/te, using open pouring methods. This would involve handling 1.2 kg dichlorvos. The aggregate MOEs are not acceptable, even for an operator wearing chemical resistant clothing, gloves and a full facepiece respirator. For the MOE to be constrained to $\geq$ 10, a maximum of only 41 tonnes of grain could be treated in a single day by an operator wearing this level of PPE. Increasing the level of respiratory protection to an air-hose respirator or SCBA would not increase the aggregate MOE appreciably, given the predominance of dermal exposure (especially hand contamination) relative to inhalation exposure. If the grain were treated at the low rate of 6 g/te, the aggregate MOEs would double but remain unacceptable, and the maximum weight of grain that could be treated would rise to 82 te/d.

Grain treatment – open mixing/loading dichlorvos 1140 & 550 EC – aggregate exposure

PPE	Aggregate MOE at 100 te grain/d	Maximum weight of grain (te) that can be treated for MOE $\geq$ 10
Overalls, gloves, no respiratory protection	2.6	26
Overalls, gloves, half facepiece respirator	3.5	35
Overalls, gloves, full facepiece respirator	3.6	36
Chemical resistant clothing, gloves, full facepiece respirator	4.1	41

Use of enclosed mixing systems would increase the MOEs by approximately 3-fold and raise the maximum weight of grain that could be treated (at 12 g/te) to 110 te/d. Again, at the lower treatment rate of 6 g/te, there would be a doubling of the MOEs and maximum weight of grain that could be treated. However, these work rates are representative of small grain handling facilities only.

Grain treatment – closed mixing/loading dichlorvos 1140 & 550 EC – aggregate exposure

PPE	Aggregate MOE at 100 te grain/d	Maximum weight of grain (te) that can be treated for MOE $\geq$ 10
Overalls, gloves, no respiratory protection	9.0	90
Overalls, gloves, half facepiece respirator	9.6	96
Overalls, gloves, full facepiece respirator	9.6	96
Chemical resistant clothing, gloves, full facepiece respirator	11	110

Conclusions: Based on the available information, it is not possible to assure adequate protection of operators involved in grain disinfestation by mechanical spray. To maintain an aggregate MOE above the acceptable level of 10, operators wearing gloves, chemically resistant clothing and a full facepiece respirator can handle only approximately 1.3 kg of dichlorvos active in liquid products, even when using closed mixing/loading systems and without additional exposure during spray application. Given that operators at large sites may be required to handle up to 50 L of dichlorvos 1140 EC in a single day (equivalent to 57 kg dichlorvos), there is evident potential for exposure to toxicologically significant doses of dichlorvos during grain treatment operations. Therefore, this use of dichlorvos should be discontinued unless supported by suitable data, including exposure data derived from operators under field conditions.

Scenario 3: Application of 500 EC formulation as a surface spray

The 500 EC dichlorvos products may be applied by surface spray in a variety of indoor situations, including domestic houses, dairies, cattle sheds, animal houses and pens, meatworks, abattoirs, wineries and wheat silos. Recommended dilution rates range from 1 g dichlorvos/L water (for use in animal housing and meatworks) up to 6 g/L (in houses). Application rates, where present on product labels, vary between 0.03 and 0.2 g/m^2.

Application in domestic houses

Dichlorvos 500 EC products are diluted to a concentration of 6 g/L and are applied by spray against flying and crawling insects, spiders and silverfish. None of the product labels nominates a specific application rate per unit area. However, rates of up to 0.2 g dichlorvos/m^2 are used for surface spray treatment of animal housing, meatworks and wineries, and PCOs used a rate of 0.19 g/m^2 in houses in the study of Gold and Holcslaw (1984). A rate of 0.2 g/m^2 will therefore be assumed. PCOs are most likely to use a hand-held sprayer, a knapsack sprayer, or a handwand supplied via a hose from a vehicle-mounted spray tank and pump.

Although 3 published studies have measured PCO exposure to dichlorvos during treatment of domestic housing [Das et al (1983), Gold and Holcslaw (1984) and Hayes at al (1980)], 2 of these are not highly suitable for use in this exposure assessment. Hayes et al (1980) did not provide sufficient information on treatment methods, and measured only the concentration of dichlorvos in the operators' breathing zone air. In the study of Das et al, a very high application rate (up to 1.0 g/m^2) was used, dichlorvos was applied mainly from aerosol cans, and it is unclear whether the dermal dosimeters were placed inside or outside the applicators' clothing. However, Gold and Holcslaw's operators used hand spray equipment and their paper described application methods and operator exposure in the greatest detail. It is therefore considered to be the most relevant and highest quality PCO study assessed, notwithstanding the fact that the data are based on a small number of observations.

Dermal exposure: Exposure has been estimated for a PCO treating 1 or 6 average-sized houses (total area: 170 or 1000 m^2) in a single working day, an activity which would require application of 33 or 200 g dichlorvos. The assessment will assume that the respective rates of dermal exposure on the body, head and hands ***under overalls and gloves*** will be those measured by Gold and Holcslaw, ie, 45.3, 14.3 and 0.56 mg dichlorvos/kg applied. The total dermal exposure will be 60 mg dichlorvos/kg applied. From the following table, it is clear that if gloves and overalls or chemical resistant clothing were worn, the dermal MOE would be unacceptable for treatment of even a single house.

Indoor surface spray application of dichlorvos 500 EC – dermal exposure

Area treated (m^2)	Active applied (kg)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.047 mg/kg bw	
			Protective clothing	
			Overalls + Gloves	Chem resistant clothes + Gloves
170	0.033	2.0	0.0285 MOE = 1.6	0.0128 MOE = 3.7
1000	0.200	12.0	0.1714 MOE = 0	0.0749 MOE = 0

Inhalation exposure: For the exposure estimate, the rate of inhalation exposure (in the absence of respiratory protection) is assumed to be 1635 µg dichlorvos/kg applied. This is based on the highest concentration of dichlorvos (0.064 mg/m^3) measured by Gold and Holcslaw in PCOs' breathing zone air. Results appear in the following table. Even without respiratory protection, the inhalation MOE would be acceptable for an operator treating a single house. Although the MOE for an unprotected operator treating 6 houses would lie below 10, an acceptable inhalation MOE could be achieved by wearing a half-facepiece respirator.

Surface spray application of dichlorvos 500 EC – inhalation exposure

Area treated (m^2)	Active applied (kg)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.020 mg/kg bw			
			Respiratory protection			
			None	Half-face	Full-face	Air-hose
170	0.033	0.054	0.00078 MOE = 26	0.00008 MOE = 259	0.00002 MOE = 1296	Nil MOE > 10 000
1000	0.2	0.327	0.00467 MOE = 4.3	0.00047 MOE = 43	0.00009 MOE = 214	Nil MOE > 10 000

Aggregate exposure: Given that an acceptable dermal MOE can not be achieved for an operator treating even a single domestic house, the aggregate MOE could not be acceptable. In this context, it is noteworthy that a PCO in Gold and Holcslaw's study developed cholinesterase poisoning after applying approximately 0.14 kg of dichlorvos to 7 small homes while wearing overalls, gloves and a half-facepiece respirator.

Effect of enclosed mixing/loading systems: The OCS has examined whether the adoption of enclosed mixing systems would confer significant additional protection to operators. PHED (model 3) predicts that an unprotected person mixing/loading liquid formulations using open pour methods would be exposed to 6.92 mg active/kg handled by the dermal route, and 2.64 µg/kg by inhalation. The corresponding values for an unprotected applicator using a low pressure handwand sprayer (PHED model 18) are 55.0 mg/kg and 2068 µg/kg. This implies that when a low pressure handwand is used, about 10% of a mixer/loader/applicator's total dermal exposure occurs during mixing and loading, while the remaining 90% occurs during application. Over 99% of inhalation exposure occurs during application. Thus, even if exposure during loading/mixing were reduced to zero, or if mixing/loading and application were performed by different operators, the dermal MOE for an operator treating a 170 m^2 house would rise from 3.7 to only 4.2 and there would be negligible reduction in inhalation exposure. Exposure would therefore remain unacceptably high.

Conclusions: Even if gloves and chemical-resistant clothing were worn, it is not possible to maintain an acceptable dermal MOE for operators mixing and applying sufficient dichlorvos to treat an area equivalent to an average domestic house by surface spray. The OCS has a high degree of confidence in this finding, given that it is based on a study with PCOs applying dichlorvos in conditions similar to those that would apply in Australia. Therefore, use of dichlorvos 500 EC as an indoor surface spray in domestic houses should be discontinued.

Other indoor situations including animal housing, milk and meat processing facilities, and grain storage structures

Animal housing, dairies, meatworks and abattoirs, and wineries are treated by indoor surface spray at rates of 0.03 – 0.2 g dichlorvos/m^2, using spraymixes containing dichlorvos at between 1 and 2.5 g/L. Label directions include application to walls and around windows and doors. Although the size of such buildings would vary considerably, it is considered that operators would seldom treat areas smaller than 1000 m^2, which would require them to mix, load and apply between 30 and 200 g dichlorvos. Some application sites would be significantly larger. PCOs are most likely to employ knapsack sprayers or handwands used with a vehicle-mounted spray tank and pump. Although no exposure studies have been performed with dichlorvos in these situations, the extent of operator exposure will be at least that measured by Gold and Holcslaw (1984). Indeed, operator exposure may be increased if significant quantities of spraymix are discharged at or above chest height, leading to contamination of the upper body and the breathing zone air. As shown above, dermal contamination would be extensive enough to erode the MOE below 10, even if only 30 g dichlorvos were mixed and applied. Given that many applications would involve larger amounts of dichlorvos, there is clear potential for toxicologically significant exposure of operators.

For use in empty grain silos, a 5 g/L dilution is recommended but no application rate is nominated. Users are directed to spray the inside walls and exit chutes until run-off. Survey respondents have identified further uses including treatment of internal floor areas of silos and walls, floors of sheds and bunkers, under-storage tunnels and elevator pits. Grain storage infrastructure would require treatment of large areas, given that silos have a capacity of up to 10 000 tonnes and sheds can hold from 3000 – 100 000 tonnes. Hand spraying equipment is likely to be used, and operators will probably discharge the spraymix at or above chest height, work in close proximity to the treated surfaces and enter enclosed or confined spaces. Again, dermal and inhalation exposure would occur at or above the level measured by Gold and Holcslaw, leading to an unacceptable MOE even if only 30 g of dichlorvos was mixed and applied.

Conclusions: Even if respiratory protection, gloves and chemical-resistant clothing were worn, it would not be possible to maintain an acceptable MOE for operators mixing and applying sufficient dichlorvos to treat animal housing and processing facilities, other large buildings and grain storage structures by indoor surface spray. Therefore, use of dichlorvos as an indoor surface spray in these situations should be discontinued.

Scenario 4: Indoor application of 500 EC formulation as a space spray

Dichlorvos 500 EC products are applied as an indoor space spray in diverse situations. Stables and piggeries are treated with a 2.5 g dichlorvos/L spraymix at a rate of 35 mg dichlorvos/m^3, with application performed by space spray. Variable treatment rates of 17.5 – 70 mg/m^3 are recommended for factories, stores, mills, abattoirs and wineries. A rate of 75 mg/m^3 is used for fumigation of tobacco stores, warehouses, and green-, glass- and mushroom houses. No specific dilution rate is specified for these applications, but product labels nominate space spraying as the application method. Operators would probably use a high pressure handwand in conjunction with a vehicle-mounted spray tank and pump. Some labels advise that all doors and windows are to be closed before application and operators should start application at a point furthest from a door and work towards the door.

Due to the variety of situations in which dichlorvos 500 EC products can be applied as a space spray, there will be wide variation in the volume of air space that has to be treated. This may range from a few hundred m^3 (in the case of small green-, glass- or mushroom houses) up to several thousand m^3. Exposure estimates will therefore be prepared for an operator treating a single small green- or mushroom house (375 m^3), 10 greenhouses or a medium-sized building of 3750 m^3 volume, or a large facility (12 500 m^3) at the maximum recommended rate of 75 mg dichlorvos/m^3.

Dermal exposure: None of the available exposure studies are directly applicable to indoor space spray application of dichlorvos. Because of its orientation towards broadacre spraying applications, POEM is considered unsuitable for modelling exposure in this situation. However, PHED has an exposure model (model 35) for mixer/loader/applicators mixing liquid formulations by open pour methods and applying the spraymix with high pressure handwand equipment. Although the algorithm is based on a single study, the data were generated in greenhouses during application to the floor, benches and overhead plants. Given that this work was done in an enclosed space and would have involved some spraying at or above chest height, the model is considered appropriate. In the absence of protective clothing, the predicted dermal exposure rate on the head and body, respectively, is 1.155 and 90.86 mg active/kg applied. The model lacks data for predicting the extent of unprotected hand contamination, but predicts an exposure rate of 0.249 mg/kg applied when gloves are worn. Applying the default assumption that there is a 10% penetration rate across chemical-resistant gloves, the OCS will utilise an exposure rate for unprotected hands of 2.49 mg/kg applied. A 20% penetration rate across overalls is assumed.

Estimates of operator exposure, dermal doses and MOEs appear in the following table. Exposure for an operator treating a single glass- or mushroom house would be acceptable provided that gloves and chemical resistant clothing were worn. Otherwise, the MOEs are below 10 and unacceptable.

Open mixing/loading and indoor space spray application of dichlorvos 500 EC – dermal exposure

Structures treated	Total volume (m^3)	Active applied (kg)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.047 mg/kg bw			
				Protective clothing			
				None	Overalls	Overalls + Gloves	Chem resistant clothes + gloves
1 Green/ mushroom house	375	0.028	2.659	0.03799 MOE = 1.2	0.00877 MOE = 5.4	0.00787 MOE = 6.0	0.00239 MOE = 20
10 Green-houses or 1 medium building	3750	0.281	26.59	0.37991 MOE = 0	0.08771 MOE = 0	0.07870 MOE = 0	0.02391 MOE = 2.0
1 Large building	12 500	0.938	88.65	1.26637 MOE = 0	0.29235 MOE = 0	0.26232 MOE = 0	0.07969 MOE = 0

Inhalation exposure: The relevant PHED model predicts an inhalation exposure rate of 264 µg active/kg applied for operators using high pressure handwand equipment indoors. However, this value is probably a significant underestimate because of the high volatility of dichlorvos. Conversely, although inhalation exposure could be estimated from the application rate of 70 mg dichlorvos/m^3, this value is likely to overestimate the true extent of exposure. Volatilisation of dichlorvos from aqueous aerosol droplets would occur more gradually than from CO_2 pressure gun efflux (see scenario 1), and a significant proportion of the droplets would precipitate onto the floor or other surfaces, upon which the dichlorvos may bind or degrade. Therefore, as discussed in Scenario 2, the OCS will account for the enhanced volatility of dichlorvos by applying a 50-fold factor to PHED's predicted exposure rate of 264 µg active/kg applied, yielding an estimate of 13 200 µg/kg.

As shown in the following table, the MOE associated with treatment of a single green- or mushroom house would be acceptable provided that a half-facepiece respirator were worn, while a full facepiece respirator would be required to maintain an acceptable MOE when treating a medium-sized building. However, unless an air-hose respirator or SCBA were used, an adequate MOE could not be assured for an operator treating a large building.

Open mixing/loading and indoor space spray application of dichlorvos 500 EC – inhalation exposure

Structures treated	Total volume (m^3)	Active applied (kg)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.020 mg/kg bw			
				Respiratory protection			
				None	Half-face	Full-face	Air-hose
1 Green/ mushroom house	375	0.028	0.371	0.00531 MOE = 3.7	0.00053 MOE = 38	0.00011 MOE = 190	Nil MOE > 10000
10 Green-houses or 1 medium building	3750	0.281	3.714	0.05306 MOE = 0	0.00531 MOE = 3.8	0.00106 MOE = 19	Nil MOE > 10000
1 Large building	12 500	0.938	12.38	0.17688 MOE = 0	0.01769 MOE = 1.1	0.00354 MOE = 5.7	Nil MOE > 10000

Aggregate exposure: Estimates of aggregate dermal and inhalation exposure have been prepared for an mixer/loader/applicator treating 375 m^3 air volume while wearing chemical resistant clothing with different levels of respiratory protection (see table below). It is apparent that although the MOE when wearing a half-facepiece respirator is acceptable, a maximum of only about 500 m^3 could be treated before the MOE was eroded below 10. Even if inhalation exposure was prevented by use of an air-hose respirator or SCBA, the highest acceptable volume (750 m^3) is well below the volume that it is anticipated may require treatment in a single workday.

Open mixing/loading and indoor space spray application of dichlorvos 550 EC – aggregate exposure

PPE	Aggregate MOE	Maximum volume of air space (m^3) that can be treated for MOE $\geq$ 10
Chemical resistant clothing, gloves, half facepiece respirator	13	488
Chemical resistant clothing, gloves, full facepiece respirator	18	679
Chemical resistant clothing, gloves, air-hose respirator	20	750

Effect of enclosed mixing/loading systems: The OCS has examined whether the adoption of enclosed mixing systems would confer significant additional protection to operators. PHED (model 3) predicts that an unprotected person mixing/loading liquid formulations using open pour methods would be exposed to 6.92 mg active/kg handled by the dermal route, and 2.64 µg/kg by inhalation. The corresponding values for an unprotected applicator using a high pressure handwand sprayer (PHED model 19) are 29.5 mg/kg and 174 µg/kg. This implies that when using a high pressure handwand, about 20% of a mixer/loader/applicator's total dermal exposure occurs during mixing and loading, while the remaining 80% occurs during application. Approximately 1.5% of inhalation exposure occurs during mixing/loading, with the remainder occuring during application. Thus, even if exposure during loading/mixing were reduced to zero, or if mixing/loading and application were performed by different operators, the dermal MOE for an operator treating a 375 m^3 airspace would rise from 20 to 25 but there would be negligible reduction in inhalation exposure. The impact on aggregate MOEs and permissible treatment volumes is illustrated in the following table. While there is a modest increase in aggregate MOEs, the maximum treatable airspace volume would still lie below 1000 m^3.

Indoor space spray application of dichlorvos 550 EC – aggregate exposure

PPE	Aggregate MOE	Maximum volume of air space (m^3) that can be treated for MOE $\geq$ 10
Chemical resistant clothing, gloves, half facepiece respirator	15	563
Chemical resistant clothing, gloves, full facepiece respirator	22	825
Chemical resistant clothing, gloves, air-hose respirator	25	938

Conclusions: Even if PPE comprising gloves, chemical resistant clothing and an air-hose respirator or SCBA were worn, it would not be possible to maintain an acceptable dermal MOE for operators applying dichlorvos by indoor space spray. Therefore, this use of dichlorvos should be discontinued.

Scenario 5: Indoor application of 500 EC formulation as a fog or mist

Dichlorvos 500 EC products can be diluted to 2.5 g active/L and applied by fogger, mister or atomiser in situations such as stables, piggeries, abattoirs and wineries at a rate of 35 g/1000 m^3. Factories, stores, mills and warehouses may be fogged at 17.5 – 35 g/1000 m^3, using solutions of 2.5 – 5 g dichlorvos/L, diluted in kerosene, dieseline or other suitable carrier. Clamp and Gazzard (2000) describe treatment of a large Australian grain terminal with dichlorvos EC using batteries of Dynafog Hurricane ULV mist sprayers, although the application rate was not given. Fogging is also nominated as a method of treating tobacco stores, warehouses, green-, glass- and mushroom houses at 7.5 g dichlorvos/100 m^3 (75 mg/m^3).

Some labels advise that fogging should be performed using a stationary fogging machine, set up outside to fill the treated building through a door or window on the windward side. Otherwise, it is assumed that stationary or portable foggers or misters would be discharged inside the treated structure. There is evident potential for significant exposure of operators during indoor use of portable misters and foggers, which produce fine droplets (15 – 30 µm diameter in the case of foggers, and 50 – 100 µm in the case of misters). Volatilisation of dichlorvos from droplets of these sizes would be rapid. In the absence of any relevant studies, the OCS will assume that the extent and pattern of operator exposure when using portable foggers or misters will be similar to those predicted for persons applying dichlorvos 50 LD/CO_2 products. By contrast, there would be considerably less operator exposure from stationary foggers and misters. Even if using equipment that required manual activation, an operator would not have to remain within the treated structure for more than a few minutes. Similarly, where foggers are set up outside a building, operator exposure to airborne dichlorvos would be low. However, irrespective of the equipment used, there is potential for operators to be exposed to dichlorvos when decanting and mixing the concentrate and filling the reservoir. Estimates will therefore be prepared for operators mixing and loading the product, applying the product using stationary equipment, and applying by portable equipment at the highest label rate of 75 mg dichlorvos/m^3.

Mixing and loading

Dermal exposure: None of the available studies on operators using dichlorvos provides data on exposure through mixing/loading, as distinct from exposure through application. As discussed in Scenario 2 (above), PHED model 3 predicts that the dermal exposure of mixer/loaders handling liquids by open pour will be 6.92 mg/kg active handled, of which head, body and hand contamination comprise 0.0116, 0.6622 and 6.248 mg/kg active handled. Dermal exposure levels, doses and MOEs at work rates of 375 – 12 500 m^3/d are shown in the following table. It is noteworthy that at or above a work rate of 12 500 m^3/d, the MOEs would be unacceptable even if the operator wore chemical resistant clothing and gloves. These results indicate that open mixing/loading of dichlorvos 500 EC products could lead to toxicologically significant exposure of operators.

Open mixing/loading of Dichlorvos 500 EC –- dermal exposure

Structures treated	Total volume (m^3)	Active applied (kg)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.047 mg/kg bw			
				Protective clothing			
				None	Overalls	Overalls + Gloves	Chem resistant clothes + gloves
1 Greenhouse	375	0.028	0.191	0.00273 MOE = 17	0.00261 MOE = 18	0.00035 MOE = 130	0.00031 MOE = 150
10 Green-houses or 1 medium building	3750	0.281	1.910	0.02728 MOE = 1.7	0.02612 MOE = 1.8	0.00351 MOE = 13	0.00311 MOE = 15
1 Industrial building	12 500	0.938	6.397	0.09139 MOE = 0	0.08705 MOE = 0	0.01170 MOE = 4.0	0.01037 MOE = 4.5
2 Industrial buildings	25 000	1.876	12.79	0.18278 MOE = 0	0.17410 MOE = 0	0.02340 MOE = 2.0	0.02074 MOE = 2.3

According to PHED model 6, use of closed mixing/loading systems will reduce dermal exposure/kg handled by a factor of 2.7 relative to open pour methods. As shown in the following table, at a work rate of 12 500 m^3/d this would increase the dermal MOEs to acceptable levels provided overalls and gloves were worn. However, if sufficient dichlorvos to treat 25 000 m^3 were handled, the MOEs would remain unacceptable.

Closed mixing/loading of Dichlorvos 500 EC –- dermal exposure

Structures treated	Total volume (m^3)	Active applied (kg)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.047 mg/kg bw			
				Protective clothing			
				None	Overalls	Overalls + Gloves	Chem resistant clothes + gloves
1 Greenhouse	375	0.028	0.071	0.00101 MOE = 47	0.00097 MOE = 49	0.00013 MOE = 351	0.00011 MOE = 405
10 Green-houses or 1 medium building	3750	0.281	0.707	0.01010 MOE = 4.7	0.00967 MOE = 4.9	0.00130 MOE = 35	0.00115 MOE = 41
1 Industrial building	12 500	0.938	2.369	0.03385 MOE = 1.4	0.03224 MOE = 1.5	0.00351 MOE = 13	0.00311 MOE = 15
2 Industrial buildings	25 000	1.876	4.739	0.06793 MOE = 0	0.06448 MOE = 0	0.00702 MOE = 6.7	0.00622 MOE = 7.6

Inhalation exposure: Inhalation exposure to dichlorvos when pouring and mixing in closed systems has been estimated at 9.429 µg/kg active handled (see Scenario 2). Inhalation exposure estimates for operators using closed mixing systems are shown in the following table. MOEs are well above the acceptable level even in the absence of protective equipment.

Closed mixing/loading of Dichlorvos 500 EC –- inhalation exposure

Structures treated	Total volume (m^3)	Active applied (kg)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.02 mg/kg bw			
				Respiratory protection			
				None	Half face	Full face	Air-hose
1 Greenhouse	375	0.028	0.00027	0.000004 MOE = 5185	0.0000004 MOE > 10 000	0.00000008 MOE > 10 000	Nil MOE > 10 000
10 Green-houses or 1 medium building	3750	0.281	0.00265	0.00004 MOE = 528	0.000004 MOE = 5279	0.0000007 MOE > 10 000	Nil MOE > 10 000
1 Industrial building	12 500	0.938	0.00884	0.00013 MOE = 158	0.00001 MOE = 1583	0.000003 MOE = 7915	Nil MOE > 10 000
2 Industrial buildings	25 000	1.876	0.01769	0.00025 MOE = 79	0.00003 MOE = 791	0.000005 MOE = 3957	Nil MOE > 10 000

Aggregate exposure: Estimated aggregate MOEs for operators using closed mixing/loading systems are shown in the table below. The estimates have been prepared assuming a work rate of 25 000 m^3/d, for different combinations of PPE. The table also displays the largest volumes of airspace that can be treated at the highest label rate, and the largest masses of dichlorvos that can be handled, without eroding the aggregate MOE below 10. It can be seen that even using a closed mixing system in conjunction with PPE comprised of gloves, chemical resistant clothing and a full facepiece respirator, an operator could handle no more than 1.4 kg dichlorvos, sufficient to treat 18 750 m^3 volume at the maximum label rate. Because exposure is predominately via the dermal route, use of an air-hose respirator or SCBA would yield negligible benefit.

