Section6

ENVIRONMENTAL ASSESSMENT

1. ENVIRONMENTAL EXPOSURE

1.1 Environmental Release

1.1.1 Volume

Approximately 25,000 kg of technical grade chlorfenvinphos (both formulated and unformulated) is imported into Australia annually. This is formulated into a variety of end use products (EUP) with a considerable proportion as ectoparasiticides at a concentration of 138 g a.i./L. About 150,000 L of EUP could therefore be used in Australia annually.

1.1.2 Use patterns and methods of application

See Agricultural Assessment (Section 3)

1.1.3 Formulation, handling and disposal

No information was supplied on the adjuvants making up the various EUPs or if they are manufactured in Australia or overseas.

When long-wooled sheep are jetted, only approximately one third of the applied solution remains in the fleece with two thirds draining off and possibly contaminating the soil; contamination has been noted to occur in this manner with other organophosphates (Environment Australia 1998). Scours, formulation wastes and spent dip baths are currently discharged to municipal sewers, or to lagoons or irrigation systems in inland situations. The label for WSD Jetting Fluid 100 advises users to "discard run-off wash with care...do not re-use" but provides no further guidance on disposal methods.

1.2 Environmental Monitoring

In a survey of pesticide residues in Australian wool clips in 1997/98, a mean concentration of 0.22 mg a.i./kg of chlorfenvinphos was found in the wool (I. Russell, pers com). As the residues are highly concentrated in the wool wax, which makes up about 13% of the wool, this equates to about 1.7 mg a.i./kg in the wool wax. Chlorfenvinphos residues were only found in 10% of the wool clips tested and only 1% contained residues higher than 2 mg a.i./kg.

A previous survey and questionnaire to wool growers across Australia from November 1992 to May 1994 found similar results (Plant 1996). In this study, 1181 clips of Australian wool were randomly selected for testing for organophosphate and pyrethroid pesticide residues, including chlorfenvinphos. Of these clips, 985 could be traced back to growers who were sent a questionnaire to determine details of pesticide use. These users had a mean of 0.7 mg a.i./kg wool while that in all clips sampled was 0.6 mg a.i./kg wool. Ten clips where treatment of individual struck sheep was reported had a mean concentration of chlorfenvinphos of 0.7 mg a.i./kg wool with a maximum of 4.1 mg a.i./kg wool.

Russell (pers com) has not detected chlorfenvinphos in the few soil samples taken from land irrigated

with scour effluents.

1.3 Implications for Exposure

Application by dipping and jetting has the potential to lead to some exposure of the soil in the vicinity of the application site as excess solution drips from treated animals. This, however should be limited in situations where such material can be collected and returned to the dip or jetting solution. As chlorfenvinphos may be stripped from treatment solutions, a higher proportion will be retained in sheep fleece compared to non-stripping pesticides and soil residues may be lower.

Given the various uses of chlorfenvinphos, there are a number of potential routes for it to reach the environment. These include direct application to soil in pasture and crop situations, disposal of used dips solutions, effluent arising from scouring of wool from treated sheep, cleaning of spray equipment used in pest control and wash off and excreta from treated animals. Volatilisation from these sources is expected be a relatively minor route of exposure.

2. ENVIRONMENTAL CHEMISTRY AND FATE

In addition to the studies supplied by the registrants of chlorfenvinphos, many from the published literature were found. The Agency for Toxic Substances and Disease Registry of the US Department of Health and Human Services published a toxicological profile on chlorfenvinphos (ATSDR 1997). As well, the UK Ministry of Agriculture, Fisheries and Food conducted a review of chlorfenvinphos (MAFF 1994) similar to the ECRP. The studies cited from the MAFF (1994) and ATSDR (1997) reports were not reviewed by Environment Australia but rather were summarised directly. The reviews of some of the studies contained very few details of experimental methodology and it is unknown if this was due to the quality of the original paper or the review report format. In addition, those studies beginning with "SC 8993/" are presumed commercial-in-confidence data and were not referenced in the MAFF (1994) review.

