Survey of Exposure to Pesticides in Greenhouses

Robert Mestres,[1]* Claude Francois,[1] Colette Causse,[1] Laurence Vian,[1]
and George Winnett[2]

[1]Laboratoire de Chimie Appliquée à l'Expertise, Faculté de Pharmacie, 34060
Montpellier Cedex, France and [2]Department of Environmental Science, NJ
Agricultural Experiment Station, Cook College, Rutgers University,
New Brunswick, NJ 08903

Much attention has recently been focused on the problems associ-
ated with reentry into treated plots by applicators and other
agricultural workers (Gunther et al. 1977). Little work has
been done to define the "reentry" problems associated with com-
mercial greenhouses.

Worker exposure to two classes of pesticide were studied --
chlorinated hydrocarbons, e.g., -dicofol, and synthetic pyre-
throids, e.g., -deltamethrin, during their application on crops
in a laboratory greenhouse together with subsequent safe reentry.
Dicofol was applied to lemon trees and deltamethrin was applied
to French Beans. The objectives of this study were (1) to de-
termine the potential dermal and inhalation exposure to mixer/
applicators who apply deltamethrin to vegetable crops in the
greenhouses of southern France, and of workers who pick fruit
from treated trees in southern France in order to attempt,
thereby, to correlate the pesticide exposures from the differ-
ent compounds and to calculate safe reentry intervals for non-
cholinesterase inhibiting pesticides.

MATERIALS AND METHODS

For the survey of exposure to dicofol, the study was performed
in a 3.7m x 6m x 2m plastic greenhouse in which 175 potted
lemon trees were arranged in 5 rows. Remadion S formulation
was applied at the rate of 960 gm a.i./ha, which was 2X the
recommended dosage, with a pneumatic disc-harrow delivering
0.55 liter per minute. The applicator wore an MDP Sol Toucan
mask, white gloves under working gauntlets and gauze pads under
the overalls or trousers. Air samplings were taken during and
after the treatment at a height of 1.5 meters. Because of the
elevated temperatures in the greenhouse (25o-31oC.), the trees
were watered by heavy sprinkling the day after the application
and on the seventh day.

The deltamethrin study was carried out in an 8.85m x 59.4m x
3.15m greenhouse of a market gardener in the city of Mont-
pellier (total volume approx. 1300m^3). There were nine rows of

*Correspondence and reprint requests can be sent to Robert
Mestres or George Winnett.

French Beans, 2m high at the time of treatment. 50 ml of Decis formulation was diluted so that 25 gm a.i./ha (2X recommended dosage) was applied using a vaporizer "Goldair: 3 HP two stroke engine: outlet air speed 137 m/sec. range 10-15 m, flow 1.5 l/min. homogeniety index: 0.285. The applicator wore an MDP Sol Toucan mask, white gloves under working gauntlets and gauze pads under the overalls or trousers covering the parts of the body recommended by the WHO protocol (1983). Air samples were taken at a height of 1.5 meters in the middle of the greenhouse during, 30 minutes after, and 48 hours after the application.

Atmospheric pesticide determinations were carried out by pumping a measured volume of air (500-2000 1) through a 2-inch ID glass column filled with 11 gms of 2% watered florisil. After washing the column with 50 ml of petroleum ether, the pesticide (dicofol or deltamethrin) was eluted with 100 ml of a 80-20% mixture of petroleum ether - diethyl ether. Recoveries of the pesticides averaged 85%.

The mixer-applicator dermal exposure measurements were performed on each individual worker in compliance with the 1983 WHO protocols except for placement of the gauze pads underneath the trousers or light overalls, in order to be able to measure the actual amount of pesticide which would reach the worker's skin. Appropriate recovery tests of the $100cm^2$ pads for each of the pesticides used, gave satisfactory results, i.e., 95% for dicofol and deltamethrin.