Closed mixing/loading of dichlorvos 500 EC – aggregate exposure

PPE	MOE	Maximum mass of dichlorvos (kg) that can be handled for MOE $\geq$ 10	Maximum volume of air space (m^3) that can be treated for MOE $\geq$ 10
Gloves, overalls	6.0	1.125	15 000
Gloves, overalls, half-facepiece respirator	6.5	1.219	16 250
Gloves, overalls, full facepiece respirator	6.5	1.219	16 250
Gloves, chemical resistant clothing, full facepiece respirator	7.5	1.406	18 750

Indoor application using hand-held foggers and misters

Dermal exposure: During the use indoors of portable fogging or misting equipment, operators are likely to be exposed to dichlorvos-containing aerosols that become deposited onto the body or clothing, particularly if the building design requires traversal of areas already treated. Dichlorvos may also precipitate from the vapour phase onto the operator. In the absence of relevant data, the OCS will assume that the extent of dermal exposure will be similar to that associated with indoor application of dichlorvos 50 LD/CO_2 manual pressure guns (ie., on the head, body and hands, respectively, 0.018, 2.68 and 0.26 mg/kg active handled, for a total of 2.95 mg/kg active handled). As shown in the following table, at the maximum label rate of 75 mg/m^3, overalls would afford sufficient protection to assure an acceptable dermal MOE at a work rate of 3750 m^3/d. However, the MOE associated with treatment of a large industrial building would be unacceptable unless gloves and chemical resistant clothing were worn. The MOE associated with treatment of 2 large industrial buildings while wearing the maximum level of protective clothing is marginally unacceptable.

Indoor portable fogger/mister application of Dichlorvos 500 EC –- dermal exposure

Structures treated	Total volume (m^3)	Active applied (kg)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.047 mg/kg bw			
				Protective clothing			
				None	Overalls	Overalls + Gloves	Chem resistant clothes + gloves
1 Greenhouse	375	0.028	0.083	0.00119 MOE = 40	0.00033 MOE = 140	0.00023 MOE = 200	0.00007 MOE = 660
10 Green-houses or 1 medium building	3750	0.281	0.830	0.01186 MOE = 4.0	0.00327 MOE = 14	0.00233 MOE = 20	0.00072 MOE = 66
1 Industrial building	12 500	0.938	2.767	0.03953 MOE = 1.2	0.01091 MOE = 4.3	0.00777 MOE = 6.0	0.00239 MOE = 20
2 Industrial buildings	25 000	1.876	5.534	0.07906 MOE = 0	0.02182 MOE = 2.2	0.01554 MOE = 3.0	0.00478 MOE = 9.8

Inhalation exposure: The OCS has no data upon which to base estimates of inhalation exposure to persons applying dichlorvos indoors using portable fogging or misting equipment. Nevertheless, the potential for exposure can be inferred from the highest recommended application rate and the length of time over which an operator would be exposed. Operators would probably hold the fogger or mister nozzle at waist or chest height as they move through the treated building. Once ejected from the nozzle, volatilisation of dichlorvos from the aerosol would be rapid. Provided the operator did not walk through the effluxive stream, the highest airborne concentration of dichlorvos to which they would be exposed would be 75 mg/m^3. However, this concentration would be attained only at end of application. When treatment commenced, the airborne concentration of dichlorvos would be zero. Therefore, even when using the maximum application rate, operators are unlikely to be exposed to dichlorvos at a TWA concentration of > 37.5 mg/m^3 while fogging or misting in an enclosed space. The duration of exposure is unknown, but may be similar to the time taken for application of dichlorvos 50 LD/CO_2 by manual pressure gun (70 sec/300 m^3).

In the following table, estimates of inhalation exposure have been prepared for an operator treating 1 or 10 greenhouses, or an industrial building. It is assumed that the airborne concentration of dichlorvos will be 37.5 mg/m^3. For all scenarios except fumigation of a single greenhouse, inhalation MOEs are unacceptable even with a full facepiece respirator. Acceptable MOEs would only be achieved by use of an air-hose respirator or SCBA, which would entirely prevent inhalation exposure.

Indoor portable fogger/mister application of Dichlorvos 500 EC –- inhalation exposure

Structures treated	Total volume (m^3)	Active applied (kg)	Duration (h)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.02 mg/kg bw			
					Respiratory protection			
					None	Half face	Full face	Air-hose
1 Greenhouse	375	0.028	0.024	0.912	0.01302 MOE = 1.5	0.00130 MOE = 15	0.00026 MOE = 77	Nil MOE > 10 000
10 Greenhouses or 1 medium building	3750	0.281	0.243	9.114	0.13021 MOE = 0	0.01302 MOE = 1.5	0.00260 MOE = 7.7	Nil MOE > 10 000
1 Industrial building	12 500	0.938	0.810	30.38	0.43403 MOE = 0	0.04340 MOE = 0	0.00868 MOE = 2.3	Nil MOE > 10 000
2 Industrial buildings	25 000	1.876	1.620	60.76	0.86806 MOE = 0	0.08681 MOE = 0	0.01736 MOE = 1.2	Nil MOE > 10 000

Aggregate exposure: The following table shows the aggregate MOEs for a mixer/loader/applicator using closed mixing equipment and wearing chemical resistant clothing, gloves and an air-hose respirator/SCBA, calculated by the formula

1 ÷ (1/MOE dermal [mix/load] + 1/MOE inhalation [mix/load] + 1/MOE dermal [application] + 1/MOE inhalation [application]).

Although there is a large aggregate MOE when treating several small structures, the MOE at a work rate of 12 500 m^3/d is unacceptable. The maximum volume that could be fumigated without eroding the aggregate MOE below 10 is approximately 11 000 m^3.

Indoor portable fogger/mister application of dichlorvos 500 EC – aggregate dermal and inhalation exposure

Structures treated	Total volume (m^3)	Total duration (h)	Active applied (kg)	Aggregate MOE
1 Greenhouse	375	0.024	0.028	239
10 Greenhouses or 1 medium building	3750	0.243	0.281	25
1 Industrial building	12 500	0.810	0.938	8.6

Conclusions: Indoor application of dichlorvos by portable fogging or misting equipment is likely to cause toxicologically significant dermal exposure when mixing the product and dermal and inhalational exposure during application. Even if a closed mixing system were employed and operators wore gloves, chemical resistant clothing and an air-hose respirator or SCBA throughout mixing/loading and application, an acceptable MOE could not be maintained if a volume of > 11 000 m^3 were treated. Given that it is impractical to impose any such limit on users, indoor application of dichlorvos 500 EC products by portable fogging or misting equipment should be discontinued.

Indoor application using stationary foggers or misters

Especially when treating large structures, operators are likely to use stationary foggers or misters with either manual or automatic release systems. In the latter case, operators would be exposed only during mixing and loading activities (see above), and to maintain a MOE of $\geq$ 10 could handle only 1.4 kg of dichlorvos, sufficient to treat 18 750 m^3 volume at the maximum label rate. This is less than the highest anticipated work rate for a PCO treating industrial premises. The situation with respect to manual activation is considered below.

Inhalation exposure: If manual activation were required, the operator may become exposed to dichlorvos by inhalation prior to vacating the fumigation site. The duration of exposure is not likely to exceed 1 or 2 minutes. Therefore, a "worst case" estimate has been prepared assuming 2 minutes' exposure at a TWA airborne concentration of 37.5 mg/m^3, during which an operator would inhale approximately 0.033 m^3 air. As shown below, the minimum PPE required to maintain the inhalation MOE above 10 would be a half-facepiece respirator.

Indoor stationary fogger/mister application of Dichlorvos 500 EC –- inhalation exposure

Duration (h)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.02 mg/kg bw			
		Respiratory protection			
		None	Half face	Full face	Air-hose
0.033	1.238	0.01768 MOE = 1.1	0.00177 MOE = 11	0.00035 MOE = 55	Nil MOE > 10000

Aggregate exposure: Calculated using the formula

1 ÷ (1/MOE dermal [mix/load] + 1/MOE inhalation [mix/load] + 1/MOE inhalation [application]),

estimates for operators wearing various combinations of PPE are shown in the following table. It is assumed that sufficient dichlorvos is handled to treat 2 X 12 500 m^3 structures at the maximum label rate, using a closed mixing system (see above) and manual release equipment. The table also includes the maximum volume of airspace that could be treated without eroding the aggregate MOE to below 10. It is evident that a minimum of gloves, overalls and a full facepiece respirator would be required to enable treatment of a single large structure. There would be a modest increase in aggregate MOE and treatable volume if chemical resistant clothing were worn with gloves and a full facepiece respirator. Elimination of inhalation exposure by use of an air-hose respirator or SCBA would raise the maximum treatable volume to 18 750 m^3, the same value as for fogging with automatic release equipment.

Indoor stationary fogger/mister application of dichlorvos 500 EC – aggregate exposure

PPE	MOE	Maximum volume of air space (m^3) that can be treated for MOE $\geq$ 10
Gloves, overalls, half-facepiece respirator	3.0	7375
Gloves, overalls, full facepiece respirator	5.5	13 750
Gloves, chemical resistant clothing, full facepiece respirator	6.0	15 000
Gloves, chemical resistant clothing, air-hose respirator	7.5	18 750

Conclusions: Operators would not normally be exposed to dichlorvos when applying it via stationary automatic release foggers or misters, and the extent of inhalation exposure when using stationary manual release equipment can be constrained to acceptable levels by use of appropriate respiratory PPE. However, there is scope for unacceptably high dermal and inhalation exposure when mixing and loading dichlorvos 500 EC products, even using closed systems and wearing PPE comprising elbow length butyl rubber gloves, chemical resistant clothing and an air-hose respirator/SCBA. Only up to about 1.4 kg of dichlorvos could be mixed/loaded without eroding the MOE to unacceptable levels. The limiting factor is dermal exposure, especially on the hands. If treatment were performed at the maximum label rate of 75 mg/m^3, the volume treated would be limited to 18 750 m^3, which lies below the maximum anticipated work rate of 25 000 m^3. Given that it is impractical to impose a limit on the amount of dichlorvos that users could prepare or apply per day, application of dichlorvos 500 EC products to buildings and other structures by stationary indoor misting or fogging equipment should be discontinued unless supported by suitable data. This could include exposure data from operators under in-use conditions, and/or information on the likely work rate when applying dichlorvos by indoors by fogging or misting.

Scenario 6: Outdoor application of 500 EC formulation by space spray, fog or mist

Dichlorvos 500 EC products may be applied to garbage dumps, beach, picnic and recreation areas at an unspecified dilution rate as a space spray at 300 mL/ha (150 g dichlorvos/ha,), or undiluted through a portable or stationary fogger at 300 mL/ha (150 g dichlorvos/ha), or by misting machine at 30 L of 0.5% product/ha (75 g dichlorvos/ha). No further information on these use patterns is available. Exposure estimates will be prepared for operators treating a 1 or 5 ha area, representative of the typical and largest areas likely to be treated within a workday. To treat a 1 or 5 ha area, respectively, operators would handle 300 or 1500 mL of 500 EC product containing 0.15 or 0.75 kg of dichlorvos. Mixing and loading.

Dermal exposure: Exposure during the mixing and loading phases may be estimated by the same methods as used in Scenario 5, which predict that the dermal exposure when handling liquids by open pour will be 6.92 mg/kg active handled, of which head, body and hand contamination comprise 0.0116, 0.6622 and 6.248 mg/kg active handled. Dermal exposure levels, doses and MOEs at work rates of 1 or 5 ha/d are shown in the following table. Although the dermal MOE at a work rate of 1 ha/d would be acceptable if overalls and gloves were worn, the MOE at 5 ha/d could not be maintained above 10 if open pour methods were used, even with chemical resistant clothing and gloves.

Open mixing/loading of Dichlorvos 500 EC –- dermal exposure

Area treated (ha)	Active applied (kg)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.047 mg/kg bw			
			Protective clothing			
			None	Overalls	Overalls + Gloves	Chem resistant clothes + gloves
1	0.15	1.054	0.01506 MOE = 3.2	0.01392 MOE = 3.4	0.00187 MOE = 25	0.00166 MOE = 28
5	0.75	5.270	0.07528 MOE = 0	0.06960 MOE = 0	0.00936 MOE = 5.0	0.00828 MOE = 5.7

As discussed in Scenario 5, use of enclosed mixing/loading systems would reduce dermal exposure by 2.7-fold compared with exposure from open pour methods. A combination of overalls and gloves would ensure an acceptable MOE at the higher work rate.

Closed mixing/loading of Dichlorvos 500 EC –- dermal exposure

Area treated (ha)	Active applied (kg)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.047 mg/kg bw			
			Protective clothing			
			None	Overalls	Overalls + Gloves	Chem resistant clothes + gloves
1	0.15	0.390	0.00558 MOE = 8.4	0.00516 MOE = 9.1	0.000694 MOE = 68	0.00061 MOE = 77
5	0.75	1.952	0.02788 MOE = 1.7	0.02578 MOE = 1.8	0.00347 MOE = 14	0.00307 MOE = 15

Inhalation exposure: Inhalation exposure to dichlorvos when pouring and mixing in closed systems has been estimated at 9.429 µg/kg active handled (see Scenario 2). Inhalation exposure estimates for operators using closed mixing systems are shown in the following table. MOEs are well above the acceptable level even in the absence of protective equipment.

Closed mixing/loading of Dichlorvos 500 EC –- inhalation exposure

Area treated (ha)	Active applied (kg)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.02 mg/kg bw			
			Respiratory protection			
			None	Half face	Full face	Air-hose
1	0.15	0.0014	0.00002 MOE = 990	0.000002 MOE = 10 000	0.0000004 MOE > 10 000	Nil MOE > 10 000
5	0.75	0.0071	0.00010 MOE = 198	0.00001 MOE = 1972	0.000002 MOE = 9859	Nil MOE > 10 000

Aggregate exposure: Estimated aggregate MOEs for operators using closed mixing/loading systems are shown in the table below. The estimates have been prepared assuming work rates of 1 and 5 ha/d, with different combinations of PPE. Gloves and overalls would be sufficient to assure a marginally adequate MOE. Addition of respiratory protection or chemical resistant clothing would yield only a small increase in MOE because exposure is predominately via the hands.

Closed mixing/loading of dichlorvos 500 EC – aggregate exposure

Area treated (ha)	PPE	MOE
1	Gloves, overalls	64
	Gloves, overalls, half-facepiece respirator	68
	Gloves, overalls, full facepiece respirator	68
	Gloves, chemical resistant clothing, full facepiece respirator	76
5	Gloves, overalls	13
	Gloves, overalls, half-facepiece respirator	14
	Gloves, overalls, full facepiece respirator	14
	Gloves, chemical resistant clothing, full facepiece respirator	15

Outdoor application by space spray

If treating the application site by space spray, operators are most likely to use a high pressure handwand in conjunction with a vehicle mounted tank and pump. There are no data on operator exposure to dichlorvos during application by space spray, and POEM does not model pesticide exposure via this method of application. However, PHED (model 19) has an algorithm for high pressure handwand application, derived from a combination of data gathered indoors and outdoors. It predicts operators will be exposed dermally at rates of 0.184, 26.8 and 2.55 mg/kg active handled, for a total of 29.5 mg/kg. Inhalation exposure is estimated at 174 µg/kg handled.

Dermal exposure: In the following table, estimates of operator exposure are displayed for work rates of 1 and 5 ha/d. MOEs are unacceptable, other than for an operator treating 1 ha/d while wearing gloves and chemical resistant clothing.

Outdoor space spray application of Dichlorvos 500 EC –- dermal exposure

Area treated (ha)	Active applied (kg)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.047 mg/kg bw			
			Protective clothing			
			None	Overalls	Overalls + Gloves	Chem resistant clothes + gloves
1	0.15	4.425	0.06321 MOE = 0	0.01917 MOE = 2.5	0.01261 MOE = 3.7	0.00399 MOE = 12
5	0.75	22.79	0.32554 MOE = 0	0.09583 MOE = 0	0.06304 MOE = 0	0.01997 MOE = 2.4

Inhalation exposure: As discussed under Scenario 2 (above), a correction factor of 50 should be applied to the PHED prediction for inhalation exposure to account for the high volatility of dichlorvos.

Estimates of inhalation exposure have been prepared assuming an exposure rate of 174 X 50 = 8700 µg/kg handled, and are shown below. A half facepiece respirator would be required to assure a sufficient inhalation MOE at the lower work rate. At a work rate of 5 ha/d, a full facepiece respirator would confer an acceptable MOE.

Outdoor space spray application of Dichlorvos 500 EC –- inhalation exposure

Area treated (ha)	Active applied (kg)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.02 mg/kg bw			
			Respiratory protection			
			None	Half face	Full face	Air-hose
1	0.15	1.305	0.01864 MOE = 1.1	0.00186 MOE = 11	0.00037 MOE = 54	Nil MOE > 10 000
5	0.75	6.525	0.09321 MOE = 0	0.00932 MOE = 2.1	0.00186 MOE = 11	Nil MOE > 10 000

Aggregate exposure: Aggregate exposures have been estimated for operators mixing/loading dichlorvos 500 EC in an enclosed system and treating a 1 ha area, while wearing chemical resistant clothing and different levels of respiratory PPE. Estimates are prepared by the equation:
1 ÷ (1/MOE dermal [mix/load] + 1/MOE inhalation [mix/load] + 1/MOE dermal [application] + 1/MOE inhalation [application]).

The table also includes the maximum area that could be treated without eroding the aggregate MOE to below 10. It is apparent that the aggregate MOE would be unacceptable unless gloves and chemical resistant clothing were worn and inhalation exposure was prevented by means of an air-hose respirator or SCBA. Even under these conditions, the maximum treatable area would be limited to 1 ha.

Outdoor space spray application of dichlorvos 500 EC – aggregate exposure

PPE	MOE	Maximum area (ha) that can be treated for MOE ≥ 10
Gloves, chemical resistant clothing, half facepiece respirator	5.3	0.53
Gloves, chemical resistant clothing, full facepiece respirator	8.7	0.87
Gloves, chemical resistant clothing, air-hose respirator	10	1.0

Conclusions: Even if PPE comprising gloves, chemical resistant clothing and an air-hose respirator or SCBA were worn, it would not be possible to maintain an acceptable MOE for operators applying dichlorvos outdoors by space spray unless the treated area were constrained to 1 ha. However, it is impractical to impose such a limit on operators and so this use of dichlorvos should be discontinued.

Outdoor application by fogging or misting equipment

Prediction of operator exposure from outdoor application of dichlorvos by fogging and misting is difficult because these operations may be performed with a variety of equipment, and will be affected by variables including the size, type and topography of the fumigation site, the wind speed and direction, and the ambient temperature. Application could be undertaken using hand-held foggers or backpack misters, semi-portable misters mounted on utility vehicles or trailers, or stationary foggers and misters. Operator exposure is likely to be greater when using portable or vehicle-mounted equipment than stationary equipment, but even in the latter case, exposure may occur if the operator remains on site to supervise application. The extent of exposure will depend heavily on whether the operator passes through the effluxive stream from the equipment in use, and the duration of exposure. The OCS has therefore prepared reasonable worst case exposure estimates for an operator mixing, loading and applying sufficient dichlorvos to treat a 5 ha area by fogging at the highest label rate of 150 g/ha, which would involve handling 0.75 kg active. It will be assumed that the extent of dermal exposure is the same as that estimated for indoor use of hand-held foggers, and that the duration of exposure is 3 hours. The exposure model also assumes that the operator will be exposed to a TWA airborne concentration of 7.5 mg dichlorvos/m^3, the concentration that would be attained if 150 g dichlorvos were dispersed evenly within a volume of 100 X 100 X 2 = 20 000 m^3 of air.

Dermal exposure: In the absence of relevant data, the OCS will assume that the extent of dermal exposure will be similar to that estimated for indoor application of dichlorvos 50 LD/CO_2 with manual pressure guns (ie. 0.018, 2.68 and 0.26 mg/kg active handled, on the head, body and hands, respectively, for a total of 2.95 mg/kg active handled). As shown in the following table, dermal MOEs would be unacceptable unless the operator wore gloves and chemical resistant clothing. If treatment was performed at the label rate recommended for misting (75 g dichlorvos/ha), exposure would be halved and the MOEs would double and become acceptable if the operator wore overalls.

Outdoor fogger application of Dichlorvos 500 EC –- dermal exposure

Area treated (ha)	Active applied (kg)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.047 mg/kg bw			
			Protective clothing			
			None	Overalls	Overalls + Gloves	Chem resistant clothes + gloves
5	0.75	2.219	0.03169 MOE = 1.5	0.00872 MOE = 5.4	0.00621 MOE = 7.6	0.00191 MOE = 25

Inhalation exposure: The table below displays the estimated inhalation exposure of operators. If a TWA concentration of 7.5 mg dichlorvos/m^3 were inhaled for 3 hours at a ventilation rate of 1 m^3/h, the total exposure would be 7.5 X 3 X 1 = 22.5 mg. The inhalation MOEs with half- or full facepiece respirators are unacceptable, and an air-hose respirator/SCBA would be required. The extent of inhalation exposure when misting at the recommended label rate of 75 g/ha would be halved to 1.109 mg, but could still not be limited to acceptable levels without the use of an air-hose respirator.

Outdoor fogger application of Dichlorvos 500 EC –- inhalation exposure

Area treated (ha)	Active applie d (kg)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.02 mg/kg bw			
			Respiratory protection			
			None	Half face	Full face	Air-hose
5	0.75	22.5	0.32143 MOE = 0	0.03214 MOE = 0	0.00643 MOE = 3.1	Nil MOE > 10 000

Aggregate exposure: Aggregate exposures have been estimated for operators mixing/loading dichlorvos 500 EC in an enclosed system and fogging a 5 ha area at 150 g/ha, while wearing gloves, chemical resistant clothing and an air-hose respirator/SCBA. Estimates are prepared by the equation: 1 ÷ (1/MOE dermal [mix/load] + 1/MOE inhalation [mix/load] + 1/MOE dermal [application] + 1/MOE inhalation [application]).

The table also includes the maximum area that could be treated without eroding the aggregate MOE to below 10. The aggregate MOE would be unacceptable even under conditions where inhalation exposure was prevented, and the maximum treatable area would be limited to 4.7 ha.

Outdoor fogger application of dichlorvos 500 EC – aggregate exposure

PPE	MOE	Maximum area (ha) that can be treated for MOE $\geq$ 10
Gloves, chemical resistant clothing, air-hose respirator	9.4	4.7

Conclusions: The exposure model developed by the OCS suggests that there is potential for toxicologically significant dermal and inhalation exposure to dichlorvos when mixing, loading and treating outdoor areas by fogging or misting. Even with the most conservative PPE, it appears that less than 5 ha could be fogged at the current label rate. Therefore, outdoor application of dichlorvos by misting or fogging should cease unless supported by relevant exposure data or more detailed information on work rates and handling practices.

Scenario 7: Application of 500 EC formulation by the wooden board method

Dichlorvos 500 EC products may be applied in tobacco stores, warehouses, greenhouses, glasshouses and mushroom houses by the “wooden board method”. This entails sprinkling the undiluted product onto wooden boards at the rate of 20 mL/150 m^3 volume (ie. 10 g dichlorvos/150 m^3 or 67 mg/m^3). To enhance effectiveness, a fan may be set up to blow over each board. The treated area remains closed overnight and after use, the boards are hosed down and stored outdoors. Exposures will be estimated for daily work rates of 375 – 12 500 m^3.

Dermal exposure: When decanting the concentrate, operators are likely to experience similar levels of dermal exposure to those arising from mixing/loading liquid formulations by open pour methods. Therefore, in the absence of relevant data, PHED model 3 (open mixing/loading of liquids) will be used to estimate the extent of dermal exposure. The PHED algorithm predicts exposure on the head, body and hands to be 0.0116, 0.662 and 6.248 mg/kg active handled, for a total of 6.92 mg/kg. Although there is an acceptable dermal MOE for an unprotected operator treating a single small structure, overalls and gloves would be required to assure an acceptable MOE if 0.25 kg dichlorvos were applied, sufficient to treat 3750 m^3 air space. The MOEs associated with treatment of a large industrial building are unacceptable even with the most conservative PPE.

Wooden board application of Dichlorvos 500 EC –- dermal exposure

Structures treated	Total volume (m^3)	Active applied (kg)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.047 mg/kg bw			
				Protective clothing			
				None	Overalls	Overalls + Gloves	Chem resistant clothes + gloves
1 Greenhouse	375	0.025	0.1730	0.00247 MOE = 19	0.00228 MOE = 21	0.00028 MOE = 170	0.00024 MOE = 200
10 Green-houses or 1 medium building	3750	0.250	1.7304	0.02471 MOE = 1.9	0.02282 MOE = 2.1	0.00275 MOE = 17	0.00239 MOE = 20
1 Industrial building	12 500	0.833	5.7659	0.08237 MOE = 0	0.07607 MOE = 0	0.00915 MOE = 5.1	0.00797 MOE = 5.9

Inhalation exposure: After the undiluted liquid formulation is decanted onto the wooden board, the airborne concentration of dichlorvos would probably increase more slowly than would occur during application by spray, pressure gun, fog or mist. This is due to the relatively small surface area of the liquid pool from which dichlorvos could volatilise, compared with the surface area of droplets within an aerosol cloud. In studies where dichlorvos was applied by watering can in mushroom houses and warehouses, Hussey and Hughes (1963 and 1964) reported that airborne dichlorvos levels rose no further than 0.04% of the nominal application rate, while Durham et al (1959) detected dichlorvos at up to 2.3% of the application rate. However, there is no evidence in either study to suggest that forced aeration was employed to hasten evaporation. Hence, airborne dichlorvos levels may approach the target value of 67 mg/m^3 more closely in situations where fan-assisted evaporation is occurring. The OCS will assume that operators are exposed to a TWA concentration of 6.7 mg dichlorvos/m^3 (ie. 10% of the nominal application rate), and are exposed for 2, 20 and 60 minutes respectively when treating 375, 3750 or 12 500 m^3 of air space. As shown in the following table, the inhalation MOE for treatment of a single small structure would be acceptable provided a half facepiece respirator was worn, but MOEs for treating 3750 or 12 500 m^3 are insufficient unless the operator used a full facepiece respirator.