2.1 Hydrolysis

Suter (1981) measured the hydrolytic half-life of chlorfenvinphos (purity unspecified) in aqueous solutions at various pH (Table 1). Thus, in the range of environmental pH, hydrolysis is not expected to be a major transformation pathway.

Table 1. Hydrolysis half-life of chlorfenvinphos at various pH's.

pH	Half-life at 30°C
1	48.96 d
5	101.0 d
7	53.1 d
9	32.7 d
13	0.63 h

These values agree with those of Tomlin (1997) with a DT50 of 1.28 h at pH 13 and 20°C but

>16.7 d at pH 9.1.

2.2 Phototransformation

No studies were submitted on the phototransformation of chlorfenvinphos in air or water, or on soil or foliage surfaces. However, ATSDR (1997) reported that direct phototransformation in water, air or on surfaces is not considered important as the maximum absorption of chlorfenvinphos occurs at a wavelength of 228 nm which is less than the 290 nm penetration limit of sunlight (Schlett 1991). However, the estimated half-life of chlorfenvinphos in the atmosphere due to hydroxyl radical reaction is about 7 h while that estimated due to ozonation is 92 h (Lyman et al. 1990, Atkinson 1988, Meylan and Howard 1993, Atkinson and Carter 1984). Therefore, any chlorfenvinphos volatilising is not expected to persist in air.

2.3 Soil Metabolism

2.3.1 Effect of temperature

Miles et al. (1983) examined the effect of temperature on the degradation of technical chlorfenvinphos in a sandy loam (pH 7.2, 1.6% OC) and an organic muck (pH 6.5, 27.8% OC). Natural and sterilised (by autoclave) soil samples were treated at 10 mg a.i./kg soil dry weight, adjusted to 60% of the moisture holding capacity (MHC), sealed and incubated in the dark at 3, 15 or 28°C. Samples were removed at various intervals up to 168 days after treatment (DAT) for analysis of microflora population and chlorfenvinphos residues by extraction and GC. Maintenance of aerobic conditions was not specified.

The authors reported no significant alterations to fungal populations in either soil that could be attributed to either temperature or chlorfenvinphos treatment and that treated muck at 3°C had lower bacterial counts than at other temperatures. These results must be treated with caution as no statistical significance was stated nor were data provided to allow confirmation. Little dissipation occurred in sterile samples of both soils suggesting that the loss of chlorfenvinphos from natural samples was due to microbial degradation (Table 2). Slower degradation in the muck soil than the sandy loam may be due to lower bioavailability associated with adsorption to the organic matter. The authors suggest that the faster degradation at higher temperatures may be due to increased production or reactivity of microbial enzymes since population counts remained stable. These values would classify chlorfenvinphos as slightly to moderately persistent in natural soil samples (Goring et al. 1975).

Table 2. Degradation rates and DT50 values of chlorfenvinphos at 60% MHC and various temperatures in Miles et al. (1983).

Incubation temperature	Sandy loam		Organic muck	
	Sterile	Natural	Sterile	Natural
3°C	=90% remaining at 168 DAT	DT50 = 98 d	=69% remaining at 168 DAT	63% remaining at 168 DAT
15°C	=90% remaining at 168 DAT	DT50 = 42 d	=69% remaining at 168 DAT	DT50 = 80 d
28°C	=90% remaining	DT50 = 16 d	=69% remaining	DT50 = 21 d

	at 168 DAT		at 168 DAT	

2.3.2 Effect of moisture

Miles et al (1984) conducted a similar experiment as Miles et al. (1983) above, except examining the effect of moisture on technical chlorfenvinphos degradation when incubated in sandy loam (pH 7.4, 1.5% OC) and organic muck (pH 7.3, 33.5% OC) soils. Sterile and natural samples of both soils were dosed at 10 mg a.i./kg soil dry weight, sealed and stored at 28°C in the dark for up to 168 d at various moisture levels (Table 3). Samples were analysed for changes in microflora populations and chlorfenvinphos residue concentrations.