The sampling, extraction and analysis of dicofol and deltamethrin residues on the leaves were conducted according to the method of Gunther et al. (1980), i.e., a single 30 second wash of 40 one inch diameter leaf discs with 40 ml. of a 2% sodium chloride aqueous solution.

RESULTS AND DISCUSSION

The results of the analyses of the atmosphere, gauze pads and leaves are given in Tables 1 through 4.

Table 1. Inhalable pesticide[*] during manual application at a maximum respiratory rate of 50 1/min. Duration of the tests: 8 min. 30 sec. for dicofol, 10 min. for deltamethrin

Tested Pesticide	Inhalable Pesticide[*]		
	µgs/test	µgs/m^3	µg/hr
DICOFOL	0.003	0.007	0.021
DELTAMETHRIN	0.9	1.8	5.4

[*] Pads under the mask covering the nose

751

Table 2. Dicofol and deltamethrin in the greenhouse atmosphere.

Time After Application	Temperature °C	Analyzed Air Volume	Pesticide µg/m³
Dicofol Test			
0 min.	27.5	414 liters	12.0 ± 4.0
30 min.	31.0 *	2000 "	2.0 ± 0.3
24 hours	26 – 36	1500 "	2.8 ± 0.1
2 days	27 – 34	1500 "	2.75± 0.05
7 days	25 – 32	1500 "	0.55± 0.05
9 days	18 – 19	1500 "	< 0.1
Deltamethrin Test			
0 min.	21.0	487 "	5.2
30 min.	21.0	1500 "	0.008
2 days	29.0	1500 "	<0.001

*
Temperature at the beginning and end of the measurement – the doors being closed during this time.

Table 3. Dislodgeable Foliar Residues

Time After Application	Dicofol Test °C	10^{-3}µg/cm²	Deltamethrin Test °C	10^{-3}µg/cm²
30 min.	31	10	21	2.5/7 *
1 day	26	17		
2 days	27	14	29	5.0
3 days			32	5.0
5 days			32	3.5
6 days	27	12	33	3.5
8 days	25	11.5		
9 days			33	2.5
10 days	18	8		
11 days			33	1.5
14 days	19	6		

*
Extrapolated from the dissipation curve

The Percent Toxic Dose (PTD) to which the applicator is exposed, as estimated by Durham and Wolfe (1962) which is accepted by the WHO protocol (1983) is expressed by the following formula:

$$PTD = \frac{\text{derm. exp.(mg per day/hr)+res. exp.(mg per day/hr)X 10}}{\text{dermal LD 50 mg/kg (rat)X 70}} \times 100$$

and was, in the case of dicofol, 0.000435 per hour with a mask and 0.00071 without a mask. These percentages extrapolated to a 4 hour working period, would be 0.0017 and 0.0028 respectively. For deltamethrin a maximum PTD only can be given, since the dermal LD 50 is not able to be estimated due to the lack of toxicity (2000 mg/kg for the rabbit and 2940 mg/kg for the rat having no effect). Thus, the maximum PTD will be 0.00165 per hour

Table 4. Applicator's dermal exposure during the application

Body Part	Body Area cm² (a)	No. of Pads	Dermal Exposure per 100 cm²	under overall	%
Dicofol test					
Upper chest V of the neck	150	1	<1 ng	<1.5 ng	
Top of shoulders near neck	300	2	<1 ng	<3 ng	
Back just below neck	100	1	<1 ng	<1 ng	
Arms	960(b)	2	<1 ng	<9 ng	
Forearms	1,200	2	0.54 ± 0.03µg	6.5 µg	8.85 %
Hands	800	gloves	3.5 ± 0.2 µg	28 µg	38.1 %
Legs from knees down	2,300	2	0.48 ± 0.12µg	11 µg	14.95 %
Legs from knees up	3,500	2	0.80 ± 0.15µg	28 µg	38.1 %

Total (with an additional 10% for the head): 0.0808 mg for 8 min. 30 sec. or equivalent to: 0.57 mg per hour.