Wooden board application of Dichlorvos 500 EC –- inhalation exposure

Structures treated	Total volume (m^3)	Active applied (kg)	Duration (h)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.02 mg/kg bw			
					Respiratory protection			
					None	Half face	Full face	Air-hose
1 Greenhouse	375	0.025	0.033	0.201	0.00287 MOE = 7.0	0.00029 MOE = 70	0.00006 MOE = 351	Nil MOE > 10 000
10 Greenhouses or 1 medium building	3750	0.250	0.33	2.01	0.02871 MOE = 0	0.00287 MOE = 7.0	0.00057 MOE = 35	Nil MOE > 10 000
1 Industrial building	12 500	0.833	1.0	6.70	0.09571 MOE = 0	0.00957 MOE = 2.1	0.00191 MOE = 10	Nil MOE > 10 000

Aggregate exposure: The following table shows the aggregate MOEs for an operator treating 3750 m^3 air space with different combinations of PPE, calculated by the formula

1 ÷ (1/MOE dermal [application] + 1/MOE inhalation [application]).

The table also contains estimates of the maximum volume of air space that could be treated without eroding the MOE below 10. Although there is an acceptable MOE if gloves, overalls and a full facepiece respirator were worn, a maximum of about 4300 m^3 could be treated while wearing this level of PPE. Use of chemical resistant clothing would enable a modest increase in MOE and maximum permissible volume, but a significant gain in protection could only be obtained by preventing inhalation exposure with an air-hose respirator or SCBA. Under these conditions, the maximum volume that could be fumigated without eroding the aggregate MOE below 10 is approximately 7500 m^3.

Wooden board application of dichlorvos 500 EC – aggregate exposure

PPE	Aggregate MOE	Maximum volume of air space (m^3) that can be treated for MOE $\geq$ 10
Gloves, overalls, full facepiece respirator	11	4291
Gloves, chemical resistant clothing, full facepiece respirator	13	4774
Gloves, chemical resistant clothing, air-hose respirator	20	7485

Conclusions: Operators treating small to medium sized buildings by the wooden board method could do so without incurring an unacceptable level of exposure to dichlorvos, provided that gloves, overalls and a full facepiece respirator were worn. However, there is potential for toxicologically significant exposure when treating larger structures, and a maximum of 7500 m^3 could be treated even with PPE comprising gloves, chemical resistant clothing and an air-hose respirator/SCBA. Because a building of this size is within the range of anticipated daily work rates, and it is not feasible to limit the volume of air space that can be fumigated in a workday, dichlorvos should not be applied by the wooden board method.

Scenario 8: Application of 500 EC formulation by watering can

Several 500 EC product labels nominate application by watering can as a treatment method against insects in domestic households, using a 6 g dichlorvos/L water solution. There is some uncertainty as to the amount of dichlorvos that would be handled in this situation, as no treatment rates are given. However, if the application rate was similar to that used for indoor surface spraying (0.2 g dichlorvos/m^2), this would involve delivering 33 mL of the diluted solution per m^2. An average house of 170 m^2 would require 33 g dichlorvos, while a total of 200 g would be applied to 6 houses, the highest number likely to be treated in a single workday.

The OCS lacks data on exposure to dichlorvos through watering can application, and neither POEM nor PHED have models for this application method. Nevertheless, the potential for operator exposure is probably similar to that arising from application by the wooden board method. In Scenario 7 (above), a dermal MOE of 17 was estimated for an operator applying 250 g dichlorvos by the wooden board method while wearing gloves and overalls, while the inhalation MOE would be 35 if a full facepiece respirator was worn. The aggregate MOE for an operator wearing this combination of PPE was 11. If 200 g dichlorvos was handled and applied by watering can using the same PPE, the dermal, inhalation and aggregate MOEs would be 21, 44 and 14, respectively. Although these values are acceptable, it can be seen that the aggregate MOE would be eroded below 10 if the mass of dichlorvos applied exceeded about 275 g.

Conclusions: It appears that if PPE comprising gloves, overalls and a half facepiece respirator were worn, exposure from application of dichlorvos via watering can may remain within acceptable levels, assuming that the pattern and extent of operator exposure are similar to those associated with application by the wooden board method. However, this finding is based on the inference that PCOs are likely to mix and apply no more than 200 g dichlorvos per day when treating domestic households. Even a relatively small increase in the mass of dichlorvos applied per day could cause unacceptable exposure to operators. Therefore, in the absence of information on the treatment rate, the OCS can not support application of dichlorvos by watering can.

Scenario 9: Application of 500 EC formulation as a liquid bait

Factories, stores, mills and food warehouses may be protected against insect pests by diluting dichlorvos 500 EC products to 2.5 g active/L and adding 50 g sugar/L water. The resulting liquid bait may be applied as a coarse spray or painted on in strips or patches where insects harbour. Product labels do not nominate any specific application rate per unit area, which limits the accuracy of any estimates of operator exposure. However, the application rate would probably be similar to those recommended for surface spray treatment of wineries and animal housing and processing facilities (up to 0.2 g/m^2; see Scenario 3).

Application by surface spray

Many of the buildings that may be treated with liquid baits are large, and the area requiring treatment is likely to reach several hundred m^2. As discussed under Scenario 3, dermal and inhalation exposure to dichlorvos would probably occur at the extent measured by Gold and Holcslaw (1984) in their study of PCOs treating domestic housing by surface spray. Given that it is not possible to maintain an acceptable dermal MOE for operators treating a 170 m^2 building by surface spray, even if gloves, chemical resistant clothing and respiratory protection are worn, application of liquid baits by this method can not supported.

Application by paintbrush

Dermal exposure: The only available means of estimating operator exposure to dichlorvos when using this application method is PHED model 22 (paintbrush application), which predicts dermal exposures on the head, body and hands of 5.4, 173.1 and 385 mg/kg active handled, for a total of 564 mg/kg. In the table below, exposure estimates have been prepared for an operator applying 20 g dichlorvos by paintbrush, sufficient to treat 100 m^2 at the anticipated rate. Even in the absence of exposure when mixing the concentrate, MOEs are unacceptable regardless of PPE.

Paintbrush application of Dichlorvos 500 EC –- dermal exposure

Total area (m^2)	Active applied (kg)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.047 mg/kg bw			
			Protective clothing			
			None	Overalls	Overalls + Gloves	Chem resistant clothes + gloves
100	0.02	11.27	0.16097 MOE = 0	0.12143 MOE = 0	0.02243 MOE = 2.1	0.01502 MOE = 3.1

Inhalation exposure: Given that paintbrush application occurs within the operator's breathing zone, significant inhalation exposure to the active constituent would be expected. This is confirmed by the relevant PHED model, which predicts an exposure of 616 µg/kg handled. Applying a 50-fold factor to account for the enhanced volatility of dichlorvos (see Scenario 2), inhalation exposure is estimated at 30.8 mg/kg handled. As shown in the following table, the inhalation MOE would be unacceptable in the absence of respiratory protection, but would be adequate if the operator wore a half facepiece respirator.

Paintbrush application of Dichlorvos 500 EC –- inhalation exposure

Total area (m²)	**Active applied (kg)**	**Exposure (mg)**	**Dose (mg/kg bw) MOE relative to 0.02 mg/kg bw**			
			Respiratory protection			
			None	**Half face**	**Full face**	**Air-hose**
100	0.02	0.616	0.00880 MOE = 2.3	0.00088 MOE = 23	0.00018 MOE = 114	Nil MOE > 10 000

Conclusions: Even if the highest possible level of PPE were worn, there is potential for toxicologically unacceptable dermal exposure to operators when applying dichlorvos as a liquid bait by surface spray or paintbrush. Therefore, this use of dichlorvos should be discontinued.

Scenario 10: Application of 500 EC formulation to bee and wasp nests

Dichlorvos 500 EC products may be diluted to 6 – 10 g/L and sprayed into bee and wasp nests. Up to 1 L of the spraymix can be discharged into each nest. Such activities would be performed outdoors, and operators are likely to use a low pressure handwand fitted with a crack/crevice tool. On most occasions, PCOs would be required to destroy a single nest, with 5 nests being a reasonable "worst case" situation. Exposure estimates will therefore be prepared for an operator handling 50 g dichlorvos and treating 5 nests.

Dermal exposure: The most suitable method of estimating operator exposure is PHED model 37, which is for open pour mixing/loading of liquid formulations and applying them by injection as a termiticide. The algorithm predicts dermal exposures on the head and body to be 0.068 and 29.5 mg/kg active handled, in the absence of PPE. However, the data set upon which the algorithm is based does not include measurements from the unprotected hands. Hand contamination under gloves is predicted at 0.227 mg/kg. Assuming that chemical resistant gloves afford 90% protection, exposure without gloves may be estimated at 2.27 mg/kg handled. Therefore, the total dermal exposure without PPE would be 31.8 mg/kg handled. As shown in the next table, the dermal MOE would be acceptable if overalls are worn.

Application of Dichlorvos 500 EC to insect nests –- dermal exposure

Number of nests treated	**Active applied (kg)**	**Exposure (mg)**	**Dose (mg/kg bw) MOE relative to 0.047 mg/kg bw**			
			Protective clothing			
			None	**Overalls**	**Overalls + Gloves**	**Chem resistant clothes + gloves**
5	0.05	1.591	0.02273 MOE = 2.1	0.00588 MOE = 8.0	0.00442 MOE = 11	0.00126 MOE = 37

Inhalation exposure: PHED model 37 predicts that inhalation exposure for an operator will be 4.84 µg/kg active handled. Applying the 50-fold factor to account for the enhanced volatility of dichlorvos (see Scenario 2, above), the corrected inhalation exposure would be 242 µg/kg active handled. Inhalation MOEs for an unprotected operator mixing/loading and applying 50 g dichlorvos are acceptable.

Application of Dichlorvos 500 EC to insect nests –- inhalation exposure

Number of nests treated	Active applied (kg)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.02 mg/kg bw			
			Respiratory protection			
			None	Half face	Full face	Air-hose
5	0.05	0.012	0.00017 MOE = 116	0.00002 MOE = 1160	0.000003 MOE = 5785	Nil MOE > 10 000

Aggregate exposure: Calculated by the formula 1 ÷ (1/MOE dermal + 1/MOE inhalation), the aggregate MOE for an operator treating 5 insect nests is estimated at 10 if gloves and overalls were worn. Addition of a half-facepiece respirator would yield negligible benefit.

Conclusions: Principally because of the low quantity of dichlorvos that would be applied when eradicating wasp and bee nests, and the method of treatment, the potential for operator exposure is relatively low and can be constrained to acceptable levels by gloves and overalls. Consequently, this use pattern is supported.

Scenario 11: Application of 500 EC formulation to avocados

A further use for dichlorvos 500 EC products is on avocados, applied at 1 L product (500 g dichlorvos)/ha together with 1 kg chlorpyrifos/ha. No application equipment is specified but upwards airblast would be the most probable method in an orchard situation. Up to 30 ha/d can be treated by airblast, which would require 15 kg of dichlorvos and 30 kg chlorpyrifos. This assessment will examine firstly the extent to which mixer/loaders would be exposed to dichlorvos. As both POEM and PHED contain predictive models for mixer/loader exposure in a broadacre setting, estimates will be prepared using each of the two methods.

PHED

Dermal exposure: The estimated whole-body dermal exposure for a mixer/loader handling 15 kg dichlorvos by open pour methods is approximately 15 X 6.92 = 104 mg, and can not be reduced to acceptable levels even by use of chemical resistant clothing and gloves. As discussed in Scenario 2 (above), comparison between PHED algorithms for dermal exposure of mixer/loaders shows that use of enclosed systems confers a 2.7-fold reduction in exposure. Therefore, for an unprotected operator, exposure on the head, body and hands would be reduced from 0.012, 0.662 and 6.25 mg/kg handled to 0.0043, 0.245 and 2.31 mg/kg. However, even mixing 1.5 kg dichlorvos within a closed system, the MOEs are unacceptable irrespective of PPE worn (see following table).

Closed mixing/loading dichlorvos 550 EC for airblast application – dermal exposure

Area treated (ha)	Active applied (kg)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.047 mg/kg bw			
			Protective clothing			
			None	Overalls	Overalls + Gloves	Chem resistant clothes + gloves
3	1.5	3.839	0.05484 MOE = 0	0.05064 MOE = 0	0.00609 MOE = 7.7	0.00530 MOE = 8.9
30	15	38.39	0.5484 MOE = 0	0.5064 MOE = 0	0.0609 MOE = 0	0.0530 MOE = 0

Inhalation exposure: Estimates of inhalation exposure from closed system mixing/loading are shown in the following table, based on a predicted exposure of 9.429 µg/kg active handled (see Scenario 2). At the high work rate of 30 ha/d, a half facepiece respirator would be required to assure an acceptable MOE.

Closed mixing/loading of dichlorvos 500 EC for airblast application –- inhalation exposure

Area treated (ha)	Active applied (kg)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.02 mg/kg bw			
			Respiratory protection			
			None	Half face	Full face	Air-hose
3	1.5	0.01415	0.0002 MOE = 99	0.00002 MOE = 989	0.000004 MOE = 4950	Nil MOE >10 000
30	15	0.1415	0.0020 MOE = 9.9	0.0002 MOE = 99	0.00004 MOE = 495	Nil MOE >10 000

Aggregate exposure: The following table displays the aggregate MOE for a mixer/loader using a closed system to prepare sufficient dichlorvos to treat a 3 ha area, which would require 1.5 kg active to be handled. The table includes estimates of the maximum amount of dichlorvos that could be handled and the largest area that could be treated (based on mixer/loader exposure) while maintaining the MOE at 10. The aggregate MOE is unacceptable and the maximum treatable area is less than 10% of the 30 ha/d work rate achievable by airblast application. Upgrading respiratory PPE to a full facepiece respirator would make negligible difference.

Closed mixing/loading of dichlorvos 500 EC for airblast application – aggregate exposure

PPE	Aggregate MOE at 3 ha/d	Maximum mass (kg) of dichlorvos for MOE >10	Maximum area (ha) that can be treated for MOE >10
Chemical resistant clothing, gloves, half facepiece respirator	8.8	1.32	2.64

POEM

The POEM algorithm for mixer/loaders differs from PHED in that it predicts dermal exposure only on the hands, and does not account for inhalation exposure. Rather than deriving estimates with respect to the mass of active handled, the POEM model is based on estimates of the amount of the concentrate transferred to the hand. This depends on the size and design of the container. Container size dictates the number of pouring operations required in a workday, and also influences the amount of hand contamination per operation. Wide neck containers cause less hand contamination per pouring operation than those of standard width.

In the following table, POEM predictions are shown for operators mixing/loading 30 L of 500 EC formulation (containing 15 kg dichlorvos, sufficient to treat 30 ha) with and without gloves. The "worst case" prediction is for a person transferring from 1 L containers, which would involve 30 pouring operations. Hand contamination is extreme, and is approximately 1.5-fold greater than the PHED prediction for whole-body dermal exposure by open pour methods (150 vs. 104 mg). However, operators are more likely to use containers of 5 L or larger. The lowest predicted extent of hand contamination occurs with 5 L wide neck containers, and is closely comparable to the PHED estimate of whole-body exposure under closed pour conditions (30 vs. 38 mg). Even so, the MOE of 1.1 is an order of magnitude lower than the acceptable level. This result suggests that mixer/loaders could not handle more than about 1.65 kg dichlorvos as a 500 EC formulation, sufficient to treat 3.3 ha. The similarity between this and the PHED maximum estimate of 1.32 kg/2.64 ha is striking.

Mixing/loading dichlorvos 500 EC for airblast application - dermal exposure on hands

Container	Contamination per operation (mL)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.047 mg/kg bw	
			Protective clothing	
			None	Gloves
1 L	0.01	150.0	2.413 MOE = 0	0.214 MOE = 0
5 L Wide neck	0.01	30.0	0.429 MOE = 0	0.043 MOE = 1.1
10 L Wide neck	0.05	75.0	1.071 MOE = 0	0.107 MOE = 0
20 L Wide neck	0.05	50.0	0.714 MOE = 0	0.071 MOE = 0

Conclusions: Exposure modelling by both PHED and POEM suggest the potential for toxicologically significant exposure of mixer/loaders handling sufficient dichlorvos to treat more than 3 ha of avocados, which is considerably less than the anticipated work rate. Both models suggest that exposure could not be reduced to acceptable levels even with the most conservative PPE. This evaluation will not address exposure of persons applying dichlorvos to avocados, and concludes that dichlorvos 500 EC formulations should no longer be used for treatment of avocados.

Scenario 12: Application of 250 EC with 225 g/L chlorpyrifos

There is a single EC product which contains 250 g/L dichlorvos in combination with 225 g/L chlorpyrifos in hydrocarbon solvent at 390 g/L. It is available in 5 L packs, and is intended for the control of insect pests in residential, commercial and industrial situations. The product is diluted to 240 mL (60 g dichlorvos, 54 g chlorpyrifos)/10 L water and applied as a low pressure spray to the point of run-off to cracks, crevices, harbourages and places where pests may occur. No specific application rate is nominated. For use against ants, the preferred technique is direct injection into the nest. The label warns against application inside buildings except as a crack and crevice treatment. Application equipment would most probably comprise a knapsack sprayer or low pressure handwand used in conjunction with a vehicle-mounted tank and pump. The label directs users to open, decant and mix the product only in well-ventilated outdoor areas. For indoor use, operators are advised to close windows and doors and commence application at the furthermost area from entry and work back.

OHS NOELs for chlorpyrifos

An occupational health and safety assessment of chlorpyrifos was performed by the NOHSC in 2000. As with dichlorvos, the most sensitive toxicological end-point with chlorpyrifos is plasma ChE inhibition. This risk assessment will therefore be based on the assumption that the toxicity of dichlorvos and chlorpyrifos will be additive. The OHS risk assessment NOEL was 0.03 mg/kg bw/d, established in a repeat-dose study in humans in which plasma ChE inhibition occurred at the next highest dose of 0.1 mg/kg bw/d. A dermal absorption factor of 3% was used in the OHS risk assessment. Adjusting for the dermal absorption factor, the dermal NOEL for OHS risk assessment purposes is therefore 1.0 mg/kg bw/d. The acceptable MOE is $\geq$ 10, resulting from application of a 10-fold uncertainty factor for intra-species variability. The inhalation absorption of chlorpyrifos was assumed to be complete, and so the inhalation NOEL for OHS risk assessment is 0.03 mg/kg bw/d. Again, the acceptable MOE is $\geq$ 10, resulting from application of a 10-fold uncertainty factor for intra-species variability.

Application by surface spray, and crack and crevice treatment

The final concentration of dichlorvos in the spraymix (6 g/L) is the same as that recommended for the 500 EC formulations when applied in domestic housing. When using the 250/225 dichlorvos/chlorpyrifos EC, operators would therefore be expected to mix, load and apply similar amounts of dichlorvos to the mass handled when using the 500 EC. Buildings that may be treated with the dichlorvos/chlorpyrifos combination product may be large, and the area requiring surface spray treatment may reach several hundred m^2. Although the product is intended for surface spray application only in outdoor situations, this would have little mitigating effect on the extent of dermal exposure to dichlorvos, which would be similar to that measured by Gold and Holcslaw (1984). Based on these authors' findings, as discussed under Scenarios 3 and 9 (above), an acceptable dermal MOE can not be maintained for operators applying dichlorvos by surface spray, even at very low work rates while wearing gloves, chemical resistant clothing and respiratory protection. Consequently, it is not possible to support surface spray application of the 250 EC formulation with 225 g/L chlorpyrifos.

The OCS has no suitable experimental data for estimating operator exposure to dichlorvos and chlorpyrifos when performing crack and crevice treatment, and neither POEM nor PHED contain relevant exposure models. The type of spray equipment used could have a major influence on the extent of exposure. Sprayers fitted with simple orifice tips for insertion into cavities may have significantly lower potential for operator exposure than those designed to produce a flat fan or conical spray jet. In the latter cases, dermal exposure may be similar to that associated with surface spraying, which is toxicologically unacceptable. Given the lack of information on which to base any exposure and risk assessment of the dichlorvos/chlorpyrifos 250/225 EC product, its use as an indoor crack/crevice treatment can not be supported.

Direct injection into ant nests

The dichlorvos/chlorpyrifos 250/225 EC product is diluted to 6 g/L dichlorvos and 5.4 g/L chlorpyrifos and injected into bee and wasp nests. A volume of 1 L is the largest amount of the spraymix likely to be discharged into a nest. Such activities would be performed outdoors, and operators are likely to use a low pressure handwand fitted with a crack/crevice tool. On most occasions, PCOs would not be required to destroy more than 5 nests. Exposure estimates will therefore be prepared for an operator handling 5 L spraymix (30 g dichlorvos and 27 g chlorpyrifos).

Dermal exposure: As discussed under Scenario 10, PHED model 37 (for open pour mixing/loading and application of termiticides) is the most relevant method for estimating operator exposure in this situation. The anticipated dermal exposure on the head, body and hands is 0.068, 29.5 and 2.27 mg/kg active handled, for a total of 31.8 mg/kg handled. In the next table, the dermal exposures to dichlorvos and chlorpyrifos are shown together with their individual and aggregated MOEs. The aggregate dermal MOE would be acceptable if overalls are worn.

Application of Dichlorvos/Chlorpyrifos 250/225 EC to insect nests –- dermal exposure

Active	**Mass applied (kg)**	**Exposure (mg)**	**Dose (mg/kg bw) MOE relative to 0.047 mg/kg bw (dichlorvos) MOE relative to 1.0 mg/kg bw (chlorpyrifos)**			
			Protective clothing			
			None	**Overalls**	**Overalls + Gloves**	**Chem resistant clothes + gloves**
Dichlorvos	0.030	0.955	0.01364 MOE = 3.4	0.00353 MOE = 13	0.00266 MOE = 18	0.00076 MOE = 62
Chlorpyrifos	0.027	0.860	0.01228 MOE = 81	0.00318 MOE = 314	0.00239 MOE = 418	0.00068 MOE = 1471
Aggregate dermal MOEs			3.3	12	17	59

Inhalation exposure: PHED model 37 predicts that inhalation exposure for an operator will be 4.84 µg/kg active handled. An unprotected operator would therefore be exposed to 0.027 X 0.00484 = 0.00013 mg chlorpyrifos, equating to a dose of 0.000002 mg/kg bw. The MOE exceeds 10 000, a value so large that inhalation exposure to chlorpyrifos can be discounted from the risk assessment for ant nest treatment. For dichlorvos, applying the 50-fold factor to account for its enhanced volatility (see Scenario 2) yields a corrected inhalation exposure of 242 µg/kg active handled. As shown in the following table, the inhalation MOE for an unprotected operator mixing/loading and applying 30 g dichlorvos is acceptable.

Application of Dichlorvos/Chlorpyrifos 250/225 EC to insect nests –- inhalation exposure

Active	**Mass applied (kg)**	**Exposure (mg)**	**Dose (mg/kg bw) MOE relative to 0.02 mg/kg bw (dichlorvos)**			
			Respiratory protection			
			None	**Half face**	**Full face**	**Air-hose**
Dichlorvos	0.030	0.00726	0.00010 MOE = 193	0.00001 MOE = 1928	0.000002 MOE = 9642	Nil MOE > 10 000

Aggregate exposure: Calculated by the formula

1 ÷ (1/aggregate MOE dermal [dichlorvos & chlorpyrifos] + 1/MOE inhalation [dichlorvos]),

an aggregate MOE of 11 is estimated for an operator wearing overalls. This value is acceptable but would be eroded below 10 if the operator applied more than 33 g dichlorvos and 30 g chlorpyrifos. A combination of gloves and overalls would assure a more adequate MOE of 16.

Conclusions: Principally because of the low quantity of dichlorvos and chlorpyrifos that would be applied when eradicating ant nests and the method of treatment, the potential for operator exposure is relatively low and can be constrained to acceptable levels by gloves and overalls. Consequently, this use pattern is supported.

Scenario 13: Application of 7 LD formulation with 1 g/L pyrethrins as a surface spray

The LD product, Knock-Down Residual Spray Insecticide, contains dichlorvos (7 g/L), piperonyl butoxide (6 g/L) and pyrethrins (1 g/L) in de-aromatised mineral solvent (780 g/L). It is intended for residual control of arthropods in houses, hospitals, factories and restaurants. The product is sprayed undiluted directly onto or around infested areas. PCOs would probably use hand or knapsack sprayers, or a handwand in conjunction with a vehicle-mounted tank and pump.

The absence of any requirement to prepare a dilute spray mixture would tend to reduce the extent of operator exposure. However, as discussed under Scenario 3 (see above), it is not possible to maintain an acceptable MOE for operators applying sufficient dichlorvos to treat domestic housing or large buildings by indoor surface spray, even if exposure during mixing and loading was eliminated and respiratory protection, gloves and chemical-resistant clothing were worn. Therefore, use of the dichlorvos 7 LD formulation as a surface spray should be discontinued.

Scenario 14: Veterinary administration of 100 PA with 200 g/kg oxibendazole

The formulation is used as an anthelmintic in horses. It is supplied in 25 mL units and presented as a pre-loaded syringe for oral administration. There are no experimental data or models suitable for predicting operator exposure to the active constituents. However, there is some potential for hand contamination, particularly when withdrawing the syringe from the horse's mouth. If 0.1% of the syringe's contents (ie. 25 mg) was transferred onto the operator's hands, this would result in dermal exposure to 2.5 mg dichlorvos and 5.0 mg oxibendazole.

OHS NOEL for oxibendazole

Toxicological assessments of oxibendazole and benzimidazole anthelmintics was performed by the DoHA in 1998 and 1994, respectively. The most sensitive toxicological end-point for oxibendazole is testicular toxicity, seen as reduced absolute and relative testicular weights in a 3-month dog study at 30 mg/kg bw/d. The NOEL in this study was 10 mg/kg bw/d. Although OHS NOELs would not normally be based on organ weight displacements from control values, testicular toxicity appears to have occurred in several studies with benzimidazoles. Therefore, OHS risk assessment NOEL for oxibendazole will be 10 mg/kg bw/d. No data on the dermal absorption of oxibendazole or other benzimidazoles were available for this review. A dermal absorption factor of 100% will therefore be used, and so the dermal NOEL for OHS risk assessment purposes is 10 mg/kg bw/d. The acceptable MOE is $\geq$ 100, resulting from application of 10-fold uncertainty factors for inter-species extrapolation and intra-species variability. Because dichlorvos and oxibendazole have different mechanisms of toxicity, it is assumed that the two chemicals would act independently.