In sterile samples of both soils, degradation was slow in both soils. The DT50 was uniform at about 11 d (nonpersistent according to Goring et al. 1975) in the natural sandy loam at 20, 40 and 60% MHC, but was slower at about 63 d (moderately persistent) in air-dried conditions. Degradation in natural muck soil samples was more dependent on moisture with 20, 40 and 60% MHC having DT50s of about 58 (moderate), 41 (slightly) and 13 (nonpersistent) d, respectively; air-dried natural muck (no moisture level specified) had a DT50 of about 91 d (moderately persistent). Microbial populations were lower in air-dried soils and the authors state there were no significant changes attributable to treatment, although no data were presented to confirm this. They also state that the cis isomer (making up about 10% of technical chlorfenvinphos originally) only made up about 5% at 168 DAT in both natural soils.

Table 3. Degradation rates and DT50 values of chlorfenvinphos at 28°C and various soil moistures in Miles et al. (1984).

Moisture holding capacity	**Sandy loam**		**Organic muck**	
	Sterile	**Natural**	**Sterile**	**Natural**
Air dried	65% remaining at 168 DAT	DT50 = 63 d	45% remaining at 168 DAT	DT50 = 91 d
20%	65% remaining at 168 DAT	DT50 = 11 d	68% remaining at 168 DAT	DT50 = 58 d
40%	55% remaining at 168 DAT	DT50 = 11 d	70% remaining at 168 DAT	DT50 = 41 d
60%	50% remaining at 168 DAT	DT50 = 11 d	60% remaining at 168 DAT	DT50 = 13 d

2.3.3 General study

Beynon and Wright (1967) treated four natural soils (sandy loam, loam, clay and a peat, pH 6.4-8.0, no other characteristics specified) with ^{14}C-labelled and unlabelled chlorfenvinphos at 15 mg a.i./kg soil wet weight (13.9-88.6% water) and stored them at a mean temperature of 22°C. Sample containers were not sealed, thus allowing the unmeasured escape of evolved gases; decrease in mass over the storage period was 5%. After incubation for 4 months, soils were extracted and analysed by TLC, electrophoresis, LSC and GLC. A total of nine different radiolabelled components were isolated with parent chlorfenvinphos as the predominant compound at 1.0-4.7 mg a.i./kg soil ww in the four soils. The next most prevalent residue was 2,4-dichloro-1-(1-hydroxyethyl)benzene at 0.06-1.0 mg/kg soil ww or 0.4-6.7% of the originally applied amount (Fig.

2); all other residues were =0.6 mg/kg soil ww.

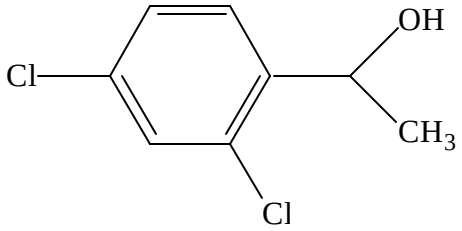


Fig. 2. The major metabolite 2,4-dichloro-1-(1-hydroxyethyl)benzene.

2.3.4 ATSDR (1997) review

None of the products found after soil degradation of chlorfenvinphos retained any pesticide characteristics (method of determination unspecified, Rouchaud et al. 1991a). Degradation occurs fastest in sandy soils and slowest in peats, most likely due to the degree of adsorption to organic matter (Beynon et al. 1973, Williams 1975).

2.3.5 MAFF (1994) review

2.3.5.1 Carrots

Finlayson and Suett (1975) studied the dissipation of chlorfenvinphos applied to carrots grown under glasshouse conditions in compost (3.6% OC). Pots were treated at up to 40 mg a.i./kg soil and analysed by GLC up to 126 DAT. Soil residue concentrations were not specified but were said to hardly decline over a period of 126 d. No other details of methodology were given. This result is in stark contrast to others.