Body Part	Body Area cm² (a)	No. of Pads	Dermal Exposure per 100 cm²	under overall	%
Deltamethrine test					
Upper chest V of the neck	150	1	0.21 µg	0.3 µg	0.06 %
Top of shoulders near neck	300	2	0.33 µg	1 µg	0.2 %
Back just below neck	100	1	0.52 µg	0.5 µg	0.1 %
Arms	960(b)	2	0.5 µg	5 µg	1 %
Forearms	1,200	2	10 µg	120 µg	23.5 %
Hands	800	gloves	1.35 µg	11 µg	2.1 %
Legs from knees down	2,300	2	0.28 µg	6 µg	1.1 %
Legs from knees up	3,500	2	10.5 µg	367 µg	71.8 %

Total (with an additional 10% for the head): 0.56 mg for 10 min. or equivalent to: 3.36 mg per hour.

(a) According to WHO (1983).
(b) Personal estimation.

with a mask and 0.0017 without a mask. The extrapolation to a
4-hour working period would be 0.0066 and 0.0068 respectively.

Since it appears that there is no serious risk according to
these data, a comparison with the "Admissible Daily Intake"
(ADI) is calculated. Since ADI refers to oral absorption, the
dermal absorption toxicity has to be compared with its oral
absorption equivalent. For dicofol, the ADI can be calculated
from the known dermal and oral toxicities:

$$\frac{\text{dermal LD 50 (rabbit)}}{\text{oral LD 50 (rat)}} = \frac{1820}{809} = 2.31$$

Thus, the dermal exposure of 0.57 mg of dicofol (per hour) is
equivalent to 0.246 mg, or 0.003525 mg/kg body weight for a man
of 70 kg, which represents about 14% of the ADI (0.025 mg/kg
body weight). After a 4-hour work period, at the same rate,
this absorption would correspond to 56% of the ADI for dicofol.

The lack of measurable dermal LD 50 for deltamethrin alters the
formula to:

$$\frac{\text{dermal LD 50 (rat)}}{\text{oral LD 50 (rat)}} = \frac{>2950}{135} \quad \text{or} = >21.85$$

Therefore, the actual dermal exposure with 0.56 mg of deltameth-
rin represents less than 0.025 mg of orally absorbed pesticide
or, 0.00036 mg/kg body weight for a man of 70 kg, the equivalent
of 3.6% of the ADI (0.01 mg/kg body weight). Extrapolation to a
one hour period of work leads to 22% while the ADI level would be
reached after five hours of work at the same rate, which would not
be possible for human and material reasons.

U.S. regulations give "safe reentry intervals" for persons work-
ing in insecticide-treated fields or groves, based on the cho-
linesterase inhibiting activity of organophosphate and carbamate
pesticides (Gunther 1977). Knaak et al. (1980) described a direct
method of evaluating the interval for new cholinesterase inhibit-
ing pesticides. For non-cholinesterase inhibiting pesticides,
such an approach cannot be followed. We shall consider therefore,
the principle of Toxic Potential which is the relationship between
the Dislodgeable Foliar Residue and the dermal LD 50, which was
used by the above authors to compare different pesticides with
the same physiological activity as the organophosphorus compounds.
We can assume that any lethal dose is a risk that can be corre-
lated to the dermal toxicity. The principle of the method is as
follows: knowing the safe reentry interval and the corresponding
Admissible Dislodgeable Foliar Residue (ADR) for an organophosphor-
us pesticide (OP), it can be assumed that the ADR of a pesticide
"X" (X.ADR) will be at least X.ADR = K (OP.ADR) with

$$K = \frac{X \cdot \text{LD 50 dermal}}{OP \cdot \text{LD 50 dermal}}$$

The Dislodgeable Foliar Residue persistence curve will then in-
dicate the safe reentry interval for pesticide "X".

For this first approach, we shall refer to studies of Gunther et al. (1977) on three OP pesticides.