Dermal exposure to dichlorvos and oxibendazole

The following table displays the doses and MOEs associated with dermal exposure to 2.5 mg dichlorvos and 5.0 mg oxibendazole. Although the dermal MOE for oxibendazole is acceptable in the absence of hand protection, gloves would be required to assure an acceptable MOE for dichlorvos.

Veterinary administration of Dichlorvos/Oxibendazole 100/200 PA –- dermal exposure

Active	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.047 mg/kg bw (dichlorvos) MOE relative to 10 mg/kg bw (oxibendazole)	
		Protective clothing	
		None	Gloves
Dichlorvos	2.5	0.03571 MOE = 1.3	0.00357 MOE = 13
Oxibendazole	5.0	0.07143 MOE = 140	0.00714 MOE = 1400

Conclusions: Operator exposure to dichlorvos and oxibendazole can be constrained to acceptable levels by use of gloves when administering the product. Therefore, continued use of dichlorvos in veterinary 100 PA formulations with 200 g/kg oxibendazole is supported, provided the product labels bear appropriate Safety Directions.

6.3 Risk management of exposure during application

Due to its high acute toxicity, volatility and comparatively extensive dermal absorption, dichlorvos presents significant hazards and risks to persons who are occupationally exposed. The published scientific literature contains a number of examples of fatal or severe anti-ChE poisoning among operators who were exposed dermally to concentrated dichlorvos products or spray mixture. Consistent with these observations, the forgoing assessment suggests that mixing, loading and applying dichlorvos in most of its registered situations of use is likely to cause toxicologically unacceptable levels of exposure and risk to operators. Based on exposure modelling, it appears that mixer/loaders can handle no more than approximately 1.4 kg of dichlorvos per day without eroding the MOE below the acceptable value of 10, even if enclosed mixing systems are used and gloves and chemical resistant clothing are worn. This amount of dichlorvos is insufficient to support the anticipated work rates associated with application of dichlorvos by indoor and outdoor fogging/misting, broadacre application to avocados, and particularly for mechanical application to grain. However, operators in the grain handling industry may handle over 50 kg dichlorvos daily when preparing spraymix for application to grain. This suggests that the exposure models used here may over-predict the extent or duration of dermal exposure to dichlorvos during mixing/loading. A suitable exposure study on dichlorvos mixer/loaders or more detailed information on handling practices may permit the exposure and risk assessments to be revised. More detailed information on current handling practices may also be of value.

Operators applying dichlorvos are likely to be exposed extensively by the dermal and inhalation routes. Based on studies in PCOs and on appropriate exposure models, the assessment has shown that even with the highest level of PPE, it is not possible to assure adequate MOEs to protect persons applying dichlorvos indoors or outdoors by surface and space spray. Similarly, MOEs are inadequate in situations where the operator has to remain inside the structure under fumigation while using hand-held CO_2 pressure guns and portable fogging/misting equipment, or applying dichlorvos by watering can or paintbrush. There is insufficient information to predict the extent of operator exposure during indoor crack and crevice treatment. Consequently, these uses of dichlorvos can no longer be supported.

The situations in which operator exposure can be constrained within acceptable limits by use of appropriate PPE are:

- fumigation treatments in which dichlorvos is discharged from pressure cylinders into buildings, sealed chambers or other enclosed spaces using fixed installations, with release being effected from outside the space under treatment;
- fumigation of the airspace within sealable silos, bins or other storage containers for grain or other commodities, where dichlorvos is discharged from manually released pressure cylinders by an operator remaining outside the space under treatment;
- fumigation of machinery and eradication of insect nests in outdoor settings, based on the comparatively low potential for operator exposure while undertaking these tasks; and
- administration of veterinary PA product by pre-loaded syringe.

There are no objections on toxicological grounds to the continuing use of dichlorvos in these situations.

7. ASSESSMENT OF POST-APPLICATION EXPOSURE

7.1 Aerial dissipation and behaviour of dichlorvos residues on solid substrates

According to the IPCS Environmental Health Criteria review of dichlorvos (WHO, 1988), direct application of dichlorvos on crops or animals will result in residues disappearing rapidly by volatilisation and hydrolysis. Airborne dichlorvos arising from fogging, spraying or volatilisation from impregnated strips is hydrolysed in the atmosphere to dimethylphosphate (DMP) and dichloroacetic acid (DCA). Losses occur through ventilation and hydrolysis on surfaces. Depending on the material, dichlorvos may be absorbed and diffuse into the material, or it may be hydrolysed on the surface.

In a laboratory investigation on the relative persistence of a 5% dichlorvos solution on concrete, glass and wood, the fastest loss occurred when the chemical was applied to concrete. After 1 hour, only 0.7% of the applied dichlorvos was present. This rapid loss was almost certainly due to alkaline decomposition. The disappearance rate on glass was less rapid, with a recovery of 1% dichlorvos 3 days after application. Dichlorvos showed the greatest persistence on wood; 65% of the applied dichlorvos still remained after 7 hours, 45-55% remained over days 2 - 18 and 39% remained on day 33 (Hussey & Hughes, 1964).

Dichlorvos is rapidly lost from leaf surfaces. Casida et al (1962) used ^{32}P labelling to study the fate of dichlorvos on the leaves of maize, cotton and pea plants, to which the chemical was applied uniformly to the upper leaf surfaces in a 0.1% aqueous solution. Half the applied material was lost by volatilisation within 5 minutes. A further 45% was absorbed within 20 minutes, with only 5% remaining on the surface at that time. The dichlorvos that penetrated into the leaves rapidly underwent hydrolysis, and had a half-life of 1.2 hours (FAO/WHO, 1971).

A study of dichlorvos residues in avocados (Melksham et al, 1986, cited in the APVMA Chemistry and Residue Evaluation Section's Evaluation Report) showed a rapid decrease in residues in avocado skin following application. Mean dichlorvos residues (N = 3) were 0.62 mg/kg skin immediately after treatment; 0.05 mg/kg skin one day after treatment and < 0.013 mg/kg skin two days after treatment. These values represent total dichlorvos present in the skin. Since slightly over 3 half-lives had elapsed during the first 24 hours, the half-life of dichlorvos in avocado skin must lie between 6 and 8 hours. However, these data cannot be used in a direct estimate of dislodgeable residue levels.

The IPCS Environmental Health Criteria review of dichlorvos (WHO, 1988) contains tabulated summaries of studies on airborne dichlorvos concentrations following treatment of domestic houses or rooms. In unventilated houses treated with 225 or 1200 mL of a 0.5% dichlorvos solution (ie. 1.13 or 6 g dichlorvos) according to typical pest control practices, airborne levels of 0.4, 0.2 and < 0.1 mg dichlorvos/m^3 were detected at 0, 8 and 24 h post-application (Neuwirth & White, 1961). In the same study, the walls of a sealed bathroom were sprayed with 25 mL of 0.5% solution (ie 0.125 g dichlorvos). Airborne dichlorvos levels declined from 1.1 mg/m^3 immediately post-treatment to 0.3 and < 0.1 mg/m^3 at 4 and 24 h, respectively. Sagner & Schondube (1982) discharged dichlorvos from spray cans into the atmosphere of an unventilated experimental "living room" at a rate of 2.3 mg/m^3. At 30 minutes and 1 hour after treatment, dichlorvos was present at 0.24 and 0.13 mg/m^3. When the room was treated by fogging at 240 mg/m^3, airborne dichlorvos levels were 37 mg/m^3 after 1 hour and 5.5 mg/m^3 after 24 hours, in the absence of ventilation. When the room was ventilated, levels of 2.5 and < 0.2 mg/m^3 were reported at 1 and 120 hours post-treatment.

The Environmental Health Criteria review also summarises some studies involving measurement of dichlorvos in the atmosphere of enclosed structures used in plant production. During thermal fogging by swingfog of 6 greenhouses at 0.2 mL (0.28 g) dichlorvos/m^3, the mean airborne concentration of dichlorvos was 16 mg/m^3, with a range of 7 – 24 mg/m^3 (Wagner & Hoyer, 1975). In a tobacco-drying unit used for mushroom production, dichlorvos was sprayed at 8 mL (11.3 g)/100 m^3 and the unit was kept closed for 24 hours. Airborne concentrations decreased from 3.3 to 0.006 mg dichlorvos/m^3 over 24 hours (Grubner, 1972).

7.2 Evaluation of aerial dissipation, surface residue and exposure studies

Brouwer DH et al (1992) Dissipation of aerosols from greenhouse air after application of pesticides using a low-volume technique. Implications for safe re-entry. Chemosphere 24 (9); 1157 – 1169.

Materials and methods

Two replicate experiments were performed in a 2800 m^2 (40 X 70 m) glasshouse used for flower production. The structure had a volume of 7000 m^3 and was ventilated passively by means of windows. The crop height was approximately 60 cm. Dichlorvos, formulated as a 550 g/L EC (Denka Chemie, Voorthuizen, The Netherlands), was applied at a rate of 0.825 kg/ha (8.25 g/100 m^2 or 82.5 mg/m^2 and 33 g/1000 m^3 or 33 mg/m^3), in an application volume of 1 L/ha. Application equipment comprised a Turbofog ULV mister operating at a nominal flow rate of 3 L/min. The mister blower had a capacity of approximately 4850 m^3/h. The volume mean aerodynamic diameter of the aerosol generated was 25 µm. Ninety % of the droplets were less than 40 µm in diameter. The mister was located in a central aisle blowing across the glasshouse, and the blower was started 30 minutes prior to application, to ensure optimal air circulation. The duration of application was approximately 56 min. The glasshouse windows were closed during application. In experiment 1, the windows remained closed for 360 min after application and were not opened before air sampling ceased. In experiment 2, the windows were opened from 330 to 390 min post-application and air sampling continued throughout the ventilation period.

In the first experiment, dichlorvos concentrations in the atmosphere were measured using 2 air sampling stations set up in the recirculating airstream at height of 160 cm above soil level and a distance of approximately 4 m on either side of the blower. A third sampler was positioned approximately 25 m in front of the blower, but offset 10 m to the side. Only 1 side sampler and the front sampler were set up during the second experiment. Each sampler was connected to a 12-inlet manifold equipped with a time-controlled valve system. A high-volume air pump drew air through a glass fibre filter and tandem impingers, each containing 100 mL water. The air was sampled over a 24-min interval immediately prior to the end of application, over the 12 – 24, 24 – 48 and 48 - 72 min periods immediately after application, and over 30 min intervals thereafter until 360 or 390 min post-application. Immediately after each sampling period, the heads were removed from the greenhouse and the filters were transferred to polypropylene tubes, to which 25 mL water was added, preventing loss of dichlorvos through evaporation. The impingers were capped with alfoil. Filters and impingers were stored at 4°C until analysis.

Estimates of surface (deposition) residues were obtained by placing water-filled polystyrene petri dishes near each sampling station at a height of 150 cm. Sampling commenced at the beginning of dichlorvos application and the sampling intervals ranged from 12 to 60 min over the 330 – 360 min following application. Dry petri dishes were also set out during the same sampling intervals. At the end of each sampling interval, 75 mL water was added to each dish to prevent losses of dichlorvos through volatilisation. The difference between the residue levels on the wet and dry dishes was used to estimate the amount of volatilisation during each sampling interval.

Water samples containing dichlorvos were saturated with sodium chloride, extracted with hexane and analysed by GC using a nitrogen-phosphorus or flame-ionisation detector. The LODs were 10 and 200 ug/L hexane with the nitrogen-phosphorus and flame ionisation detectors, respectively. Recovery of dichlorvos from filters, impinger fluid and petri dishes was > 97% and the between-day CV was 6%. Duplicate measurements of both concentration and deposition yielded a CV of 14% for air sampling and 15% for deposition sampling.

The time course of log-transformed concentrations of airborne dichlorvos was analysed by linear regression. Data from air samples where > 10% of the recovered dichlorvos was in the second impinger were excluded. Within each experiment, slopes or regression coefficients of the regression lines were compared by the 2-tailed F test. If no significant difference was observed, parallel lines were assumed and a pooled slope was calculated. Intercepts and regression lines were compared by paired T-test. Air exchange rates were compared by the Mann-Whitney U-test.

Results

The ambient temperature rose from 11.6 to 14 °C during experiment 1 and from 12 to 24 °C during experiment 2. In both experiments, the highest airborne concentrations of dichlorvos were detected at the front sampling station. Levels at the side sampling stations were generally about 20 – 30% lower than those in front of the blower. Dichlorvos concentrations were highest during the final 24 minutes of application and decreased rapidly during the first 1 - 2 hours post-application, with an initial depletion half life of about 30 minutes in both experiments (see following table). However, the rate of depletion decreased progressively with time. This pattern was most marked in experiment 2, during which the concentration of dichlorvos stabilised at approximately 1000 $\mu g/m^3$ between 160 and 330 minutes post-application, and did not fall further until the windows were opened. Airborne dichlorvos levels were consistently about 20 - 30% higher at the front sampling station compared with the side position, but the rate of decrease was identical at all locations. Based on data from the front sampling station, the intercept was 3.84 in both experiments and the slopes of the regression lines were -0.0031 in experiment 1 and -0.0043 in experiment 2 (up until 240 minutes). Both the airborne dichlorvos concentrations and regression slopes differed significantly ($p < 0.0001$) between the two experiments. In addition to the higher ambient temperature during the latter half of experiment 2, the study authors noted that the rate of air exchange was 50% of the rate in experiment 1.

Airborne dichlorvos concentrations (µg/m^3) in glasshouse following mist application*

Sampling interval	Experiment 1	Experiment 2
-24 – 0 min	11080	9910
0 – 12	8860	8080
12 – 24	6105	6015
24 – 48	5045	4190
48 – 72	3685	2815
72 – 102	2826	2120
102 – 132	2205	1580
132 – 168	2045	1130
168 – 204	1465	995
204 – 240	ND	875
240 – 270	930	920
270 – 300	825	1035
300 – 330	ND	1050
330 – 360	715	395^
360 - 390	ND	85^

*All values from front air sampling station.
^Windows open.

The rate of dichlorvos deposition (as measured by the 'wet' petri dishes) ranged from 650 µg/m^2/min immediately after application to approximately 50 µg/m^2/min at 6 hours post-application. Throughout the observation period, the amount of dichlorvos recovered from the 'dry' petri dishes (a measure of net deposition and loss through volatilisation) was consistently about 80% of the amount present on the 'wet' petri dishes. This implies that approximately 20% of the dichlorvos that became deposited on the 'dry' dish surfaces, subsequently re-entered the atmosphere. However, the study authors acknowledged that this result was probably not applicable to dichlorvos deposited on soil or foliage.

Comment

The highest airborne dichlorvos concentrations measured are not necessarily the peak concentrations, which may have been attained during the first 30 minutes of application, before air sampling commenced. The study suggests that the rate of decline of airborne dichlorvos levels in glasshouses depends on environmental conditions, including temperature and air exchange within the structure. Using the data from experiment 2, it is possible to estimate the rate of decrease in dichlorvos concentration during the 60-min period after ventilation commenced. If the initial and final concentrations are taken as 1050 and 85 µg/m^3, respectively, the slope of the Log_{10} concentration vs time curve can be obtained from the equation [Log_{10} initial – Log_{10} final] ÷ Δt. Thus, the gradient of the slope was 3.02 – 1.93 ÷ 60 = 0.018.

Das YT et al (1983) Exposure of professional pest control operator to dichlorvos (DDVP) and residue on house structures. Toxicol Lett 17; 95 – 99.

Materials and methods

Surface residues were measured in a house that had been treated with approximately 66 – 96 g of dichlorvos (0.7 – 1.0 g/m^2 assuming 100 m^2 area). The applicator used a combination of Vapona aerosol insecticide (65 g dichlorvos/L and 4.9 g "related compounds"/L) and spray mixture containing 5 g dichlorvos/L, prepared from Vaponite-2 emulsifiable insecticide (228 g dichlorvos/L and 17 g "related compounds"/L) and applied with a 3.8 L sprayer. No further information on the application procedure was provided, and it is unclear whether the dichlorvos was applied as a space spray, surface treatment, or a combination of both techniques.

Pairs of 10 cm^2 gauze dosimeters were placed on the floor, wall, ceiling, cabinet, table and closet within the house prior to treatment and were assayed at the end of the treatment day. Another set of dosimeters was left in place for 5 days. Further fresh dosimeters were placed on the 2^{nd} – 5^{th} days following treatment and exposed for 24 hours. After exposure, dichlorvos residues on the dosimeters were extracted in n-hexane and analysed by GC. The LOD was not given and no information was presented on the ambient temperature within the treated house during the 5-day period during which dosimeters were exposed.

Results

The concentration of dichloros residues on dosimeters was highest on day 1 and varied markedly between locations, being highest on the floor, ceiling, wall and table. There was also gross variation between the levels present on some pairs of pads placed in the same locations. The reason for this is unknown, due to the limited detail presented on where the dosimeters were placed in relation to the treated areas. Dichlorvos levels on the dosimeters left *in situ* for 5 days were approximately 23% of the initial level. The half-life of dichlorvos on the gauze dosimeters was therefore approximately 2.5 days under the study conditions. Results are presented in the table below.

Dichlorvos residue levels (ug/cm^2) on pairs of dosimeters in a treated house

Day	Floor	Wall	Ceiling	Cabinet	Closet	Table
1	0.491 0.568	0.273 0.052	0.465 ND	0.098 0.085	0.037 0.002	0.295 0.008
5	0.058 0.044	0.053 0.014	0.071 0.087	0.118 0.090	0.014 0.025	0.014 0.072

ND = not determined

Dichlorvos was also detected on dosimeters placed between days 2 and 5. The highest concentrations found were 0.045 ug/cm^2 on the wall and 0.028 ug/cm^2 on the floor, cabinet, ceiling, closet and table. There was no consistent time-related trend towards decreasing residue deposition, and the study authors ascribed the observed fluctuations to variation in air currents, ventilation, temperature and humidity.

Hussey NW & Hughes JT (1963) Report on observations made following the application of DDVP in mushroom houses.

And

Report on observations made on use of DDVP to control mushroom flies at GHCRI Littlehampton. Glasshouse Crops Research Unit. Unpublished.

A study of dichlorvos dissipation following applications to mushroom houses showed rapid volatilisation of dichlorvos after application by space spray. Following application of a 50% EC product as a fine spray at an application rate of 212 mg dichlorvos/m^3, room air concentrations of dichlorvos were 24 mg/m^3 over 0-30 minutes, 4.95 mg/m^3 over 30 minutes - 1.5 hours, 1.05 mg/m^3 over 1.5-2.5 hours and 0.30 mg/m^3 over 6.5-17 hours. The house was kept closed and unventilated during this period. The half-life of airborne dichlorvos over the monitoring period was approximately 2 hours.

Following application of the 50% EC product as a 10% solution (ie. approximately 5 g active/L) by the wooden board method, using a watering can, at a rate of 2010 mg dichlorvos/m^3, room air concentrations of dichlorvos were 0.80 mg/m^3 at 0-17 hours, 0.31 mg/m^3 at 40-57 hours, 0.03-0.10 mg/m^3 over days 4 to 8 and $\leq$ 0.02 mg/m^3 at days 11 and 14-15. No information was provided on ventilation during this phase of the study. The half-life of airborne dichlorvos from application until days 4 – 8 was approximately 35 hours.

Comment:

The more prolonged half-life of airborne dichlorvos after wooden board treatment is probably due to gradual volatilisation of dichlorvos from the liquid applied.

Durham WF et al (1959) Toxicological studies of O,O-dimethyl-2,2-dichlorovinyl phosphate (DDVP) in tobacco warehouses. AMA Archives of Industrial Health 20: 30-38

Materials and methods

Thirteen volunteers simulated “standard” warehouse work 1 hour to 4 days after dichlorvos application to tobacco warehouses. Air samples were taken from treated and control warehouses from 2-3 hours to 7 days post application, collected on Celite absorption columns and concentrations of dichlorvos were measured by analysis of phosphorus (Nakamura, 1952). Experimental animals were also used in this study (male and female adult cynomologous and rhesus monkeys and Sherman strain rats). Before exposure and periodically thereafter, blood samples were drawn from the experimental animals (rats appear to have been sacrificed at bleeding) and volunteers for assay of ChE activity by the electrometric method of Michel (1949). The dichlorvos applied was technical grade material manufactured by the Norda Essential Oil and Chemical Co., New York, USA.

The study was conducted in two parts, the first in 1956 and the second in 1957. The 1956 study was undertaken in North Charleston, SC, USA and involved 4 volunteers working in 3 warehouses. Each warehouse was brick with hollow tiles and concrete floor. The gross volume of each warehouse was 8155 m^3 (5125 m^3 of free space around the tobacco hogsheads). The warehouses were closed and described as “relatively tight” during the treatments. Target application rates of 35, 71 and 353 mg/m^3 were used. The required amount of dichlorvos (288, 576 and 2880 g, respectively) was based on the gross volume of the warehouses and mixed with perchlorethylene in a garden sprinkler can and sprinkled on the floor. Prior to treatment, 3 rats/sex were placed in each warehouse and 2 monkeys were placed in the warehouses treated at 71 and 353 mg/m^3. The animals remained in the warehouses during treatment and for up to 7 days thereafter. On the day after treatment, pairs of volunteers spent 8 hours in the warehouses treated at 35 or 71 mg/m^3. The next day all 4 men entered the warehouse treated at 353 mg/m^3, where 3 remained for 7 hours. The fourth came out after 4 hours for reasons unrelated to the experiment.

The 1957 study was performed in Winston-Salem, NC, USA and involved 9 volunteers working in 3 warehouses. Each warehouse was 2 storeys tall, of corrugated iron construction with wooden floors. Some circulation of air was available via cracks between the corrugated iron. Only the upper storeys were treated. The gross volume of each warehouse was 12799 m^3 (8665 m^3 of free space around the tobacco hogsheads). Target application rates of 17, 35 and 71 mg/m^3 were used. The required amount of dichlorvos (227, 454 and 908 g, respectively) was mixed with light oil and dispersed as a thermal aerosol using a “TIFA machine”. A fourth untreated warehouse was used as a control. Approximately 24 hours after dichlorvos was applied, 4 rats/sex and 2 monkeys were placed in each of the 4 warehouses. The rats remained in the warehouses for up to 4 days post-treatment. Nine volunteers entered the warehouses at 1, 2 and/or 3 days post-treatment and were exposed to the atmosphere for between 3 and 24 hours in total. However, while the authors stated that the men were exposed “especially” in the 71 mg/m^3 warehouse, no further information was provided.

Two further warehouses were treated twice weekly with dichlorvos at 35 and 71 mg/m^3, respectively. Four rats/sex remaining from the single-application study (above) were placed in the warehouse treated at 71 mg/m^3, where they remained for 18 days (5 treatments) or 46 days (13 treatments). Two monkeys previously held in the 17 mg/m^3 warehouse (above) were placed in the building treated repeatedly at 71 mg/m^3, while another 2 monkeys were moved from the control warehouse to that which was treated repeatedly at 35 mg/m^3. Animals were held on the lower floor while the upper level was treated, then transferred to the upper level approximately 12 hours later. The monkeys appear to have been exposed to 13 treatments.

Results

The concentrations of dichlorvos detected in the atmosphere of the treated warehouses were significantly lower than and correlated poorly with the target levels, implying that either the target levels were not achieved, or that clearance of dichlorvos from the atmosphere was very rapid. The highest concentration measured was 2.2 mg/m^3, present at 4 hours post-application in a warehouse treated at 71 mg/m^3. Seven days post-application, dichlorvos was still detectable at 0.40 mg/m^3 in the atmosphere of the warehouse treated at 353 mg/m^3 but had declined to less than 0.04 mg/m^3 at the lower treatment rates. Given that peak levels were not measured and few samples were taken during the first 12 hours post-treatment, it is not possible to estimate the half-life of airborne dichlorvos under the study conditions.

Concentration of dichlorvos in air of tobacco warehouses at various times after treatment

Interval after treatment	Dichlorvos concentration (mg/m^3) (N = 1 or 2 samples)					
	Application rate using watering can			Application rate using fogger		
	35 mg/m^3	71 mg/m^3	353 mg/m^3	17 mg/m^3	35 mg/m^3	71 mg/m^3
2-3 h	0.60	1.65	-	-	-	-
4 h	-	-	-	1.30	1.50	2.20
12	-	-	-	-	-	0.51
24 h	0.20	0.80	0.90	0.27	0.12	0.14
48 h	<0.30	<0.40	1.4	0.05	0.12	0.15
72 h	-	-	-	0.03	0.06	0.07
7 days	<0.04	<0.04	0.40	-	-	-

Highlighted data coincide with exposure of the human volunteers in the 1956 study.

Experimental animals: In the 1956 study, no clinical signs were observed in either the rats or monkeys exposed to dichlorvos. The study authors interpreted the data on plasma and RBC ChE activity as indicating significant inhibition at 353 mg/m^3, with 41 and 35% depression, respectively in male rats and 20% depression in both enzymes in females on the first day after exposure. However, little confidence can be placed in the finding, given that results were derived from only one animal/sex/group. By contrast, interpretation of results from the monkeys was assisted by baseline measurements of ChE activity and repeated observations from each animal. There was approximately 30% and 75% depression in plasma ChE activity in monkeys exposed at 71 and 353 mg/m^3, respectively, which reversed over the following 20 days. RBC ChE activity at the two concentrations was inhibited by about 33 and 55%, and reversed over approximately 70 days.

In the 1957 study, ChE activity in rats was unaffected by single treatment at any concentration, but although control data were not presented, appeared to decline following multiple treatments at 71 mg/m^3. Plasma ChE activity was reduced by 35% in males exposed for 46 days, compared with those having an 18-day exposure period. No corresponding effect occurred in females, but RBC ChE activity declined by 42% in males and 35% in females between days 18 and 46. A similar pattern was observed in monkeys. There was no apparent effect on ChE activity after a single exposure in the 71 mg/m^3 warehouse, whereas a decline did occur after multiple treatments. Data presented in graphical form showed a clear trend towards increasing ChE inhibition with exposure to an increasing number of treatments, with approximately 35 – 40% inhibition of plasma ChE activity after the 13th and final treatment at 35 and 71 mg/m^3. RBC ChE data are difficult to interpret but the graph suggests approximately 50% inhibition in RBC ChE activity in animals held in the warehouse treated at 71 mg/m^3. Cessation of treatment was followed by a return towards baseline plasma and RBC ChE activity during the subsequent 10 – 30 days.