2.3.5.2 Belgian soils

Chlorfenvinphos applied at 48 mg a.i./kg soil in four soils (OC 0.4-1.9%, pH 5.1-7.1) was incubated at 23°C for 63 d (Van de Steene and de Smet 1988). Analysis revealed slight degradation in sterilised soils but DT50 values of 50 and 56 d in nonsterile soils. In two soils which were suspected of containing microbial populations selected for chlorfenvinphos degradation, the DT50 values were 25 and 30 d.

2.3.5.3 Persistence 1

Chlorfenvinphos was applied to a sandy loam (1.7% OC, pH 8) and an organic soil (28.4% OC, pH 7.6) at 10 mg a.i./kg soil by Miles et al. (1979). Soils were sterilised by autoclaving or left nonsterile before incubating at 28°C and 60% FCM in the dark. Analyses of samples removed up to 168 DAT showed DT50 values of >168 d for both sterilised soils. In contrast, the natural sandy loam had DT50 and DT95 values of <7 and 35 d, respectively, while the organic soil had values of 7 and 63 d.

2.3.5.4 Persistence 2

Suett and Jukes (1990) applied chlorfenvinphos at 25 mg a.i./kg soil to eight soils (1.6-3.0% OC, pH 5.3-6.6). They were incubated in the dark at 15°C and at FCM for up to 56 d. GC analyses

showed 50-80% of the applied dose remained by the end of the exposure in a steady decline in concentration with no lag phase.

2.4 Anaerobic Soil Metabolism

No study was submitted on this subject.

2.5 Degradation in Sediment/Water in the Laboratory

2.5.1 Study 1

Edwards & Gibb (1981) allowed natural sediment and water from a pond in England to equilibrate in the laboratory for at least 24 h before treating with ^{14}C-chlorfenvinphos (=99%) to a final concentration of 1.0 mg/L. The heavy clay sediment had a pH of 7.4-7.5 and organic carbon content of 1.04-2.32% varying with depth to 10 cm. Samples were held at either 10 or 25°C and analysed by LSC, TLC, HPLC and GC/MS after a maximum of 140 d. Only samples at 25°C were aerated and only one of these had a volatile trap incorporated into its design. Aerobic conditions were maintained in an untreated sample but not monitored for in any of the treatments.

In the cold water treatment, radioactivity slowly moved from the aqueous phase into the sediment (half-life in water ˜ 70 d) with 16.8-19.0% of the originally applied amount in both media at 140 DAT. The only major metabolite was identified as 2,4-dichloro-1-(1-hydroxyethyl)benzene which peaked at 11.2 and 27.7% in the sediment and water, respectively, at 63 DAT. The half-life in the whole water-sediment system was 90.5 d. In contrast, the majority of radioactivity in the 25°C treatment shifted from the aqueous phase into the sediment by 14 DAT with a half-life in water of about 7 d. No metabolite was identified at >10%. The traps for volatiles attached to the single sample contained only 2% of the applied radioactivity as $^{14}CO_2$ and the generally low recoveries were attributed to volatilisation losses. The half-life for the whole system was 27.0 d. Analyses of sterile control samples confirmed that microbial activity was responsible for the degradation. However, because of the many limitations of this study, these results should be treated with caution. As well, the adsorption of chlorfenvinphos to the heavy clay sediment may have reduced availability for biodegradation.

2.5.2 Study 2

Wahle (1993) dosed samples of natural water and sediments with ^{14}C-chlorfenvinphos (99%) to determine biodegradation rates and products. Sediment from two streams in Germany were characterised as loam and sand but were reclassified as silty loam (pH 7.2, 2.6% OC) and loamy sand (pH 7.7, 0.5% OC) by Environment Australia based on their particle size distributions. Samples of sediment and their natural waters were treated at a rate equivalent to 5 kg a.i./ha and incubated in the dark at 20±2°C under aerobic conditions. Controls of sterilised water/sediment were handled similarly. At various times up to 103 d, samples were extracted and analysed by LSC, HPLC and TLC.