Table 5. Data on three OP pesticides (Gunther et al. 1977)

Pesticide	Safe Reentry Interval in Citrus Grove	Admissible Foliar Dislodgeable Residues $\mu g/cm^2$	Dermal LD 50 Rat – mg/kg
Azinphosmethyl	30 days	0.07	220
Parathion	30 days	0.0005 – 0.01	21
Phosphamidon	14 days	0.05	143

For dicofol, the only dermal LD 50 known is 1870 mg/kg (rabbit). The calculated ratios for K for the three OP's and the deducted ADR are given in Table 6. The estimated values 0.6 to 0.9 $\mu g/cm^2$ being greater than the initial 0.018 $\mu g/cm^2$, no reentry interval has to be set for dicofol in this case.

Table 6. Evaluation of safe reentry interval for dicofol in a citrus grove

Reference OP Pesticide	K Dermal LD 50 Dicofol/OP	Admissible Dislodgeable Dicofol $\mu g/cm^2$	Dicofol Safe Reentry Interval
Azinphosmethyl	8.5	0.6	0 day
Parathion	89.0	0.45 – 0.89	"
Phosphamidon	13.0	0.65	"

The use of an LD 0 (2940 mg/kg for the rat), instead of an LD 50 introduces an additional safety coefficient for deltamethrin since there is no effect, hence no LD 50. The values are given in Table 7. Despite the very different ratios of K with the three OP pesticides, the calculated ADR's are of the same order of magnitude, i.e., 1 $\mu g/cm^2$, a level 140 times greater than the initial dislodgeable deposit of 0.007 $\mu g/cm^2$, so it would seem that no reentry interval has to be set.

Table 7. Evaluation of safe reentry interval for deltamethrin in a french bean kitchen garden

Reference OP Pesticide	K Dermal LD 50 (Deltamethrin/OP)	Admissible Dislodgeable Deltamethrin $\mu g/cm^2$	Deltamethrin Safe Reentry Interval
Azinphosmethyl	13.3	0.93	0 day
Parathion	140.0	0.7 – 1.4	"
Phosphamidon	20.5	1.0	"

In conclusion, the preliminary tests using the acaricide dicofol on lemon trees under artificial conditions far from a citrus grove, and a survey of worker's exposure to deltamethrin agree as to the lack of inhalation risk for these two compounds. The field

755

surveys of exposure to these two pesticides confirmed the need for protective clothing, particularly in avoiding needless exposure of the hands and lower limbs. Under normal and usual conditions of work, the "Percentage Toxic Dose" received by the applicator is very low. Reentry intervals for non-cholinesterase inhibiting pesticides were evaluated from the measurement of Foliar Dislodgeable Residues and a theoretically estimated Admissible Dislodgeable Level. No reentry interval appeared to be necessary for dicofol and deltamethrin under the given conditions of the application.

REFERENCES

Durham WF, Wolfe HR (1962) Measurement of the exposure of workers to pesticides. Bull WHO 25:75-91

Gunther FA, Iwata Y, Carman GE, SMith CA (1977) The citrus reentry problem: Research on its causes and effects, and approaches to its minimization. Residue Reviews 67:1-132

Gunther FA, Iwata Y, Papadopoulou E, Berck B, Smith CM (1980) Rapid field method for estimating organophosphorus insecticide residues on crop foliage. Bull Environ Contam Toxicol 24:903-909

Knaak JB, Schlocker P, Ackerman CR, Seiber JN (1980) Reentry research: Establishiment of safe levels on foliage. Bull Environ Contam Toxicol 12:796-804

Serat WF (1973) Calculation of a safe reentry time into an orchard treated with a pesticide chemical which produces a measurable physiologic response. Arch Environ Contam Toxicol 1:170-181

Serat WF, Baily JB (1974) Estimating the relative toxicologic potential of each pesticide in a mixture of residues on foliage. Bull Environ Contam Toxicol 12:682-686

WHO (1983) Field studies of exposure to pesticides. Annex II of Toxicology Committee. Standard Protocol 01-20-1983 Doc VBC/82.1