Humans: In the 1956 study, none of the volunteers showed signs or reported symptoms suggestive of OP intoxication. “Subject 1” developed bronchial asthma during his second day of exposure. Biologically significant ($\geq$ 20%) inhibition in plasma ChE activity was detected in Subjects 2 and 4, respectively after the first day’s exposure (in the 71 mg/m^3 warehouse) and after the second day (in the 353 mg/m^3 warehouse). RBC ChE activity in these men was not affected, but was 38 – 40% lower than baseline levels in Subjects 1 and 3 after the second day’s exposure (see table below). However, in the absence of plasma ChE inhibition in these latter cases, the finding may have arisen from experimental variation in the assay used.

In the 1957 study, Subjects 1 and 6 showed biologically significant ($\geq$ 20%) inhibition in plasma ChE inhibition. However, it is unclear which warehouses the men had been inside during their exposures to dichlorvos. RBC ChE activity was not affected in these or the remaining subjects.

Blood ChE activities of volunteers after simulated work in treated tobacco warehouses

Study and subject number		Time and length of exposure (interval from application to first exposure: total hours spent in warehouse)				ChE activity (% of pre-exposure value) following re-entry on days 1, 2, 3 or 4 post application							
		17 mg/m^3	35 mg/m^3	71 mg/m^3	353 mg/m^3	Plasma				Erythrocyte			
						1	2	3	4	1	2	3	4
1956	1	-	24 h, 8 h	-	48 h: 7 h	92	96	-	-	94	60	-	-
	2	-	24 h, 8 h	-	48 h: 7 h	78	89	-	-	113	92	-	-
	3	-	-	24 h: 8 h	48 h: 7 h	92	95	-	-	88	62	-	-
	4	-	-	24 h: 8 h	48 h: 4 h	85	77	-	-	106	153	-	-
1957 *	1	1 h: 20 h total			-	77	76	82	75	82	103	85	88
	2	12 h: 24 h total			-	102	103	102	103	108	110	121	118
	3	12 h: 13 h total			-	94	93	-	-	91	99	-	-
	4	12 h: 7 h total			-	113	-	-	-	81	-	-	-
	5	2 h: 5 h total			-	83	-	93	-	123	-	118	-
	6	2 h: 3 h total			-	72	-	77	-	98	-	108	-
	7	20 h: 18 h total			-	-	103	106	103	-	86	117	108
	8	22 h: 6 h total			-	-	102	100	116	-	116	106	128
	9	44 h: 15 h total			-	-	-	108	92	-	-	104	113

* most exposures occurred in the warehouse treated at 71 mg/m^3 however the study authors did not provide individual exposures for each warehouse; exposures occurred on multiple days up to 4 days after application

Comment

The achieved inhalation doses of dichlorvos absorbed by the subjects in the 1956 study can be estimated from the atmospheric concentrations measured during their exposure, assuming an inhalation rate of 1.0 m^3/h (light activities), an absorption factor of 70% and a bodyweight of 70 kg. On the first day of exposure, the dose would have been approximately 0.2 mg/m^3 X 8 h X 0.7 X 1.0 m^3/h ÷ 70 kg = 0.016 mg/kg bw for Subjects 1 and 2, and 0.8 mg/m^3 X 8 h X 0.7 X 1.0 m^3/h ÷ 70 kg = 0.064 mg/kg bw for Subjects 3 and 4. On the second day of exposure, the dose would have been 1.4 mg/m^3 X 7 h X 0.7 X 1.0 m^3/h ÷ 70 kg = 0.098 mg/kg bw for Subjects 1 – 3, and 1.4 mg/m^3 X 4 h X 0.7 X 1.0 m^3/h ÷ 70 kg = 0.056 mg/kg bw for Subject 4. However, there may have been additional, unmeasured exposure via dermal contact with dichlorvos residues.

It is not possible to estimate the doses to which the subjects were exposed during the 1957 study, due to inadequate documentation of the warehouses they entered. However, if a person entered the warehouse fogged at 71 mg/m^3 at 12 hours post-application and worked there for 8 hours, their inhalation dose of dichlorvos would have been approximately 0.51 mg/m^3 X 8 h X 1.0 m^3/h X 0.7 ÷ 70 = 0.041 mg/kg bw.

Gold RE & Holcslaw (1984) Dermal and respiratory exposure of applicators and residents to dichlorvos-treated residences. In: Dermal exposure related to pesticide use: discussion of risk assessment (RC Honeycutt, G Zwerg & N Ragsdoleet eds). American Chemical Society Symposum Series No. 273.

And

Gold RE et al (1984) Dermal and respiratory exposure to applicators and occupants of residences treated with dichlorvos (DDVP). J Econ Entomol 77; 430 – 436

Materials and Methods

Twenty domestic residences were treated with dichlorvos as a 0.5% (5 g/L) water-emulsion spray prepared from Vaponite 2EC (24.7% or approximately 250 g dichlorvos/L). The application rate was 0.19 g dichlorvos/m^2 (38.7 mL spray mixture/m^2) and the average residence size was 103$\pm$33 m^2. Temperature and humidity were 26.1°C and 82%, respectively. The spray was applied as a continuous band along the baseboards, doorways, windows, all entrances, under the sink, stove and refrigerator, shelves, cabinets and around plumbing and utility installations. Residents were advised not to re-enter their premises for two hours, but it is unclear whether the premises were ventilated prior to re-entry.

Blood and urine samples were collected from one resident at each premises prior to and then 24 hours after treatment. To monitor environmental exposure, exposure pads were placed on top of the refrigerator, stove, kitchen table and floor and collected two hours post-treatment. Air samplers were also placed in the kitchen/utility area in each house and operated for 24 hours prior to treatment and then at 0-2 and 2-24 hours post-treatment.

Following acetone extraction (exposure pads), dichloromethane extraction (air pump samples) or hexane extraction (urine), dichlorvos was analysed by GC. Serum and RBC ChE activities were measured in blood samples. Following derivatisation and extraction, dichloroacetic acid (a metabolite of dichlorvos) was measured in urine by GC.

Results

Fifteen % of residents reported a headache following re-entry into their premises. The mean pre-application atmospheric concentration of dichlorvos was 9 $\pm$ 4 μg/m^3 (Range: 8 – 18). The greatest mean level of dichlorvos detected by air samplers was during the first 2 hours after application (548$\pm$297 μg/m^3; Range: 131 – 1270). Over the 2 - 24 hour post-application (re-occupation) period, the mean level of dichlorvos was 183$\pm$71 μg/m^3 (Range: 94 - 364). The study authors estimated that residents (who spent a mean of 15.8 hours in their treated residences between 2 and 24 hours post-application) were exposed to 0.078 mg dichlorvos/kg bw, based on a ventilation rate the same as applicators and a mean bodyweight of 75 kg. [A dichlorvos concentration of 364 μg/m^3 appears to have been used for this calculation.] They noted that the potential respiratory exposure to residents was an order of magnitude greater than the applicators, and that the concentration of dichlorvos in the ambient air was greater than detected in the spray operators' breathing zone air. This was because the fixed air samplers were located in the kitchen/utility areas, where 50 – 60% of the spray mixture was applied. In addition, the spray operators were continually moving to untreated areas of the houses. The mean level of dichlorvos detected on the exposure pads situated within the residences was 0.319$\pm$0.183 μg/cm^2/h up to 2 hours post-application (ie. 0.638 μg/cm^2).

By comparison with baseline levels, 24-hour post-treatment serum ChE activity rose by up to 12.4% in 5 of the 20 residents but this was offset by a decline of up to 27.6% in 14 others. Overall, there was a slight (7.9%) though significant reduction ($p<0.05$) in mean serum ChE activity at 24 hours post-application. RBC ChE activity was decreased by up to 37.5% in some residents but was increased by up to 30.9% in others. The mean percentage change from baseline was zero. No information was presented which would enable any correlation to be made between the duration of residents' exposure and the extent of ChE inhibition. No dichloroacetic acid was detected in the urine of residents.

Comment

During the first 24 hours post-application, the half-life of airborne dichlorvos was approximately 8 hours. Residents spent an average of 15.8 hours in their treated premises. Estimated inhalation doses for residents are tabulated below. It is assumed that the residents were sedentary throughout the exposure period and absorbed 70% of inhaled dichlorvos.

Estimated inhalation doses for residents following treatment of homes with dichlorvos

Age group	Bodyweight (kg)	Ventilation rate (m^3/h)	Dose (mg/kg bw) at 183 μg/m^3	Dose (mg/kg bw) at 364 μg/m^3
Adults	70	0.5	0.014	0.029
Children 1 – 12 y	23	0.4	0.035	0.070
Infants < 1 y	8	0.4	0.101	0.202

The true extent of exposure was probably higher than estimated because of additional absorption of dichlorvos via the dermal route. This study suggests that toxicologically significant exposure of residents (especially infants) can occur following the application of dichlorvos. Although this study has some limitations in methodological reporting, it may be used for risk assessment purposes.

McDonald EC (1991) Indoor fogger dermal and inhalation exposure study with DDVP. Study No. 4-02-333. Lab: British Columbia Research Corporation, Vancouver, British Columbia, Canada. Sponsor: AMVAC Chemical Corporation, Los Angeles, CA, USA. Study Duration: 11 October 1990 – 21 June 1991. Report date: 21 June 1991.

Quality-assured and GLP-compliant study.

Materials and methods

The objective of this study was to quantify the transfer of dichlorvos from the carpet to human skin in a room treated by aerosol fogging, and to quantify subsequent absorption of dichlorvos through human skin. The study comprised 3 phases: (1) examination of the deposition on and dissipation of dichlorvos from carpet in a treated room; (2) transfer of dichlorvos from the carpet to clothing worn by volunteers; and (3) transfer of dichlorvos from the carpet to bare skin. Four male volunteers participated in phases 2 and 3, and provided pre- and post-exposure urine samples, which were analysed by GC for dimethyl phosphate (DMP), a metabolite of dichlorvos. Inhibition of ChE activity in plasma and RBC was also measured before and after exposure.

The study was undertaken in a number of different rooms in a hotel, in which pesticides had not been applied for at least a year. The rooms were all 5.03 X 3.35 X 2.4 m in size (41 m^3 volume) and had a 72 X 82 cm openable window. In some of the rooms, a structural pillar was situated immediately adjacent to the window. All furniture and fittings except the headboard and a lamp table were removed. A heater fan was placed on the lamp table and set to maintain a temperature of 24 ^oC. The hotel had a central forced-air heating system but the vents within test rooms were sealed to prevent dispersal of dichlorvos into untreated areas of the building. The study authors noted that the test rooms lacked the usual amount of furniture and drapery found in a domestic house, and would have fewer sites for adsorption of dichlorvos vapour. Both factors would have tended to increase the concentration of dichlorvos in the air and on the carpet.

Each room was treated with a single aerosol fogger, placed on a small table in the centre so that the valve was 100 cm above the floor. The foggers were prepared by Chem-Tech Ltd., Des Moines, Iowa, USA and contained 0.53% dichlorvos, 71.5% trichloroethane and 28% propellant A-70 (a mixture of propane and butane). Each fogger released an average of 749 mg active (range: 735 – 786 mg) when completely discharged. The mean treatment rate was therefore 44.4 mg dichlorvos/m^2 or 18.3 mg dichlorvos/m^3. Two hours after treatment, the window was opened for 1 hour, and then closed for the remainder of the study period.

Phase 1:

Three rooms were used. Cotton gauze dosimeters were placed on the floor throughout each room, and further sets of 4 dosimeters were placed at 90^o intervals on and immediately adjacent to the fogger table. These additional “orientation” dosimeters were intended to provide information about the dispersion characteristics of the foggers. The dosimeters had an exposed area of 24 cm^2. Pairs of control dosimeters were collected before treatment, and the “orientation” dosimeters were collected at 2 hours post-treatment. Pairs of the remaining floor dosimeters were collected 2, 3, 4, 5, 7, 9, 11, 15 and 24 hours post-treatment. Field stability control dosimeters were also included.

Dislodgeable residues were collected from 8 areas of carpet per room with 10 cm^2 cotton fabric pieces, which were secured to the underside a wooden block. A 4 kg weight was placed over the block and the assembly was pulled across 125 cm of carpet over a period of approximately 12 seconds. A 56.5 cm^2 area of cloth was in contact with the carpet. The procedure was intended to simulate the pressure exerted by a 10 kg child while walking or crawling. The same sampling times were used as described above, except for omission of the 2-hour sample. Three replicate measurements were taken in each room at each time point. Field recovery samples were prepared by applying known quantities of dichlorvos onto the carpet, which was then subjected to the wiping procedure described above. Field stability samples were also prepared, for which known quantities of dichlorvos were added to fabric samples.

To minimise losses of dichlorvos from dosimeters and fabric samples through volatilisation, the samples were placed into jars of hexane immediately after collection. The jars were stored at room temperature before being transported to and stored within the analytical laboratory under refrigeration. A GC assay was used to quantify dichlorvos on dosimeters and fabric samples. The LOD was 0.5 µg dichlorvos/dosimeter and 0.05 µg/fabric sample. Chlorpyrifos was used as an internal standard. Storage stability control dosimeters were assayed before the experimental phases of the study commenced.

Pairs of air samplers were set up at opposite ends of the test rooms, and at each sampling station, air samples were collected simultaneously on XAD-2 adsorbent resin tubes at heights of 30 and 100 cm above floor level. Air was drawn through the resin tubes at 1 L/min with calibrated air sampling pumps. The sampling periods were for 1 hour pre-treatment and over 2 – 3, 3 – 9, 9 – 15, 15 – 23 and 23 – 25 hours post-treatment. The XAD tubes were held at room temperature prior to transport to the analytical laboratory, where they were stored under refrigeration until extracted with hexane and analysed for dichlorvos by GC. The LOD was 0.02 µg dichlorvos. The study authors included appropriate air-purged and static controls for field recovery, assay recovery and cross-contamination.

Phase 2:

Eight rooms were treated in the same manner as in phase 1. The 4 volunteers performed a standardised JAZZERCISE exercise routine in pairs of treated rooms at 3, 6, 9 and 15 hours after dichlorvos was applied. The exercise routine took 19 minutes and was done once in each treated room. During each exercise routine, the volunteers wore a cotton long-sleeved shirt, tights, gloves, socks and women’s briefs over their own underpants. All articles of clothing were washed with a non-phosphate detergent before the experiment. After each exercise routine, the test clothing was removed and placed in jars filled with hexane. Appropriate procedures were used to minimise the likelihood of inadvertent cross-contamination during removal of the clothing. The participants showered after the final routine. The test clothing was then transported to the analytical laboratory, where they were stored under refrigeration before for GC assay of dichlorvos. The LOD of dichlorvos was 30 µg/shirt, 20 µg/pair of tights, 4 µg/pair of gloves, 1.5 µg/pair of socks and 1 µg/pair of briefs. Appropriate field recovery, assay recovery, storage recovery and negative controls were included.

Gauze dosimeters were placed on the carpet and collected pre-treatment and immediately before the exercise routine was performed. Simultaneously, dislodgeable residues were collected from the carpet. Air samples were collected at 30 cm above floor level over a 1 hour interval before treatment, from 3 hours post-treatment up to when the exercise routine commenced, and for 4 hours during and after the routine. Analytical procedures were the same as in phase 1, except that the LOD of dichlorvos on fabric samples was 0.1 µg/sample, and XAD-2 tubes were stored frozen.

Three of the volunteers and the study director undertook a study of their ventilation rate while performing the exercise routine. They inserted a mouthpiece which was attached to meteorological balloons via a valve. The volume of air inside the balloons was measured and divided by the time taken, to deliver a ventilation rate in L/min.

The volunteers gave 2 pre- and 2 post-exposure blood samples, which were sent to different hospital laboratories for measurement of plasma and RBC ChE activity. The post-exposure blood samples were taken within 24 hours and on the 3rd day after the experiment. The study authors did not specify which analytical methods were used.

Pre-exposure urine samples were collected over a 12-hour period during the 2 days before exposure. Post-exposure samples were collected starting at 9:00 AM on the test day for 12-hour periods up to 72 hours. Urine samples collected at the test site were stored at room temperature until transportation to the laboratory, where they were refrigerated. The total volume of the samples was measured and aliquots were withdrawn and stored frozen until analysis for DMP by GC. Assay recovery, field recovery and storage stability controls were run. Urine samples were also analysed for creatinine.

<u>Phase 3:</u>

This part of the study was undertaken approximately 1 month after phase 2. Four rooms were treated as described previously. The same 4 volunteers performed the exercise routine once in each room while wearing only shorts, 3 hours after the rooms were treated. They remained at the test site for 5 hours after exposure to maximise dermal absorption of dichlorvos, and then showered. Again, gauze dosimeters were placed on the carpet and collected before treatment and prior to the exercise routine, while dislodgeable residues were collected from the carpet at these same times. Air samples were collected over a 1 hour interval before treatment and for 4 hours during and after the routine. The volunteers' clothing was not analysed for dichlorvos residues. One pre-exposure and two post-exposure blood samples were taken and analysed for ChE activity, as described for phase 2. Pre-exposure urine samples were collected as described for phase 2 but the post-exposure collection was extended to 96 hours.

Results

<u>Analytical methods:</u>

Recovery of dichlorvos from gauze dosimeters was approximately 97%. Dosimeters stored at room temperature gave recoveries of 86 – 88%, while recovery from dosimeters stored frozen was $\geq$ 94%. Recovery from phase 1 and 3 field controls was 87% (SD = 1.5%), while lower recovery (mean: 76%, SD = 15%) was observed for field recovery controls in phase 2. Test results were corrected for these recoveries. Dichlorvos was not detected on "blank" field controls.

Recovery of dichlorvos from fabric pieces used for carpet wipes was 100 - 102%, while samples stored for up to 24 hours at room temperature and for up to 14 days at -20 °C yielded recoveries of $\geq$ 98%. Recovery from field controls was 103% (SD = 0.8%) and test results were corrected for this result. Dichlorvos was not detected on "blank" controls.

Mean recovery of dichlorvos from XAD-2 resin tubes and field controls was 95% or greater, and there were no detectable losses from air movement through the tubes. Test air sample results were corrected for recovery. Dichlorvos was not detected on negative control tubes. However, during phase 1 there was evidence of cross-contamination between test and "blank" resin tubes that were stored together under refrigeration, with up to 0.034 µg of dichlorvos being detected in "blank" controls. This was attributed to volatilisation of dichlorvos from the exterior of some tubes from the treated rooms. Cross contamination did not occur between tubes that were stored frozen during the subsequent phases.

Extraction and storage recovery tests on shirts and tights showed recoveries of $\geq$ 94% and $\geq$ 83%, respectively. Field recoveries from shirts, tights and gloves and socks were 98 $\pm$ 1%, 93.9 $\pm$ 0.3%, 97.5 $\pm$ 2.7% and 97.7 $\pm$ 1.1%, respectively. Dichlorvos was not detected on negative control shirts, tights, gloves or briefs, but 6.9 – 8.7 µg dichlorvos was found on 3 pairs of negative control socks. The average value of 7.7 µg was therefore subtracted from test socks and field control socks.

Method extraction recovery of DMP from urine samples stored at 4 °C for 12 hours and frozen for 14 days was 79 and 98%, respectively. Field recovery controls from phases 2 and 3 yielded mean recoveries of 103 ± 4% and 143 ± 3%, for which test results were corrected. The reason underlying the result from phase 3 was not discussed.

Phase 1:

The release of dichlorvos from foggers was uneven. High concentrations of dichlorvos (18.7 – 22.1 µg/cm^2) were deposited on 1 dosimeter on each table, while the remaining 3 dosimeters showed dichlorvos concentrations of only 2.07 – 4.63 µg/cm^2. However, although the highest concentrations of dichlorvos were found on floor "orientation" dosimeters that were directly in line with the most heavily contaminated dosimeters on the fogger tables, distribution of dichlorvos on the floor was comparatively even. For example, in room1, the range of concentrations present on the 4 floor "orientation" dosimeters was 1.90 – 3.12 µg/cm^2. These results suggest that the foggers released the aerosol spray over a 90° arc, and produced some heavy droplets, which tended to land immediately in front of the device.

Over the period spanning 2 – 7 hours after treatment, there was an upwards trend in the concentration of dichlorvos on the floor dosimeters distributed throughout the 3 test rooms. In 2 of the rooms, the concentration subsequently declined, while the concentration continued to rise until 24 hours in the third. The mean results obtained from the 3 rooms are tabulated below. Based on the results from the gauze dosimeters, the study authors were able to account for up to 86% of the dichlorvos that had been applied. The results do not permit estimation of the dissipation half-life of dichlorvos from the floor under the study conditions.

Dichlorvos concentration on dosimeters placed on the floor of 3 treated rooms

Time post-application (h)	Mean concentration (µg/cm^2)*	Standard Deviation	Coefficient of Variation
- 0.5	< 0.02	-	-
2	2.83	0.28	9.9
3	2.74	0.35	12.8
4	3.48	0.27	7.8
5	3.40	0.29	8.5
7	3.79	0.15	4.0
9	3.72	0.21	5.6
11	3.03	0.98	32.3
15	3.13	1.08	34.5
24	3.56	0.60	16.9

*Results are from 2 dosimeters in each of 3 rooms at each time point.

The transfer of dichlorvos residues from the carpet to cotton fabric samples was not extensive. Dislodgeable residue levels never exceeded 0.029 µg dichlorvos/cm^2, and declined rapidly between 4 and 9 hours post-treatment. The half-life of dislodgeable dichlorvos residues over this time interval was approximately 6 hours. However, the rate of decrease in dislodgeable residue levels was markedly less between 9 and 24 hours. It is difficult to estimate a dissipation half-life over this latter period, but it would have exceeded 15 hours. Reproducibility of results was good, with a maximum difference of 20% between the lowest and highest mean quantity of dichlorvos on the cotton fabric samples from the 3 rooms. The transfer coefficient, based on the floor dosimeter residue levels shown in the above table, was 1.06% at 3 hours post-treatment and declined progressively to ¼ of this level. Possible reasons for the decline in transfer coefficient include permeation of dichlorvos into the carpet fibres, migration downward into non-contact areas such as the backing, and adsorption onto dust particles. Results from this section of phase 1 are presented below.

Deposition of dichlorvos on dosimeters drawn across the carpet in 3 treated rooms

Time post-application (h)	Mean concentration (μg/cm^2)*	Transfer coefficient (%)
3	0.029	1.06
4	0.029	0.83
5	0.022	0.65
7	0.017	0.45
9	0.014	0.38
11	0.013	0.43
15	0.012	0.38
24	0.009	0.25

*Results are from 3 replicate measurements in each of 3 rooms.

The concentration of dichlorvos in the atmosphere of the test rooms was consistent regardless of the height from which they were collected, or the location of samplers. The highest average concentration in any individual room was 430 μg/m^3, during the first 2 – 3 hours after treatment (ie. during the venting period). The decrease in airborne dichlorvos levels appeared to be bi-phasic. During the first half of the observation period (including venting) the half-life of airborne dichlorvos was about 8 hours, but there was a lower rate of decrease from 15 hours onwards, with an apparent half-life of 12 hours. Twenty-four hours after application, airborne dichlorvos levels were approximately 20% of the initial concentrations. Results are summarised in the following table.

Dichlorvos concentration in the atmosphere of 3 treated rooms

Time post-application (h)	Mean concentration (μg/m^3)*	Range	Standard deviation	Coefficient of variation
-2 - -1	< 0.28	-	-	-
2 – 3	382	355 – 430	41.9	11.0
3 – 9	292	281 – 307	13.6	4.7
9 – 15	139	131 – 155	13.9	10.0
15 – 23	104	96.2 – 117	11.4	11.0
23 - 25	75.4	69.5 – 86.4	9.5	12.6

*Results are from 2 samples at 30 cm and 2 samples at 100 cm above floor level in each of 3 treated rooms.

<u>Phase 2:</u>

The amounts of dichlorvos on floor dosimeters followed a similar time-related trend to that observed in phase 1, but the concentrations of dichlorvos were approximately 1.6 times higher. The peak mean residue level was 5.9 μg dichlorvos/cm^2, attained at 9 hours post-treatment (see table below). The study authors attributed the higher levels of dichlorvos to a combination of factors: first, the room temperature at the end of the venting period was colder than at the corresponding time during phase 1, and second, a higher correction factor had been applied to compensate for losses during transport/storage than was used in phase 1 (1.32 vs 1.14).

Between 0.15 and 0.23 μg dichlorvos was detected on pre-treatment fabric samples exposed to the carpet in 4 of the rooms used in phase 2. Since these rooms had not been treated during phase 1, the finding was attributed to accidental contamination. The level of contamination was 6 – 13% of the amounts of dichlorvos found post application. The mean concentrations of dislodgeable residues that coincided with the exercise periods are shown in the following table. Even though results were corrected for the background levels on pre-treatment samples, the concentrations of dislodgeable residues were 30 – 50% higher than the corresponding values found in phase 1. The average of the mean concentrations decreased most rapidly between 3 and 9 hours post-application, with a dissipation half-life of approximately 7.5 hours. Transfer coefficients at 3, 6, 9 and 15 hours were very similar to those in phase 1.

Airborne dichlorvos concentrations during phase 2 were similar to those detected during phase 1. The study authors performed regression analysis of the Ln concentration vs time curve and demonstrated that the dissipation of dichlorvos was a first-order process (R^2 = 0.89) with a half-life of 8 hours. The fitted regression equation was Y = -0.0864X + 6.2467, ie. the Y intercept was 6.2467 and the slope was -0.0864. The extrapolated mean concentrations during the 19-minute exercise periods are tabulated below.

Dichlorvos concentrations in treated rooms during exercise routines

Time post-application (h)	Mean conc. on floor dosimeters (µg/cm^2)*	Mean transferable residue conc. (µg/cm^2)**	Transfer coefficient (%)	Mean airborne conc. (µg/m^3)^
3	4.33	0.039	0.90	390
6	5.10	0.030	0.60	299
9	5.90	0.022	0.38	232
15	5.05	0.016	0.31	138

*Results are from 8 dosimeters in each of 2 rooms
**Results are from 4 replicate measurements in each of 2 rooms
^Results are extrapolated from *ln* concentration vs time curve

Dichlorvos was detected on all items of clothing worn by the volunteers during their exercise routines, including underwear. The presence of dichlorvos on the underwear indicates that dichlorvos penetrated through the outer clothing, but the extent of penetration can not be estimated from the available data. The concentration of dichlorvos on the tights, gloves and socks was approximately double the concentration on shirts. This may reflect differences in the duration and/or pressure of contact between the carpet and the various parts of the body. The concentration of dichlorvos on clothing declined with time, to 28 - 38% of the initial levels. Similarly, there was a time-related decrease in the total amount of dichlorvos that became deposited on the volunteers' clothing, which fell to 1/3 of the initial level by 15 hours post-treatment. Results are presented in the following table. Mean transfer coefficients for shirts decreased from 0.91 to 0.31% from 3 to 15 hours, while transfer coefficients for the other clothing fell from 1.64 – 2.15% to 0.42 to 0.52% at these times. Neither plasma nor RBC ChE activity was depressed in the volunteers when measured 1 and 4 days post-exposure.

Distribution of dichlorvos on the clothing of volunteers exercising in treated rooms

	Time post-application (h)			
	3	**6**	**9**	**15**
Conc. on shirts (µg/cm^2)	0.039	0.032	0.027	0.015
Conc. on tights (µg/cm^2)	0.075	0.056	0.046	0.021
Conc. on gloves (µg/cm^2)	0.070	0.054	0.048	0.024
Conc. on socks (µg/cm^2)	0.091	0.051	0.047	0.026
Amount on shirts (µg)	288	237	202	114
Amount on tights (µg)	565	420	347	157
Amount on gloves (µg)	50	38	34	17
Amount on socks (µg)	102	57	52	29
Amount on underwear (µg)	13	11	9	4
Total amount on clothing (µg)	1018	763	644	321

Note: Results are means from 4 volunteers performing exercise routines in 2 treated rooms at each time point.

The study author performed regression analysis of Ln dichlorvos concentration on clothing, the results of which are presented in the following table.

Regression analysis of Ln dichlorvos concentration on volunteers' clothing

Clothing	Line of best fit	Y intercept	Slope	R^2	SEE
Shirts	Y= -0.0768X – 2.990	-2.990	-0.0768	0.8822	0.1287
Tights	Y= -0.1054X – 2.248	-2.248	-0.1054	0.9142	0.1480
Gloves	Y= -0.0869X – 2.389	-2.389	-0.0869	0.7610	0.2231
Socks	Y= -0.0956X – 2.232	-2.232	-0.0956	0.8354	0.1985

Ln % transfer coefficient for clothing was also subjected to regression analysis, and is summarised below.

Regression analysis of Ln % transfer coefficient of dichlorvos from carpet to volunteers' clothing

Clothing	Line of best fit	Y intercept	Slope	R^2	SEE
Shirts	Y= -0.0880X + 0.0944	0.0944	-0.0880	0.7641	0.2242
Tights	Y= -0.1167X + 0.8407	0.8407	-0.1167	0.8542	0.2209
Gloves	Y= -0.0980X + 0.6971	0.6971	-0.0980	0.7923	0.2300
Socks	Y= -0.1095X + 0.8641	0.8641	-0.1095	0.7596	0.2822

The mean ventilation rate of the 3 tested volunteers and study director was 19.7 L/min (range: 17.3 – 22.8) while performing the exercise routine. Using the airborne dichlorvos concentrations at 3, 6, 9 and 15 hours (see above) and assuming a ventilation rate of 20 L/min and an exposure duration of 20 minutes for each routine performed, the study authors calculated that the volunteers would have inhaled 847 µg dichlorvos. If the individual ventilation rates were used (with the study director's rate as a surrogate for Volunteer D), dichlorvos inhalation would have been 790, 845, 964 and 735 µg in the 4 respective volunteers.

The 4 respective volunteers excreted 1544, 857, 771 and 983 µg DMP (mean: 1039) in their urine during the 72 hours following exposure. In 3 cases, the majority of the excretion occurred during the first 12 hours. The remaining subject (Volunteer C) excreted approximately 27% more DMP over the 12 – 24 hour period than between 0 and 12 hours. Low quantities of DMP (35 µg or less) were also detected in the volunteers' pre-exposure urine. This may have arisen from dietary exposure to dichlorvos or another OP pesticide, or may have been caused by interference in the GC assay. Given that background excretion probably accounted for less than 10% of the total measured excretion of DMP, this is considered not to unduly bias interpretation of the results (see table below). DMP excretion over the 60 – 72 hour interval was close to the background level, indicating that most of the metabolite arising from dichlorvos exposure was accounted for in the 72 hour urine save. The study authors noted that the volunteer who excreted the most DMP had fed his dog 30 mg of cythioate (an OP insecticide), about 48 hours after he was exposed to dichlorvos. However, this volunteer had already excreted 1300 µg DMP before handling the cythioate, and so his results have not been excluded from the following data set.

Excretion of DMP in the urine of 4 volunteers exposed to dichlorvos

Time period	Mean excretion (µg)	Standard deviation
12 - 0 h pre-exposure	19.5	10.7
0 – 12 h post-exposure	633	230
12 – 24 h	263	132
24 – 36 h	64.3	39.0
36 – 48 h	70.0	53.0
48 – 60 h	36.3	15.2
60 – 72 h	25.5	12.6

Note: Each volunteer performed 2 exercise routines 3, 6, 9 and 15 hours after rooms were treated with dichlorvos while wearing a shirt, tights, gloves and socks.

Assuming that 100% of absorbed dichlorvos is metabolised to and excreted via the urine as DMP, the study authors calculated that the volunteers' average dose of dichlorvos was 1822 µg, as shown in the following table. The absorbed dose exceeded the estimated inhaled dose by approximately 1000 µg. This is most likely to have arisen from dermal absorption of dichlorvos that penetrated through the clothing.

Estimate of total dichlorvos dose in 4 volunteers exposed in treated rooms

Volunteer	DMP excreted (µg)	Dichlorvos absorbed (µg)*
A	1544	2708
B	857	1503
C	771	1353
D	983	1724
Mean	1038	1822

*Dichlorvos absorbed = DMP excreted X 1.754, the ratio of the molecular weights of dichlorvos (221) and DMP (126).

Phase 3:

Although dichlorvos was not detected on the pre-treatment samples from carpets within the rooms used during phase 3, it was detected in the atmosphere of all 4 rooms at a mean concentration of 0.60 µg/m^3. The dichlorvos was thought to have originated from the phase 2 treatment of the rooms, which had been performed 5 weeks previously. Given that the carpets had been cleaned professionally after phase 2 and background residues were not detected on the carpet before the phase 3 treatments, the airborne dichlorvos may have originated from material deposited on the walls and ceiling.

When the exercise routines were performed at 3 hours post-treatment, the mean concentration of dichlorvos on the floor dosimeters was 3.02 µg/cm^2 and the mean dislodgeable residue level was 0.022 µg/cm^2. The mean airborne concentration of dichlorvos over the 4-hour period during and after the exercise routines was 230 µg/m^3. The study authors estimated that the volunteers were exposed to a concentration of 252 µg dichlorvos/m^3 during their exercise routines. Using the same assumptions outlined above, the study authors estimated that the volunteers were exposed by inhalation to an average of total of 403 µg dichlorvos during the exercise routines. Based on individual breathing rates, inhalation exposure of the 4 respective volunteers would have been 375, 403, 459 and 350 µg dichlorvos.

In phase 3, the volunteers excreted approximately half as much DMP as they had following the phase 2 exposures. Despite making extensive bare skin contact with the treated carpet, the extent of their systemic exposure may have been reduced by performing half as many exercise routines as in phase 2. Cumulative excretion by volunteers A, B, C and D reached 481, 505, 963 and 353 µg DMP over 96 hours (mean: 576 µg). However, the rate of DMP excretion from 48 hours onwards was similar to the background level. As in phase 2, Volunteer C excreted similar amounts of DMP over 0 – 12 and 12 – 24 hours, whereas the other volunteers excreted most of the metabolite during the first 12 hours. According to the study authors, on the day of exposure, Volunteer C visited an apartment that had been treated with an unidentified insecticide. It is unclear whether this contributed to his elevated excretion of DMP, but the similarity between his excretion profile in phases 2 and 3 suggests that most of his urinary DMP originated from dichlorvos.

Excretion of DMP in the urine of 4 volunteers exposed to dichlorvos

Time period	Mean excretion (µg)	Standard deviation
12 - 0 h pre-exposure	13.8	5.2
0 – 12 h post-exposure	333	71.4
12 – 24 h	130	143
24 – 36 h	46.0	50.0
36 – 48 h	26.0	26.5
48 – 60 h	15.3	7.0
60 – 72 h	16.0	5.0
72 – 84 h	22.3	12.9
84 – 96 h	19.5	12.5

Based on the same assumptions described above, the study authors calculated that the volunteers' average dose of dichlorvos was 1110 µg, as shown in the following table. Again, this value significantly exceeds the amount of dichlorvos inhaled, most probably because of dermal absorption of dichlorvos from the treated carpet.

Estimate of total dichlorvos dose in 4 volunteers exposed in treated rooms

Volunteer	DMP excreted (µg)	Dichlorvos absorbed (µg)*
A	481	844
B	505	886
C	963	1689
D	353	619
Mean	576	1110

*Dichlorvos absorbed = DMP excreted X 1.754, the ratio of the molecular weights of dichlorvos (221) and DMP (126).

By comparison with baseline values obtained during the week before exposure, two of the volunteers displayed 5 – 10% inhibition in plasma ChE activity at 24 or 48 hours post-exposure, and 11 – 13% inhibition at 72 hours. This finding may have been biologically significant. However, plasma ChE activity in a third volunteer was reduced by only 1.5% at the first reading, and had increased above baseline activity at the second. A pre-exposure reading was not obtained from the remaining volunteer. There was no correlation between plasma ChE inhibition and the extent of DMP excretion (see above), and nor were effects seen on RBC ChE activity in any of the volunteers.

Comment

This study was exhaustively documented and appropriately controlled, and is highly suitable for exposure and risk assessment for household occupants following re-entry into treated premises, once adjusted for the use rate of dichlorvos in Australia. Assuming 70 kg bodyweight, the average dose of dichlorvos absorbed by the volunteers was 0.026 mg/kg bw in phase 2 and 0.016 mg/kg bw in phase 3.

In this study, the authors estimated the doses of dichlorvos that were absorbed by the volunteers, using the quantity of DMP that was excreted in their urine over 72 – 96 hours post-exposure. They assumed that there was a 1:1 stoichiometric ratio between the amount of dichlorvos absorbed and the amount of DMP excreted. This assumption was based on a supplementary part of a dermal absorption study in rats by Jeffcoat (1990), which was not included in the report evaluated by the OCS (2004). Jeffcoat (1990) applied 325 µg dichlorvos to the skin of 4 rats, and quantified the urinary excretion of DMP for 24 hours post-administration. The animals excreted an average of 51% of the dichlorvos dose as DMP (range: 37 – 82 µg). The recovery of DMP was unexpectedly high, given that the greatest extent of dermal absorption occurring in the main study was approximately 30%. Noting that there was insufficient urine to permit measurement of DMP recovery, the study authors suggested that the result may have arisen from experimental imprecision. The OCS considers this explanation to be reasonable, and that the study does support the assumption that all dichlorvos that is absorbed dermally will be excreted in the urine as DMP.

If the amount of dichlorvos inhaled by the volunteers is corrected for the 70% inhalation absorption factor (see Section 4) and subtracted from their estimated total dose, it is possible to estimate the amount of the chemical that was absorbed dermally. As illustrated in the following table, approximately 67 and 75% of the total dose was absorbed dermally in phases 2 and 3, respectively.

Estimate of dermal absorption of dichlorvos by 4 volunteers

Phase of study	Mean µg total dichlorvos absorbed	Mean µg dichlorvos absorbed via inhalation*	Dichlorvos absorbed dermally (µg)	Ratio inhalation:dermal intake
2	1822	593	1229	1:2.1
3	1110	282	828	1:2.9

*Estimated µg dichlorvos inhaled X 0.7

Dermal intake may have been enhanced in phase 3 because the volunteers made extensive bare skin contact with dichlorvos on the carpet. However, the extent of dermal absorption during phase 2 is remarkable, given that only the volunteers' facial skin was uncovered. The findings suggest that a significant proportion of the dichlorvos on the volunteers' clothing penetrated through the material and was subsequently absorbed across the skin. The mean dermally absorbed dose (1229 µg) is approximately 22% of the cumulative mean mass of dichlorvos detected on the external clothing [which was (1018 X 2) + (763 X 2) + (644 X 2) + (321 X 2) = 5492 µg].

The data from phase 3 may be used to verify the accuracy of the dermal absorption factor of 30% estimated for dichlorvos over an 8 hour workday (see Section 4). From the phase 2 exposure data set, the volunteers would have been exposed to a cumulative total of 4 X 1018 = 4072 µg dichlorvos via the dermal route when performing their exercise routines. The dichlorvos remained on the skin for 5 hours, until the volunteers showered. If the dermal absorption factor is reduced to 5/8 of 30% (ie. to 19%), accounting for the shorter duration of exposure, then the dermal intake would have been 0.19 X 4072 = 764 µg. This value is very close to the 828 µg estimated experimentally. Hence, the 30% dermal absorption factor for an 8 hour workday is considered appropriate.

Schofield CM (1993a) Exposure assessment of dichlorvos in a food handling establishment: Manufacturing facility. Study No. SARS – 92 – 15. Labs: Stewart Agricultural Research Associates, Inc., Macon, MO, USA and Horizon Laboratories Inc., Columbia, MO, USA. Sponsor: AMVAC Chemical Corporation, Los Angeles, CA, USA. Study Duration: 27 October 1992 – 30 April 1993. Report date: 30 April 1993.

Includes: Schofield CM (1993b) Confidential attachment to the above study, dated 30 April 1993.

The study was quality-assured and GLP-certified but did not conform to all conditions required for GLP. The exceptions related to a failure to record pesticide use history and atmospheric conditions at the application site or to maintain SOPs for the pesticide application equipment. In addition, progress inspections were not performed during laboratory analysis.

Materials and methods

The study was conducted at a 7-story baked food manufacturing facility in St Charles, IL, USA to assess the exposure of workers following the use of dichlorvos. Three processing areas on separate floors were selected for evaluation: a 3336 m^3 packaging room (Location 1), a 3021 m^3 room where final products were received from other locations (Location 2), and a 634 m^3 ingredient mixing room (Location 3).

The facility received a single application of dichlorvos (ULD V-500, manufactured by Microgen, containing 5.6% active), at a rate of 2.4 g active/1000 ft^3 (ie. 85 g/1000 m^3). A single portable electric fogger and multiple commercial wall-mounted fogging units were used. Six hours after application, the building was vented for approximately 1 hour before re-entry by the workforce. It is unclear whether the building was ventilated mechanically (via an air conditioning system) or passively during this period or at other times during the study. The temperature range within the facility during the study period was 22 – 26 ^oC. During the 6 months prior to study initiation, the building had been treated once or twice each month with dichlorvos at a rate of 25 g active/1000 m^3. This had last occurred 14 days before the study was performed.

Air samples were collected in XAD-2 resin tubes with stationary air samplers placed centrally in each location at heights representative of sitting and standing breathing zones. The air samplers were calibrated to deliver an airflow of 1.3 L/min. Sampling was performed on the day prior to application and during the 0 – 3, 3 – 6, 6 – 10, 22 – 28 and 42 – 48 hour periods after dichlorvos was applied. Additional air samples were obtained at standing height from two of the locations over the 10 – 15 hour post-application interval. After sampling, the XAD tubes were capped, placed in a screw top tube, sealed and transferred to a freezer for shipment to the analytical laboratory. Appropriate static and air-purged stability controls were prepared to verify the capacity of the XAD tubes and retention of dichlorvos on the resin.

On the day prior to dichlorvos application, isopropyl alcohol hand rinsates were collected from 1 worker within each location at the end of the working day. The procedure was repeated at the mid-shift break and at the end of the day's work on the first and second days post-application, and at mid-shift on day 3. The hand rinsates were stored and shipped frozen to the analytical laboratory. Dichlorvos stability during transport and storage was controlled for by adding known amounts of the chemical to isopropyl alcohol at the study location.

Hand rinsates and air filtration samples were then analysed for dichlorvos. The reference material, analytical grade dichlorvos, was provided by the sponsor (Lot No. KB-40-10-4, purity 99.8%). Dichlorvos residues were desorbed from XAD-2 resin with 1% acetone/iso-octane and quantified by GC. Mean recovery of known amounts of dichlorvos from XAD-2 tubes was 99.2 $\pm$ 4.5% and the LOQ was 0.105 µg/cartridge. Losses from XAD tubes through air purging over 6 hours lay between 4 and 5%. Recovery of dichlorvos from a further set of control XAD tubes analysed concurrently with the test samples averaged 91.7 $\pm$ 16.3%. Results from test samples were presented without correction for recovery.

Hand rinsates were diluted with brine, partitioned against methylene chloride, dried and dissolved in iso-octane prior to analysis by GC. Mean recovery of dichlorvos from isopropanol assay controls was 90.6 $\pm$ 3.0%, but recovery of extra "low level" controls (prepared at the laboratory for consistency with the levels measured in hand rinsings) was 78.8%. The mean recovery from field rinsate controls was 80 $\pm$ 7%. Recovery from a further set of "fortified" controls analysed concurrently with the test samples averaged 86.6 $\pm$ 8.4%. Results from test samples were presented without correction for recovery.

Results

Pre-application: Dichlorvos was detected in the air at all three locations before the test application, at concentrations ranging between 0.001 and 0.004 mg/m^3. At the end of the workday prior to application, totals of 0.20 and 0.27 µg dichlorvos were recovered from the hands of the workers at locations 3 and 1, respectively. These findings were attributed to the building's previous history of treatment with dichlorvos.

Post-application airborne dichlorvos: The decline in airborne dichlorvos levels was biphasic, the first phase being defined by the period spanning application to the end of venting, and the second phase occurring after venting was complete. Similar results were observed at all three locations studied. The results are tabulated below. At the 3 locations tested, the mean time-weighted concentrations of airborne dichlorvos were 8.41 – 11.9 mg/m^3 during the 3 hours immediately post-application, falling to 0.28 – 0.45 mg/m^3 during the 4 – 9 hours following the venting period (ie. 10 – 15 hours post-application). There was some evidence of a relationship between dichlorvos concentration and height, as the levels present in the standing breathing zone were generally about 10% higher than those in the seated breathing zone. The study author's regression analysis of $_{Ln}$concentration vs time had an intercept of 2.996, a slope of -0.4207 and a R^2 of 0.98. The half-life of airborne dichlorvos during this first dissipation phase was 1.6 hours.

During the post-ventilation period, mean time-weighted airborne dichlorvos levels at the 3 locations fell progressively to between 0.03 – 0.07 mg/m^3 by study termination, with a half-life of 12.7 hours. The dichlorvos concentrations in the standing and seated breathing zones were equivalent. The study author's regression analysis of the second phase $_{Ln}$concentration vs time data had an intercept of -0.611, a slope of -0.0544 and a R^2 of 0.74. From the regression analysis, the study authors estimated that the airborne dichlorvos concentration at re-entry was 0.85 mg/m^3.

Mean time-weighted concentrations of dichlorvos in the standing breathing zone at Locations 1, 2 & 3

Time (hours) after application	Range of mean concentrations (mg/m^3)
0 – 3	9.53 - 11.94
3 – 6	2.369 – 3.628
6 – 10*	0.503 – 0.677
10 – 15^	0.278 - 0.456
22 – 28	0.076 - 0.191
42 – 48	0.035 – 0.072

*The building was vented and re-entered during this time interval.
^Location 3 was not sampled during this time interval.

Post-application dermal exposure: Dichlorvos residues were recovered from the hands of all workers participating in the study. The highest amounts of dichlorvos (7.49 – 20.7 µg) were detected on the morning of the first post-application day. Residue recovery during the afternoon of day 1 had decreased by approximately 20 - 73% (53% overall), depending on the location of the workers examined. The trend continued over the subsequent 2 days, such that dichlorvos residues in the final hand rinses had declined to 5.8 – 8.6% of the initial amounts recovered. The author's regression analysis of the $_{Ln}$ mass recovered vs time data had a Y intercept of 2.649, a slope of -0.0526 and a R^2 of 0.72. The [environmental] dissipation half-life of dichlorvos residues recovered from the hands was estimated at 13 hours, a value that closely matches the second-phase airborne half life. Results are summarised in the following table.

Dichlorvos recovery (µg) from hands of 3 workers in a treated building

	Individual shift data		Total daily residues	
Time	**Mean**	**Range**	**Mean**	**Range**
Day 1 mid-shift	13.16	7.49 – 20.7	18.55	13.47 – 27.79
Day 1 end workday	5.39	3.11 – 7.09		
Day 2 mid-shift	1.94	1.06 – 2.95	3.25	1.58 – 5.06
Day 2 end workday	1.31	0.52 – 2.11		
Day 3 mid-shift	1.01	0.59 – 1.77	-	-
Day 3 end workday	0.60*	-		

*Calculated by extrapolation

Comment

Even if the extraction of dichlorvos residues from the human hand was 100% efficient, the amounts detected would be an underestimate of the true extent of dermal exposure, as some dichlorvos would have been absorbed into the skin before hand rinsing was performed. In addition, dichlorvos may have become deposited on other areas of exposed skin that were not examined for residues. However, as can be seen from the following table, the systemic dose of dichlorvos arising from dermal exposure would have been approximately 2 orders of magnitude less than intake via inhalation. The calculations are based on top-of-range data and assume 8 h/d exposure, a ventilation rate of 1.0 m^3/h (light activities), 70% absorption via inhalation, 30% absorption via the skin over 8 hours (15% over 4 hours), and 70 kg bodyweight. The total doses on days 2 and 3 were approximately 1/3rd of the corresponding value on the preceding day.

Estimated intake of dichlorvos by occupants of treated food production facility

Day		Dichlorvos concentration (mg/m^3)	Inhalation intake (mg)	Dermal intake (mg)	Total intake (mg)	Dose (mg/kg bw/d)
Pre-application*		0.004	0.022	0.0001	0.022	0.0003
1	0 – 4 h	0.677	1.896	0.0031	1.899	-
	4 – 8 h	0.456	1.277	0.0011	1.278	-
	0 – 8 h	-	3.173	0.0042	3.177	0.0454
2	0 – 4 h	-	-	0.0004	-	-
	4 – 8 h	-	-	0.0003	-	-
	0 – 8 h	0.191	1.070	0.0007	1.077	0.0154
3	0 – 4 h	-	-	0.0003	-	-
	4 – 8 h**	-	-	0.0001	-	-
	0 – 8 h	0.072	0.403	0.0004	0.404	0.0058

*14 days after building previously treated
**Extrapolation

7.3 Evaluation of dislodgeable foliar residue studies

Armstrong TF (1998a) Determination of transferable turf residues on turf treated with dichlorvos in California. Study No. 98ABG01. Lab: Covance Laboratories Inc., Madison, WI, USA. Sponsor: AMVAC Chemical Corporation, City of Commerce, CA, USA. Study duration: 29 January – 19 June, 1998 Report date: 19 June, 1998.

GLP and quality-assured study performed according to US EPA Occupational and Residential Exposure Test guidelines OPPTS Series 875 Group B: Post application exposure.

Materials and methods

The aim of the study was to determine the dislodgeable residue levels of dichlorvos on turf following 2 sequential foliar broadcast spray applications at the maximum label treatment rate of 2 pints/acre (ie. 0.946 L/4047 m^2 = 2.34 L product/ha or 0.53 kg dichlorvos/ha) and minimum dilution. The product used was DDVP 2E, an EC formulation containing 22.8% dichlorvos (AMVAC Chemical Corporation, Lot No. JF7010998).

The trial was conducted in California on a field that had not been treated with OP pesticides for the preceding 3 years. The treated plot consisted of a 12 X 15 m area containing 40 sub-plots in rows separated by walkways. Air sampler poles were placed in the centre of the treated plot. A control plot was established at a distance exceeding 330 m from the treated area. Two applications were performed under light wind conditions at a 7-day interval with a tractor-mounted boom sprayer at an application rate of 71 – 74 gallons/acre (ie. 269 L/4047 m^2 or 664 L/ha). There was 100% cloud cover and 70% relative humidity during the first application, while the second occurred in clear conditions at a relative humidity of 28%. The ambient temperature during application was 15.6 – 16.7 ^{o}C. There was no rainfall or irrigation within 3 days of the final application.

Turf in groups of 3 treated sub-plots was sampled randomly using a modified California roller method before application, after application and at 0, 2, 4, 8, 12, 24, 48 and 72 hours after the final application. At each sampling, a 69 X 99 cm cotton percale cloth dosimeter was placed under a frame, covered with plastic and compressed onto the turf with 5 passes of a 14.5 kg roller. Dosimeters were then uncovered, sealed in a plastic bag, placed over ice and maintained frozen until laboratory analysis.

In addition, duplicate air samples were collected from 45 and 90 cm above ground level at 0, 2, 4, 8, 12 and 16 hours after the final application to measure volatility. Air was drawn into filters by pumps calibrated to operate at a flow rate of 2 L/min. Filters were stored frozen until shipment. Spray solution samples were collected after each of the 2 applications to confirm the application rate. The study included negative controls and controls for stability of residues collected on dosimeters and air filters during collection, shipment and storage, which were prepared indoors.

Cloth dosimeters were extracted with ethyl acetate. Air filters were extracted with toluene. Spray solution samples were diluted in ethyl acetate. All samples were assayed by GC. The duration from sampling to analysis was 1 – 6 days. The LOQ of dichlorvos was 0.088 ng/cm^2 on the cloth dosimeters, 0.05 µg/layer of air filter (there appear to have been 2 layers per filter) and 20 µg/ mL spray solution. The LOD was 50% of the LOQ.

Results

Analysis of the spray solution samples confirmed that the application rates were within 96.8 $\pm$ 5% of target. There were no dichlorvos residues on the control cloth dosimeter samples and assay recoveries were 102 $\pm$ 1.4%, 90.6 $\pm$ 7.5% and 90.1 $\pm$ 9.9% for spray solutions, air filters and dosimeter samples, respectively. The field recovery of dichlorvos residues on the cloth dosimeters was 80.5 $\pm$ 3.6%.

Results from cloth dosimeters and air filters are summarised in the table below. There was no accumulation of dislodgeable residues between the 2 applications. Following the final application, the half-life of dichlorvos DFRs during daylight was 1.66 hours and dissipation approximated first order kinetics. The slope of the Ln DFR level vs time plot was -10.1049 and the Y intercept was 1.03195, with a correlation coefficient (R) of -0.9086 and an R^2 of 0.8256. However, the dissipation rate decreased during the night and the overall half-life of dichlorvos DFRs was 13.4 hours. DFR levels were markedly enhanced when turf was sampled 12 and 24 hours post-application, which was attributed to formation of dew. Hence, when the entire data set was subjected to regression analysis, the Y intercept was 0.185, the slope was -1.2484, R was -0.5834 and R^2 was 0.3403, indicating a poor fit.

There was a rapid decrease in the airborne concentration of dichlorvos, such that the chemical was no longer detectable at 45 cm above ground by 12 hours post-application. The highest concentrations were present in the first samples, which accounted for spray drift and volatility from the treated turf, whereas dichlorvos in subsequent samples arose from volatility alone. Dissipation obeyed first order kinetics, with a slope of -0.2612, a Y intercept of -0.1733, an R value of 0.9715 and an R^2 of 0.9439. The half-life of airborne dichlorvos was 2.65 hours. Airborne concentrations at 90 cm above ground level over the first sampling period were 1/6th of those present at 45 cm, and declined below detectable levels thereafter.

DFR and airborne levels of dichlorvos following application to turf, California

Sampling time	Mean DFR ± SD (ng/cm^2) (N = 3)	Concentration in air 45 cm above ground (µg/m^3)	Concentration in air 90 cm above ground (µg/m^3)
1 d pre treatment 1	ND	-	-
Treatment 1	16.5 ± 6.68	-	-
1 d pre treatment 2	ND	-	-
Treatment 2	5.58 ± 0.84	8.2	1.3
2 h post treatment 2	0.782 ± 0.108	3.1	ND
4 h post treatment 2	0.293 ± 0.027	1.0	ND
8 h post treatment 2	0.153 ± 0.070	0.1	ND
12 h post treatment 2	3.05 ± 0.64	ND	ND
16 h post treatment 2	-	ND	ND
1 d post treatment 2	0.432 ± 0.143	-	-
2 d post treatment 2	ND	-	-
3 d post treatment 2	ND	-	-

ND = Not detected; LOD for DFRs = 0.044 ng/cm^2

Armstrong TF (1998b) Determination of transferable turf residues on turf treated with dichlorvos in Florida. Study No. 98ABG02. Lab: Covance Laboratories Inc, Madison, WI, USA. Sponsor: AMVAC Chemical Corporation, City of Commerce, CA, USA. Study duration: 13 May – 7 July 1998. Report date: 7 July 1998.

GLP and quality-assured study performed according to US EPA Occupational and Residential Exposure Test guidelines OPPTS Series 875 Group B: Post application exposure.

Materials and methods

The trial was conducted in Florida on a field that had not been treated with OP pesticides for the preceding 3 years. The treated plot consisted of a 13 m^2 area containing 56 sub-plots in rows separated by walkways. A control plot was established at a distance of 49 m from the treated area. The materials and methods used in this study were identical to those described in the evaluation of Armstrong (1998a; see above), except in respect of the parameters discussed hereafter. The two applications of dichlorvos were performed under light wind conditions at a 7-day interval with a "platform backpack sprayer" at an application rate of 56 – 57 gallons/acre (ie. 212 - 216 L/4047 m^2 or 524 - 533 L/ha). There was 10% cloud cover during the first application and 5% cloud cover during the second. The relative humidity during each application was 48%. The ambient temperature during application was 28 – 33 ^{o}C. There was no rainfall or irrigation within 3 days of the final application.

In addition to dichlorvos DFR levels on the turf and airborne dichlorvos concentrations, as described above, total foliar residues were measured on clipped grass samples collected 1, 2, 4, and 8 hours after the final dichlorvos application. Pairs of grass samples were extracted with ethyl acetate and analysed by GC, the LOQ being 0.01 mg/kg. The LOD was 50% of the LOQ.

Results

Analysis of the spray solution samples confirmed that the application rates were within 95 ± 0.7% of target. There were no dichlorvos residues on the control cloth dosimeter samples and assay recoveries were 101 ± 4.6%, 107 ± 5.7%, 79 ± 4.5% and 78.9 ± 7.4% for spray solutions, air filters, grass and dosimeter samples, respectively. The field recovery of dichlorvos residues on the cloth dosimeters was 83.5 ± 9.2%.

The results of the study are summarised in the table below. There was no accumulation of dichlorvos DFRs over the two treatments. The peak DFR level occurred after the initial application, but was only

1/7th of the highest DFR level measured in the California study (Armstrong, 1998a). After the final application, DFR levels on the cloth dosimeters had declined by approximately 90% by 8 hours post-application, but rose slightly at 12 hours before declining to undetectable levels from 24 hours onwards. DFR dissipation approximated to first order kinetics. Regression analysis of Ln-transformed data vs time showed a slope of -4.4369, a Y intercept of 0.3504, an R value of -0.8296 and an R^2 of 0.5844. The half-life of dichlorvos DFRs was 3.74 hours. Losses of DFRs were apparently more rapid during the middle part of the day than in the early morning or evening.

The decline in dichlorvos residues on grass occurred in parallel with the decrease in DFRs, falling from 8.1 to 1.81 mg/kg between 1 and 4 hours post-application. Regression analysis of Ln-transformed data vs time showed a slope of -0.2439, a Y intercept of 1.9853, an R value of -0.9106 and an R^2 of 0.7438. The half-life of dichlorvos on the grass was 2.84 hours.

Dichlorvos was detected in the atmosphere above the test site throughout the 16-hour sampling period, declining by approximately 90% between first and second sampling periods post-application and showing a half-life of 3.99 hours. Regression analysis of Ln-transformed data vs time showed a slope of -0.1738, a Y intercept of 12.3411, an R value of -0.7167 and an R^2 of 0.5126. Airborne dichlorvos concentrations 90 cm above ground were approximately 30% of those present at 45 cm. The peak airborne concentration was approximately twice as high as the corresponding value from the California study.

DFR and airborne levels of dichlorvos following application to turf, Florida

Sampling time	Mean DFR ± SD (ng/cm^2) (N = 3)	Residues on grass (mg/kg) (N = 2)	Concentration in air 45 cm above ground ($\mu g/m^3$)	Concentration in air 90 cm above ground ($\mu g/m^3$)
1 d pre treatment 1	ND	-	-	-
Treatment 1	2.26 ± 0.43	-	-	-
1 d pre treatment 2	ND	-	-	-
Treatment 2	1.86 ± 0.34	-	17.7	6.6
1 h post treatment 2	-	8.10	-	-
2 h post treatment 2	1.38 ± 0.49	3.92	1.4	0.6
4 h post treatment 2	0.48 ± 0.09	1.81	0.6	0.2
8 h post treatment 2	0.14 ± 0.04	1.26	0.2	0.1
12 h post treatment 2	0.29 ± 0.04	-	0.5	0.2
16 h post treatment 2	-	-	0.3	0.1
1 d post treatment 2	ND	-	-	-

ND = Not detected; LOD for DFRs = 0.044 ng/cm^2

Armstrong TF (1998c) Determination of transferable turf residues on turf treated with dichlorvos in Ontario, Canada. Study No. 98ABG03. Lab: Covance Laboratories Inc, Madison, WI, USA. Sponsor: AMVAC Chemical Corporation, City of Commerce, CA, USA. Study duration: 13 May – 21 October 1998. Report date: 21 October 1998.

GLP and quality-assured study performed according to US EPA Occupational and Residential Exposure Test guidelines OPPTS Series 875 Group B: Post application exposure.

Materials and methods

The trial was conducted in Ontario, Canada on a field that had not been treated with OP pesticides for the preceding 3 years. The treated plot consisted of a 14 X 15 m^2 area containing 48 sub-plots in rows separated by walkways. A control plot was established at a distance of 36 m from the treated area. The materials and methods used in this study were identical to those described in the evaluation of Armstrong (1998a; see above), except in respect of the batch of DDVP 2E used (Lot No. JF7010998, 23.0% dichlorvos) and that an additional grass sample was taken 6 hours after the second application. The two applications of dichlorvos were performed under nil to light wind conditions at a 7-day interval with a “platform backpack sprayer” at an application rate of 55 – 56 gallons/acre (ie. 208 - 212 L/4047 m^2 or 514 - 524 L/ha). There was 80% cloud cover during the first application and 50% cloud cover during the second. The relative humidity was 80% during the first application and 74% during the second. The ambient temperatures during the two respective applications were 26 and 17 °C. Very light dew was present during both applications but there was no rainfall or irrigation within 3 days of the final application.

Results

Analysis of the spray solution samples confirmed that the application rates were within 92 ± 5.6% of target. There were no dichlorvos residues on the control cloth dosimeter samples and assay recoveries were 101 ± 4.7%, 94.7 ± 4.4%, 91 ± 3.3% and 99 ± 4.6% for spray solutions, air filters, grass and dosimeter samples, respectively. The field recovery of dichlorvos residues on the cloth dosimeters was 46.5 ± 3.7%. The comparatively low recovery was attributed to volatilisation of dichlorvos during the "spiking" procedure, which was performed outdoors. The results appear not to have been corrected for the low field recovery.

The results of the study are summarised in the table below. There was no accumulation of dichlorvos residues over the two treatments. Dichlorvos DFR levels immediately post-application were higher than those detected in the California or Florida studies, possibly because of the presence of dew. Initial dissipation of DFRs was very rapid, and approximated to first order kinetics with a half life of 0.53 hours. Regression analysis of Ln-transformed data vs time showed a slope of -31.56, a Y intercept of 3.587, an R value of 0.978 and an R^2 of 0.957. DFRs decreased below detectable levels within 8 hours of application, but were again detected 1 day post-application. However, no DFRs were detected at 2 or 3 days post-application.

Losses of dichlorvos residues on grass and in the atmosphere were also rapid, with half-lives of 1.71 and 0.66 hours in the respective media. Eight hours post-application, airborne dichlorvos was no longer detectable but residues on grass were still present, albeit at only approximately 5% of the initial concentration. Regression analysis of Ln-transformed grass residue data vs time showed a slope of -0.406, a Y intercept of 2.668, an R value of 0.986 and an R^2 of 0.972. For Ln air filter residues vs time, there was a slope of -1.052, a Y intercept of -2.914, an R value of 0.985 and an R^2 of 0.969.

DFR and airborne levels of dichlorvos following application to turf, Ontario

Sampling time	Mean DFR ± SD (ng/cm^2) (N = 3)	Residues on grass (mg/kg) N = 2	Concentration in air 45 cm above ground (µg/m^3)	Concentration in air 90 cm above ground (µg/m^3)
1 d pre treatment 1	ND	-	-	-
Treatment 1	31.2 ± 26.1	-	-	-
1 d pre treatment 2	ND	-	-	-
Treatment 2	26.5 ± 3.80	-	14.1	9.4
1 h post treatment 2	-	11.2	-	-
2 h post treatment 2	5.37 ± 1.49	6.66	2.8	2.0
4 h post treatment 2	0.17 ± 0.02	2.07	0.5	0.4
6 h post treatment 2	-	1.18	-	-
8 h post treatment 2	ND	0.66	ND	ND
12 h post treatment 2	ND	-	ND	ND
16 h post treatment 2	-	-	ND	ND
1 d post treatment 2	1.06 ± 1.26	-	-	-
2 d post treatment 2	ND	-	-	-

ND = Not detected; LOD for DFRs = 0.044 ng/cm^2

7.4 Calculation of re-entry and re-handling intervals

Based on the occupational exposure and risk assessment (see Section 6), the OCS has concluded that most uses of dichlorvos can no longer be supported, except administration of veterinary PA products, application of some EC or LD products to insect nests, and indoor application of 50 LD/CO_2 products under conditions that do not involve the operaror's presence within the fumigated structure. (These comprise fumigation of buildings, sealed chambers or other enclosed spaces via fixed installations, or manual fumigation of airspace within sealable silos, bins or other storage containers). Entry into sealed grain storage would not normally be required, and treated grain would seldom be handled manually before the WHP had expired. It is also unlikely that exposure to dichlorvos would result from handling an animal that had received the chemical orally. Hence, calculation of REIs or RHIs for these situations is unnecessary.

Furthermore, re-entry or re-handling intervals need not be estimated for occupants of domestic residences, agricultural workers engaged in avocado production or for other uses that the OCS has recommended should cease because the MOEs for mixer/loaders or applicators are unacceptable. If any of these uses are restored following a revised exposure and risk assessment, then the OCS will calculate suitable REIs. The OCS does not see any requirement to nominate specific REIs where dichlorvos has been applied to machinery or insect nests in outdoor settings, as the chemical is expected to disperse rapidly, thereby limiting the extent to which humans would be exposed.

Re-entry into treated buildings

The label of the sole registered 50 LD/CO_2 product recommends that indoor areas remain closed for 4 hours during treatment, and warns against re-entry within 4 hours of treatment. Label directions stipulate that licensed or authorised personnel must thoroughly ventilate treated premises for 30 minutes prior to re-occupation. Ventilation would undoubtedly reduce the airborne concentration of dichlorvos. However, over a 3-day period, Schofield (1993) detected airborne dichlorvos within a bakery after it had been ventilated for 1 hour post- treatment, and also detected dichlorvos on workers' hands. Indeed, dichlorvos was still present in the building's atmosphere and on workers' hands a fortnight after a previous fumigation. Thus, even if a building is treated once, the occupants may be exposed for many successive days. If a building is treated repeatedly, occupants may be exposed continually. This precludes setting OHS NOELs for building occupants based on single dose exposure, and so the exposure and risk assessment must utilise the OHS dermal and inhalation NOELs already set in Section 4.

Inhalation exposure at ventilation: Entry into treated areas before ventilation may not be necessary if the structure is ventilated mechanically, by means of an air conditioning system. However, if ventilation entails opening doors, windows or vents from inside, PCOs would have to enter and remain within the premises for some time while doing so. This task would probably take only a few minutes, and would seldom exceed 30 minutes. The concentration of dichlorvos vapour to which a PCO would be exposed on re-entry can be estimated from Schofield (1993), in which a large industrial building was fogged with dichlorvos at a target concentration of 85 mg/m^3. Airborne dichlorvos levels were measured for 6 hours after application, and the building was then ventilated for 1 hour. Schofield's regression analysis of L_n concentration vs time data obtained before venting had a Y intercept of 2.996 (which is L_n 20.0 mg/m^3), a slope of -0.4207/h and a R^2 of 0.98. The half-life of airborne dichlorvos during this first dissipation phase was 1.6 hours.

The target rate when applying the Australian dichlorvos 50 LD/CO_2 product is 33 mg/m^3, or 38.8% of the application rate used in Schofield's study. If Schofield's regression plot intercept is adjusted downwards to 2.049 (which is L_n [20.0 X 0.388 = 7.76 mg/m^3]), and the dissipation rate is the same as measured by Schofield, then the airborne concentration of dichlorvos will be $e^{(2.049 + [-0.4207 X 4.0])} = e^{0.366}$ or 1.442 mg/m^3 when the building is re-entered at 4 hours post-application. If the duration of exposure was 30 minutes, then the extent of inhalation exposure would be as shown in the following table. Although the MOE without respiratory protection would be unacceptable, a half facepiece respirator would assure a MOE $\geq$ 10.

Re-entry into building treated at 33 mg dichlorvos/m^3 - inhalation exposure at venting

Airborne dichlorvos conc. (mg/m^3)	Dura-tion (h)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.02 mg/kg bw (dichlorvos)			
			Respiratory protection			
			None	Half face	Full face	Air-hose
1.442	0.5	0.721	0.01030 MOE = 1.9	0.00103 MOE = 19	0.00021 MOE = 97	Nil MOE > 10 000

Inhalation exposure post-ventilation: Schofield (1993) found that persons re-occupying a fogger-treated workplace building are exposed to dichlorvos mainly by inhalation. As an example, dermal and inhalation exposures over the first and third post-treatment workdays are shown in the following table. When compared with the Australian inhalation NOEL, the MOEs are severely inadequate. Dermal exposure (as judged from hand contamination) is approximately two orders of magnitude lower than inhalation exposure, and there are large MOEs. Therefore, dermal exposure need not be taken into account in setting a REI for workplace building occupants.

Re-entry into building treated at 85 mg dichlorvos/m^3 – dermal and inhalation exposure^ during first and third workdays after venting (from Schofield, 1993)

Route of exposure	Time post-exposure	Airborne dichlorvos concentration (mg/m^3)	Exposure (mg)	Dose (mg/kg bw)	MOE*
Inhalation	D1, 0 – 4 h	0.677	2.708	0.06474	0.3
	D1, 4 – 8 h	0.456	1.824		
	D3, 0 – 8 h	0.072	0.576	0.00823	2.4
Dermal	D1, 0 – 4 h	-	0.021	0.00040	118
	D1, 4 – 8 h	-	0.007		
	D3, 0 – 8 h	-	0.0024	0.000034	1388

^Based on top – of – range data
*Relative to 0.020 mg/kg bw/d (inhalation) or 0.047 mg/kg bw/d (dermal)

In Schofield's study, the dissipation half-life of dichlorvos during the post-ventilation period was 12.7 hours. The study author's regression analysis of the post-ventilation L_n concentration vs time data had a slope of -0.0544 and a R^2 of 0.74. This regression line may be used to estimate a REI for buildings treated at 33 mg/m^3, by applying the equation (L_n Initial concentration – L_n Final concentration) ÷ Slope. As discussed in Section 4, to ensure that the inhalation MOE for workers does not fall below 10, the maximum TWA concentration of dichlorvos in the atmosphere over an 8-h workday should be 0.02 mg/m^3. If the dichlorvos concentration at the start of venting is 1.442 mg/m^3 (or $e^{0.366}$, as discussed above) and the slope is -0.0544/h, then the time taken for the concentration to decline to 0.02 mg/m^3 (or $e^{-3.912}$) will be (0.366 – [-3.912]) ÷ 0.0544 = 78.6 hours. Because a REI of 3.3 days would not be meaningful, it should be set at 4 days after the onset of ventilation.

Conclusions: To maintain an acceptable inhalation MOE for a person entering a treated building prior to ventilation, a half-facepiece respirator should be worn. To assure an adequate inhalation MOE for workplace building occupants re-entering a premises treated with dichlorvos 50 LD/CO_2 at the Australian label rate of 33 mg/m^3, a REI of 4 days would have to be applied. The OCS is highly confident in this finding, as it is based on a well-documented and closely relevant exposure study. Therefore, dichlorvos is not suitable for application to buildings which are to be re-occupied within 4 days of treatment.

Re-entry into treated glass- or greenhouses

Workers re-entering treated glasshouses or similar plant production facilities would be exposed to dichlorvos by inhalation and dermal exposure, but the extent of exposure may not be the same as would occur in a large industrial building. The airborne concentrations of dichlorvos in treated glasshouses will influenced by structure layout, temperature, airflow and photochemical degradation, all of which may vary from the conditions in other structures. Furthermore, workers may be exposed to dichlorvos from handling vegetation onto which dichlorvos has been deposited. However, this may not be a significant source of exposure if there is a delay between treatment and handling, given that only about 5% of dichlorvos applied on leaf surfaces remains on the surface after 20 minutes (WHO/IPCS, 1971).

Inhalation exposure pre-ventilation: In a glasshouse misted by Brouwer et al (1992) at 33 mg dichlorvos/m^3, the dissipation kinetics in 2 replicate experiments showed considerable variation, especially after the first 240 minutes post-application. In the first replicate, the glasshouse was unventilated and there was a narrow temperature range (11.6 – 14 ^oC). Airborne dichlorvos levels declined progressively from 8860 to 715 µg/m^3 over 6 hours. When regression analysis of Log_{10} concentration vs time was performed, the Y intercept was 3.84 (or 6900 µg/m^3) and the slope was -0.0031/min. In the second replicate, the dichlorvos concentration fell from 9910 to 875 µg/m^3 over 240 minutes. Regression analysis yielded a Y intercept of 3.84 and a slope of -0.0043/min. However, after

240 minutes the dichlorvos concentration increased to about 1000 µg/m^3. This probably occurred in response to a rise in temperature from 12 to 24 ^oC.

The forgoing data can be used to estimate the concentration of dichlorvos 240 minutes after treatment with dichlorvos 50 LD/CO_2 at the label rate of 33 mg/m^3. Taking the results of Brouwer's first replicate, which demonstrated the slowest initial decline in dichlorvos level, the airborne concentration of dichlorvos at 240 minutes will be $10^{(3.84 + [-0.0031 X 240])} = 10^{3.096}$ or 1247 µg/m^3. A person re-entering the treated glasshouse to ventilate it would therefore be exposed by inhalation at approximately 1.25 mg/m^3. If the duration of exposure was 30 minutes, the worst-case upper limit, the inhalation MOE would be acceptable if a half-facepiece respirator was worn (see next table).

Re-entry into glasshouse treated at 33 mg dichlorvos/m^3 - inhalation exposure at venting

Airborne dichlorvos conc. (mg/m^3)	Dura-tion (h)	Exposure (mg)	Dose (mg/kg bw) MOE relative to 0.02 mg/kg bw (dichlorvos)			
			Respiratory protection			
			None	Half face	Full face	Air-hose
1.247	0.5	0.624	0.00891 MOE = 2.2	0.00089 MOE = 22	0.00018 MOE = 112	Nil MOE > 10 000

Inhalation exposure post-ventilation: In Brouwer's second replicate, the slope of the post-ventilation Log_{10} concentration vs time plot was -0.018. This regression line may be used to estimate a REI for glasshouses treated at 33 mg/m^3, from (Log_{10} Initial concentration – Log_{10} Final concentration) ÷ slope. As discussed in Section 4, to ensure that the inhalation MOE for workers does not fall below 10, the maximum TWA concentration of dichlorvos in the atmosphere over an 8-h workday should be 0.02 mg/m^3 (or 20 µg/m^3). If the dichlorvos concentration at the start of ventilation is 1247 µg/m^3 (or $10^{3.096}$) and the slope is -0.018, then the time taken for the concentration to decline to 20 µg/m^3 (or $10^{1.30}$) will be (3.096 – 1.30) ÷ 0.018 = 100 minutes or 1.66 hours. To allow for environmental variation between different structures, a REI for treated glasshouses and similar plant production facilities should be set at 4 hours after the onset of ventilation.

Conclusions: To maintain an acceptable inhalation MOE for a person entering a treated glasshouse or similar plant production facility prior to ventilation, a half-facepiece respirator should be worn. To assure an adequate inhalation MOE for persons re-entering a glasshouse treated with dichlorvos 50 LD/CO_2 at the label rate of 33 mg/m^3, a REI of 4 hours would have to be applied.

Re-entry into mushroom houses

Little information is available on the off-label use of dichlorvos 50 LD/CO_2 in mushroom production, except that the product is most often applied via fixed installations to spawning rooms, after the rooms have been filled and sealed. Spawning rooms remain closed under controlled atmosphere for 10 days, during which entry would not normally occur. It is unknown whether growers apply dichlorvos 50 LD/CO_2 at the label rate of 33 mg/m^3, or use a different rate.

In a study (Hussey & Hughes, 1963) of dichlorvos dissipation in a closed and unventilated mushroom house sprayed at 212 mg/m^3, there was an initial rapid decline in the airborne concentration of dichlorvos from 24 mg/m^3 over 0 – 30 minutes to 4.95 mg/m^3 over 0.5 – 1.5 hours, and 1.05 mg/m^3 over 1.5 – 2.5 hours. The half-life of airborne dichlorvos during this initial phase would have been approximately 20 minutes. Subsequently, there was a marked reduction in the dissipation rate, with dichlorvos levels decreasing to 0.30 mg/m^3 over 6.5 – 17 hours. During the second phase, the half-life would have been approximately 7 hours.

The OCS has estimated a re-entry interval from these data. If Δt is set at 9.75 hours, using the mid-points of the final two sampling intervals (which were at 2 h and 11.75 hours), the slope of the second phase Log_{10} concentration vs time curve may be calculated as (Log_{10} 1.05 - Log_{10} 0.3) ÷ 9.75 which is (0.0212) – (-0.523) ÷ 9.75 = 0.0558/h. The Y intercept (at t = 0) is $10^{0.0212 + (0.0558 X 2)} = 10^{0.1328}$ or 1.358 mg/m^3.

If the 50 LD/CO_2 product is applied at the label rate of 33 mg dichlorvos/m^3, the application rate will be 15.6% of the rate used in Hussey and Hughes's study. If the regression plot intercept is adjusted downwards to -0.674 (which is Log_{10} [1.358 X 0.156 = 0.212 mg/m^3]), and the dissipation rate is the same as measured by Hussey and Hughes, then it will take (-0.674 – [-1.70]) ÷ 0.0558 = 18.4 hours for the airborne concentration of dichlorvos to decrease to the revised exposure standard of 0.02 mg/m^3. A REI of 24 hours therefore appears to be appropriate for dichlorvos application in mushroom house spawning rooms. However, this value should not be set until the application rate of dichlorvos in mushroom spawning rooms has been confirmed.

The APVMA Agriculture Report indicates that mushroom growers may also apply dichlorvos during or after the growing or picking phases of production, which are undertaken in different rooms than spawning. However, a separate REI for use during growing/picking can not be set because there are no suitable data for estimating the rate of dichlorvos dissipation under these circumstances.

Conclusions: A REI to support the use of dichlorvos 50 LD/CO_2 products in mushroom houses can not be set at present because there is inadequate information on the rates of use or dissipation of dichlorvos in this situation.

Re-handling flowers after treatment in fumigation chambers

Dichlorvos 50 LD/CO_2 is used by some growers for fumigating cut flowers in sealed chambers. Although operators would not be exposed to dichlorvos during fumigation itself, they may be exposed dermally to small quantities of the chemical on the plants when removed from the chamber after treatment. Given that the plants would be handled immediately after fumigation, there would be little opportunity for any dichlorvos residues to degrade or be absorbed into and metabolised by the plants, as discussed in Section 7.1. Exposure to dichlorvos residues from this source could potentially reach unacceptable levels. A dermal exposure of 0.329 mg (or 0.23 µL volume) of dichlorvos is the highest to which an operator could be exposed without eroding the MOE below 10.

Although studies on dichlorvos DFRs have been assessed (see Section 7.3), they were performed outdoors on turf following spray application, and are unsuitable for estimating a RHI for plants after fumigation. Given that it would be unrealistic to pursue additional residue data to support this minor use pattern, the most practical means of obviating any risk is to ensure that operators wear gloves when handling plants immediately after fumigation.

7.5 Risk management of post-application exposure

After indoor application, the fate and behaviour of dichlorvos residues in the air and on surfaces are strongly influenced by a number of environmental parameters. The most important of these are probably the rate of air exchange, temperature and the amount of sunlight entering the structure. However, a proportion of airborne dichlorvos becomes deposited on surfaces, where may degrade or become adsorbed. A significant proportion of deposited dichlorvos can subsequently re-enter the atmosphere (Brouwer et al, 1992). Although dichlorvos decomposes rapidly if it contacts concrete or glass, it persists in carpet fabric (McDonald, 1991) and is highly persistent on wood (Hussey & Hughes, 1963), which may act as reservoirs. Therefore, it is not surprising that dichlorvos has been detected in the atmosphere of buildings fumigated several weeks previously (McDonald, 1991 and Schofield, 1993), and that divergent results were obtained in the available studies on the dissipation of dichlorvos within buildings, glasshouses and mushroom houses.

Consequently, although the OCS has recommended that only one type of product (the 50 LD/CO_2) should be applied within buildings and other structures, it is not possible to nominate a single REI suitable for all situations. Given that dichlorvos was least persistent when applied in a glasshouse, a comparatively short REI of 4 hours after ventilation is suitable for these and similar structures. Dichlorvos was moderately persistent when applied in a sealed mushroom house, but a REI can not be set until the application rate of dichlorvos 50 LD/CO_2 in this situation is confirmed. By contrast, even when adjusting the findings of Schofield (1993) to the lower Australian application rate of dichlorvos 50 LD/CO_2, the experimental evidence shows that workers will be exposed to toxicologically unacceptable airborne concentrations of dichlorvos for 3 days when re-entering a treated industrial building. A 4-day REI would be supportable, but compliance would be impractical in many situations. Therefore, the OCS considers that dichlorvos should not be applied within industrial or similar buildings which are to be re-occupied within 4 days of treatment.

8. SAFETY DIRECTIONS

The OCS Review of the Mammalian Toxicology and Metabolism/Toxicokinetics of Dichlorvos (see the toxicology assessment report at http://www.apvma.gov.au/chemrev/dichlorvos.shtml) has recommended revisions to the hazard-based label Safety Directions for most products, and has also recommended hazard-based statements applicable to other products that are not covered by a FAISD Handbook entry. Based on the exposure and risk assessments performed in Sections 6 and 7, this Occupational Health and Safety Review has identified a need to revise the currently-recommended PPE for use by persons handling and applying dichlorvos 50 LD/CO_2 products, and to recommend appropriate PPE for persons applying the 100 g/L PA with 200 g/L oxibendazole. The revised and new Safety Directions from the Toxicology and OHS Reviews are combined and shown below. New statements are in bold type, while deleted statements are overstruck.

LD 50 g/kg or less in compressed liquid carbon dioxide

130 131 132 **133**	Poisonous if absorbed by skin contact ~~and~~ inhaled **or swallowed**
180	
190	Repeated exposure may cause allergic disorders
207 162 164	Repeated minor exposure may have a cumulative poisoning effect
210 211	
220 **222** 223	Will damage the eyes and skin
373	Avoid contact with eyes and skin
289b* 290 292a 294a 300 303	Do not inhale **vapour or** spray mist
	Obtain an emergency supply of atropine tablets 0.6 mg
~~279 280~~ **289** 290 ~~292~~ **291b** 294 301 303	If applying by fixed installation wear cotton overalls buttoned to the neck and wrist, elbow-length PVC gloves and half facepiece respirator with combined dust and gas cartridge
279 handling plants immediately after fumigation 290 294	~~When opening the container~~, **If applying by hand** wear ~~cotton overalls~~ **chemical resistant clothing** buttoned to the neck and wrist and a washable hat, elbow length PVC gloves and full facepiece respirator with combined dust and gas cartridge or canister
320	
349	When handling plants immediately after fumigation wear elbow-length PVC gloves
	Thoroughly ventilate treated areas before reoccupying
330 331 332	Avoid re-entry for **four hours** after use in glass houses ~~or other confined spaces~~ **or four days in other indoor situations**. If re-entering, wear all protective clothing including respirator
340 341 342	If clothing becomes contaminated with product or wet with spray remove clothing immediately
340 341 343	
350	If product or spray on skin immediately wash area with soap and water
360 361 364 366	If product or spray in eyes, wash it out immediately with water
	After use and before eating, drinking or smoking, wash hands, arms and face thoroughly with soap and water
	After each days use, wash gloves, respirator and if rubber wash with detergent and warm water and contaminated clothing.

*Proposed new statement

100 g/L PA with 200 g/L oxibendazole

130 131 133 180 190 373 160 162 164 210 211 279 283 290 294 340 342 351	Poisonous if absorbed by skin contact or swallowed Repeated exposure may cause allergic disorders Repeated minor exposure may have a cumulative poisoning effect Obtain an emergency supply of atropine tablets 0.6 mg Will irritate the eyes and skin Avoid contact with eyes and skin When using the product wear elbow-length PVC gloves If product on skin immediately wash area with soap and water Wash hands after use

Other products

Safety Directions will be recommended for the remaining product categories (including 1140 and 500 g/L EC and 250 g/L EC with 225 g/L chlorpyrifos) when the OCS receives confirmation of their continuing registration.

REFERENCES

Armstrong TF (1998a) Determination of transferable turf residues on turf treated with dichlorvos in California. Study No. 98ABG01. Lab: Covance Laboratories Inc., Madison, WI, USA. Sponsor: AMVAC Chemical Corporation, City of Commerce, CA, USA. Study duration: 29 January – 19 June, 1998 Report date: 19 June, 1998. [AMVAC; submission to NOHSC, Vol 1 of 8]

Armstrong TF (1998b) Determination of transferable turf residues on turf treated with dichlorvos in Florida. Study No. 98ABG02. Lab: Covance Laboratories Inc, Madison, WI, USA. Sponsor: AMVAC Chemical Corporation, City of Commerce, CA, USA. Study duration: 13 May – 7 July 1998. Report date: 7 July 1998. [AMVAC; submission to NOHSC, Vol 2 of 8]

Armstrong TF (1998c) Determination of transferable turf residues on turf treated with dichlorvos in Ontario, Canada. Study No. 98ABG03. Lab: Covance Laboratories Inc, Madison, WI, USA. Sponsor: AMVAC Chemical Corporation, City of Commerce, CA, USA. Study duration: 13 May – 21 October 1998. Report date: 21 October 1998. [AMVAC; submission to NOHSC, Vol 3 of 8]

Bisby JA & Simpson GR (1975) An unusual presentation of systemic organophosphate poisoning. Med J Australia **2;** 394-395.

Brouwer DH et al (1992) Dissipation of aerosols from greenhouse air after application of pesticides using a low-volume technique. Implications for safe re-entry. Chemosphere 24 (9); 1157 – 1169.

Cavagna G, Locati G & Vigiliani EC (1970) Exposure of new born babies to vapona insecticide. European Journal of Toxicology **3**(1): 49-57. [Kiwi Brands Pty Ltd; sub: 11606, Vol 2 of 4]

Clamp P & Gazzard G (2000) Dichlorvos treatment of structures, showing promise at Newcastle Grain Terminal. GrainCorp Operations Ltd, Sydney, NSW, Australia. At http://sgrl.csiro.au/aptc2000/clamp_gazzard.pdf

Das YT et al (1983) Exposure of professional pest control operator to dichlorvos (DDVP) and residue on house structures. Toxicol Lett 17; 95 – 99.

DoHA (1994) Benzimidazole anthelmintics: review of toxicology profile and poisons schedule classification. Toxicology Evaluation Section, Chemicals Safety Unit, Department of Health and Community Services, Canberra, Australia.

DoHA (1998) Toxicology review of oxibendazole/praziquantel. Chemical Products Assessment Section, Therapeutic Goods Administration, Department of Health and Ageing, Canberra, Australia.

DoHA (1999) Review of the Mammalian Toxicology and Metabolism/Toxicokinetics of Dichlorvos, Chemical Review and International Harmonisation Section, Chemicals and Non-Prescription Drugs Branch, Therapeutics Goods Administration, Department of Health and Ageing, Canberra, Australia.

DoHA (2004) Review of the Mammalian Toxicology and Metabolism/Toxicokinetics of Dichlorvos, Chemicals Review, Office of Chemical Safety, Therapeutics Goods Administration, Department of Health and Ageing, Canberra, Australia.

Durham WF et al (1959) Toxicological studies of O,O-dimethyl-2,2-dichlorovinyl phosphate (DDVP) in tobacco warehouses. AMA Archives of Industrial Health **20;** 30-38 [Novartis; sub: 11605]

FAO/WHO (1971) Pesticide residues in food. Report of the 1970 Joint Meeting on Pesticide Residues. (FAO Agrcultural Studies No. 87; FAO Meeting Report No. 1970/M/12/1; WHO Technical Report Series No. 474. World Health Organization, Geneva, Switzerland. At http://www.inchem.org/documents/jmpr/jmpmono/v070pr07.htm

Gledhill AJ (1996) A study to investigate the effect of a single oral dose of dichlorvos on erythrocyte cholinesterase inhibition in healthy male volunteers. CTL Report No. CTL/P/5393. CTL Study No. XH6064. Lab: Zeneca Central Toxicology Laboratory, Alderley Park, Macclesfield, Cheshire, UK and Medeval Limited, University of Manchester, Manchester Science Park, Manchester, UK. Sponsor: AMVAC Chemical Corporation, unspecified location. Unpublished. [AMVAC; sub: 12161, Vol 38 of 85]

Gledhill AJ (1997a) First supplement to dichlorvos: A study to investigate the effect of a single oral dose of dichlorvos on erythrocyte cholinesterase inhibition in healthy male volunteers. CTL Report No. CTL/P/5393. CTL Study No. XH6064. Lab: Zeneca Central Toxicology Laboratory, Alderley Park, Macclesfield, Cheshire, UK and Medeval Limited, University of Manchester, Manchester Science Park, Manchester, UK. Sponsor: AMVAC Chemical Corporation, unspecified location. Unpublished. [AMVAC; sub: 12161, Vol 41 of 85]

Gledhill AJ (1997b) Dichlorvos: A single blind, placebo controlled, randomised study to investigate the effects of multiple oral dosing on erythrocyte cholinesterase inhibition in healthy male volunteers. CTL Report No. CTL/P/5392. CTL Study No. XH6063. Zeneca Central Toxicology Laboratory, Alderley Park, Macclesfield, Cheshire, UK and Medeval Limited, University of Manchester, Manchester Science Park, Manchester, UK. Sponsor: AMVAC Chemical Corporation, unspecified location. Unpublished. [AMVAC; sub: 12161, Vol 52 of 85]

Gledhill AJ (1997c) First supplement to dichlorvos: A single blind, placebo controlled, randomised study to investigate the effects of multiple oral dosing on erythrocyte cholinesterase inhibition in healthy male volunteers. CTL Report No. CTL/P/5392. CTL Study No. XH6063. Lab: Zeneca Central Toxicology Laboratory, Alderley Park, Macclesfield, Cheshire, UK and Medeval Limited, University of Manchester, Manchester Science Park, Manchester, UK. Sponsor: AMVAC Chemical Corporation, unspecified location. Unpublished. [AMVAC; sub: 12161, Vol 50 of 85]

Gold RE et al (1984) Dermal and respiratory exposure to applicators and occupants of residences treated with dichlorvos (DDVP). J Econ Entomol **77;** 430 – 436

Gold RE & Holcslaw (1984) Dermal and respiratory exposure of applicators and residents to dichlorvos-treated residences. In: Dermal exposure related to pesticide use: discussion of risk assessment (RC Honeycutt,G Zwerg & N Ragsdoleet eds). American chemical Society Symposum Series No. 273. [AMVAC; sub: 12161, Vol 27 of 85]

Handbook of First Aid Instructions and Safety Directions, (2004) Commonwealth Department of Health and Family Services and National Occupational Health and Safety Commission, Australian Government Publishing Service, Canberra.

Hayes AL et al (1980) Assessment of occupational exposure to organophosphates in pest control operators. Am Ind Hyg Assoc **41;** 568 – 575

Hayes WJ (1982) Pesticides studied in man. Williams & Wilkins, Baltomore, MD, USA.

Hunter CG (1970a) Dichlorvos: inhalational exposures with human subjects. Part 1. Report No. TLGR.0061.70. Lab/Sponsor: Shell Research Centre (Tunstall Laboratory), Sittingbourne, UK. Unpublished. [Kiwi Brands Pty Ltd; sub 11606, Vol 2 of 4]

Hunter CG (1970b) Dichlorvos: inhalational exposures with human subjects. Part II. Report No. TLGR.0067.70 Lab/Sponsor: Shell Research Centre (Tunstall Laboratory), Sittingbourne, UK. Unpublished. [Kiwi Brands Pty Ltd; sub 11606, Vol 2 of 4]

Hussey NW & Hughes JT (1963) Report on observations made following the application of DDVP in mushroom houses and Report on observations made on use of DDVP to control mushroom flies at GHCRI Littlehampton. Glasshouse Crops Research Unit. Unpublished.

Hussey NW & Hughes JT (1964) Investigations on the use of dichlorvos in the control of the mushroom phorid *Megaselia halterata* (Wood). Ann Appl Biol **54;** 129 – 139.

Jeffcoat R (1990) Dermal absorption of dichlorvos® in rats. RTI Study No. 4615-1. Lab: Research Triangle Institute, Research Triangle Park, North Carolina, USA. Sponsor: AMVAC Chemical Corporation, Los Angeles, California, USA. Unpublished [AMVAC; sub: 12161, Vol 69 of 85]

Lamb IC (1992) A range-finding acute study of dichlorvos in rats. WIL study No. WIL-188002. Lab: WIL Research Laboratories Inc, Ashland, Ohio, USA. Sponsor: AMVAC Chemical Corporation, Los Angeles, California, USA. Unpublished. [AMVAC; sub: 12161, Vol 18 of 85]

Lamb IC (1993a) An acute neurotoxicity study of dichlorvos in rats. WIL study No. WIL-188003. Lab: WIL Research Laboratories Inc. Ashland, Ohio, USA. Sponsor: AMVAC Chemical Corporation, Los Angeles, California, USA. Unpublished. [AMVAC; sub: 12161, Vol 7, 8 & 9 of 85]

Mathias CGT (1983) Persistent contact dermatitis from the insecticide dichlorvos. Contact Dermatitis **9;** 217 – 218.

McDonald EC (1991) Indoor fogger dermal and inhalation exposure study with DDVP. Study No. 4-02-333. Lab: British Columbia Research Corporation, Vancouver, British Columbia, Canada. Sponsor: AMVAC Chemical Corporation, Los Angeles, CA, USA. Study Duration: 11 October 1990 – 21 June 1991. Report date: 21 June 1991. [AMVAC; submission to NOHSC, Vol 4 of 8]

Menz M et al (1974) Long-term exposure of factory workers to dichlorvos (DDVP) insecticide. Arch Environ Health **28;** 72 – 76.

Morris T (1996a) A study to investigate the effect of a single oral dose of dichlorvos on erythrocyte cholinesterase inhibition in healthy male volunteers (STUDY PROTOCOL). CTL Study No. XH6064. Lab: Zeneca Central Toxicology Laboratory, Alderley Park, Macclesfield, Cheshire, UK and Medeval Limited, University of Manchester, Manchester Science Park, Manchester, UK. Sponsor: AMVAC Chemical Corporation, unspecified location. Unpublished. [AMVAC sub: 12161, Vol 39 of 85]

NOHSC (2000) The NRA review of chlorpyrifos. Occupational Health and Safety Assessment. National Occupational Health and Safety Commission, Sydney, Australia.

Rider JA (1967) Determination of the minimal incipient toxicity of dichlorvos in humans. Report and Study No.s unspecified. Lab: Gastrointestinal Research Laboratory, Franklin Hospital, San Francisco, CA, USA. Sponsor: Shell Chemical Company, Agricultural Chemicals Division, New York, New York, USA. Unpublished. [Kiwi Brands Pty Ltd; sub 11606, Vol 2 of 4]

Schofield CM (1993a) Exposure assessment of dichlorvos in a food handling establishment: Manufacturing facility. Study No. SARS – 92 – 15. Labs: Stewart Agricultural Research Associates, Inc., Macon, MO, USA and Horizon Laboratories Inc., Columbia, MO, USA. Sponsor: AMVAC Chemical Corporation, Los Angeles, CA, USA. Study Duration: 27 October 1992 – 30 April 1993. Report date: 30 April 1993. [AMVAC; submission to NOHSC, Volume 5 of 8]

Schofield CM (1993b) Confidential attachment to: Exposure assessment of dichlorvos in a food handling establishment: Manufacturing facility. Study No. SARS – 92 – 15. Labs: Stewart Agricultural Research Associates, Inc., Macon, MO, USA and Horizon Laboratories Inc., Columbia, MO, USA. Sponsor: AMVAC Chemical Corporation, Los Angeles, CA, USA. Study Duration: 27 October 1992 – 30 April 1993. Report date: 30 April 1993. [AMVAC; submission to NOHSC, Volume 6 of 8]

Thongsinthusak T, Ross JH, Meinders D (1993) Guidance for the Preparation of Human Pesticide Assessment Documents, Department of Pesticide Regulation, California Environmental Protection Agency, HS-1612, May 1993.

Tyl RW, Marr MC & Myers CB (1990a) Developmental toxicity evaluation of DDVP administered by gavage to CD (Spragues-Dawley) rats. RTI ID No. 60C-4629-10/20. Lab: Reproductive and Developmental Toxicology Laboratory, Centre for Life Sciences and Toxicology, Chemistry and Life Sciences, Research Triangle Institute, Research Triangle Park, North Carolina, USA. Sponsor: AMVAC Chemical Corporation, Los Angeles, California, USA. Unpublished.[AMVAC; sub: 12161, Vol 26 of 85]

Tyl RW, Marr MC & Myers CB (1990b) Developmental toxicity evaluation of DDVP administered by gavage to New Zealand White Rabbits. RTI ID No. 60C-4629-30/40. Lab: Reproductive and Developmental Toxicology Laboratory, Centre for Life Sciences and Toxicology, Chemistry and Life Sciences, Research Triangle Institute, Research Triangle Park, North Carolina, USA. Sponsor: AMVAC Chemical Corporation, Los Angeles, California, USA. Unpublished. [AMVAC; sub: 12161, Vol 35 of 85]

UK DEFRA (1995) Dichlorvos: Review of its use in public hygiene and amateur insecticides. Evaluation report by the Health and Safety Executive, Pesticides Registration Section, Bootle, Merseyside, UK. Dated February 1995.

Ueda K & Nishimura M (1967) Effect of vapona/strips to human beings. No Report/Study No. Lab/Sponsor: Japanese Environmental Sanitary Association. Report date: November 1967. Unpublished. [Kiwi Brands Pty Ltd; sub: 11606, Vol 2 of 4]

WHO (1988) Environmental Health Criteria 79. Dichlorvos. World Health Organisation, Geneva, Switzerland. At http://www.inchem.org/documents/ehc/ehc/ehc79.htm

Secondary Citations

[References cited within evaluated studies, toxicological databases, correspondence or Committee records, but not submitted to or assessed by the OCS.]

Grubner P (1972) [Residue problems in the use of phosphoric acid ester insecticides in mushroom cultures.] Nachrichtenbl Pflanzenschutzdienst (DDR) **26;** 245 – 247. (In German)

Jian T & Zhiying F (1990) Chronotoxicological studies on dichlorvos in mice and humans. Environ Sci **2;** 83 -89.

Kirkland VL (1971) Some aspects of acute inhalation pharmacology of dichlorvos in swine. Paper presented at: American Chemical Society for Pharmacology and Experimental Therapeutics and the Division of Medical Chemistry, Burlington, Vermont, 25 August 1971.

Lee MK & Serat WF (1977) A simple method for cholinesterase determination using an expanded scale pH meter. Bull Env Contam Toxicol **17;** 331 - ?

Melksham KJ, Waite GK and Cheyne J (1986) Dichlorvos residues in avocados treated to control leafrollers *Cryptoptila immersana* (Walker) and *Homona spargotis* (Meyrick) (Lepidoptera: Tortricidae). Unpublished.

Michel HO (1949) An electrometric method for the determination of red blood cell and plasma cholinesterase activity. J Lab Clin Med **34;** 1564 - ?

Nakamura GR (1952) Microdetermination of phosphorus. Anal Chem **24;** 1372 - ?

Neuwirth EA & White TT (1961) Safety aspects of DDVP. Soap Chem Spec **37 (3);** 95 – 98.

Sagner G & Schondube M (1982) [Determination and toxicological appraisal of indoor concentrations of dichlorvos after the application of spraying products.] Schriftenr Ver Wasser Boden Luftthyg **53;** 359 – 368. (in German)

Voss G & Sachsse K (1970) Red cell and plasma cholinesterase activities in microsamples of human and animal blood determined simultaneously by a modified acetylthiocholine/DNTH procedure. Toxicol Appl Pharmacol **16;** 764 – 772.

Wagner R & Hoyer J (1975) [Method of determining workplace concentrations and on occupational hygiene conditions during thermal fogging atomization of pesticides in the greenhouse.] Z Gesamte Hyg **21 (1);** 18 – 20. (In German)

ANNEX I

NOHSC OCCUPATIONAL HEALTH AND SAFETY ASSESSMENT

Hazard classification

Dichlorvos is listed in the National Occupational Health and Safety Commission (NOHSC) Hazardous Substances Information System (NOHSC, 2004). It is classified as T+ (Very Toxic) and the following health-related risk and safety phrases apply for labelling purposes:

R26 Very toxic by inhalation
R24/25 Toxic in contact with skin and if swallowed
R43 May cause skin sensitisation by skin contact
S1/2 Keep locked up and out of reach of children
S28 After contact with skin, wash immediately with plenty of soap-suds
S36/37 Wear suitable protective clothing and gloves
S45 In case of accident or if you feel unwell, seek medical advice immediately (show the label whenever possible)

The cut-off concentrations and associated classifications and risk phrases for dichlorvos are as follows:

Conc ≥ 25 %	T+, R26, R24/25, R43
7% ≥ Conc < 25%	T+, R26; R21/22, R43
3% ≥ Conc < 7%	T, R23; R21/22, R43
1% ≥ Conc < 3%	T, R23; R43
0.1% ≥ Conc < 1%	Xn, R20

The additional classifications and risk phrases applying to dilute preparations are:

T	Toxic
Xn	Harmful
R/21/22	Harmful in contact with skin and if swallowed
R23	Toxic by inhalation
R20	Harmful by inhalation

All formulations of dichlorvos are classified as hazardous when they contain $\geq$ 0.1% dichlorvos.

NOHSC Exposure Standards

Several of the products that contain dichlorvos are manufactured in Australia. Persons engaged in the production of dichlorvos products may be exposed throughout each workday for weeks or months in succession. For these individuals, the most likely causes of exposure would be dermal contact with dichlorvos or inhalation of dichlorvos vapour. Furthermore, given that dichlorvos is used for treatment of commercial and industrial premises, persons working within treated buildings may also be exposed to dichlorvos vapour.

The current NOHSC exposure standard for dichlorvos as an atmospheric contaminant in the occupational environment is a TWA concentration of 0.1 ppm or 0.9 mg/m^3. The TWA value for dichlorvos was adopted from the ACGIH (1991) *Documentation of the Threshold Limit Values and Biological Exposure* Indices. The basis for the TWA value is unknown. A STEL has not been established for dichlorvos.

A worker exposed by inhalation to dichlorvos for 8 hours at a TWA concentration of 0.9 mg/m^3 would inhale 5.04 mg of the chemical (the calculation assumes a ventilation rate of 1.0 m^3/h and that 70% of inhaled dichlorvos in absorbed). For a 70 kg person, this would represent a dose of 0.072 mg/kg bw.

This review has recommended a NOEL of 0.014 mg/kg bw/d for repeated occupational exposure to dichlorvos, with a MOE of $\geq$ 10 resulting from application of a 10-fold uncertainty factor for intra-species variability. MOEs < 10 are unacceptable from a toxicological viewpoint. To ensure that the MOE for workers does not fall below 10, the maximum TWA concentration of dichlorvos in the atmosphere should be 0.017 mg/m^3, a value which may be rounded up to 0.02 mg/m^3. This value is derived on the assumption of 8 h exposure/day, an inhalation rate of 1 m^3/h, 70% absorption of inhaled dichlorvos and 70 kg bodyweight.

RECOMMENDATIONS TO THE NOHSC

1. It is recommended that the Australian standard for dichlorvos in the workplace atmosphere be revised from 0.9 mg/m^3 to a TWA concentration of 0.02 mg/m^3.

REFERENCES

National Occupational Health and Safety Commission (1995a) Exposure Standards for Atmospheric Contaminants in the Occupational Environment, Guidance Note [NOHSC:3008(1995)] and National Exposure Standards [NOHSC: 1003(1995)], Australian Goverment Publishing Service, Canberra.

National Occupational Health and Safety Commission (2004) Hazardous Substances Information System [Ver 1.2.2 (September 2004) Last Updated December 2004].