Recoveries were generally acceptable at 89.6-102.3% of the originally applied radioactivity except for the final sample in the silty loam system which only had 74.0%. Nonextractable radioactivity rose steadily in both sediments during the exposure and peaked at 28.0-28.6% at 103 DAT. $^{14}CO_2$ peaked at 9.1-10.0% at the same time with organic volatiles =5.4%. Environment Australia calculated the half-lives of parent compound in the silty loam and loamy sand whole systems to be

38.0 and 40.3 d, respectively. The major metabolite was 2,4-dichloro-1-(1-hydroxyethyl)benzene (see Fig. 2) which peaked at 10.6 and 17.4% in both sediments respectively (approximately 3X higher than in the associated water phases) at 61 DAT. No other metabolites were detected at >10% and none were detected in the sterilised controls.

2.6 Dissipation in Natural Sediment/Water Field Study

Beynon et al. (1970) and Beynon et al. (1971) treated a natural pond in the UK with chlorfenvinphos, formulated as a 24% emulsifiable concentrate, at 74 kg a.i./ha giving an initial measured concentration of 6.1 mg/L. Water and sediment were sampled before and after treatment up to 33.9 DAT. Details on methodology were scant and it was likely that sediments were held for up to 2 weeks at 5°C. Chlorfenvinphos dissipated from the water column with a half-life of 8.3 d. The whole system half-life could not be calculated from the data presented. The concentration in sediment peaked at 0.32 mg a.i./kg sediment at 4.8 DAT and declined to 0.15 mg a.i./kg sediment by 33.9 DAT.

2.7 Adsorption/Desorption

Briggs (1981) measured the K_{OM} of chlorfenvinphos (analytical grade) in a silt loam (2.0% OC, pH 6.1) by shaking the soil with the chemical solution for 2 h. As the author claimed the linear isotherm provided a good fit of the data, adsorption was measured only at the initial (unspecified) concentration. The K_{OM} value was 170 (units unspecified) with the equivalent K_{OC} of 293 indicating medium mobility (McCall et al. 1981).

2.8 Leaching and Surface Run-off

2.8.1 Field study

Edwards et al. (1971) determined the leaching and surface run-off potential of chlorfenvinphos applied to sloping arable land (degree of slope not specified) at two field sites in England. A silty clay loam (no pH or %OC specified) seeded with spring barley was treated with chlorfenvinphos (24% emulsifiable concentrate) at 22 kg a.i./ha in March in a strip 14 m by 1.8 m, approximately 8 m up slope from the edge of a pond. Two identical strips on the downward side and parallel to the treated strip (ie between the treated strip and pond) were used for sampling. A 1 m discard path was left between strips. Rainfall in the first 119 d was 135 mm. Soil and sediment cores (25 and 10 cm deep, respectively) and water samples taken at 1, 28, 56 and 161 DAT only detected chlorfenvinphos in soil. The treated strip had the highest concentration of 8.7 mg a.i./kg soil 1 DAT which declined to 0.09 mg a.i./kg soil at 161 DAT with a half-life of about 28 d. Only at 28 DAT was a detection of 0.03 mg a.i./kg soil found in the third strip (closest to the pond) presumably from run-off. All other samples were below the limits of detection (0.01 mg a.i./kg soil and 0.005 mg a.i./L water).

At the second site, an apparently bare clay loam was treated following similar methodology except three sampling strips were used and no pond was present. As well, no soil quality characteristics were provided. The slope was approximately 1:19. Treatment occurred in April and barley was later sown at an unspecified date. Total rainfall during the experiment was 228 mm. Soil samples taken at 0, 14, 42, 70 and 98 DAT confirmed the low mobility as detections were only made in the treated strip to 25 cm depth and the adjacent strip to 15 cm. However, the peak concentration in the treated strip of 5.9 mg a.i./kg soil immediately after treatment declined more slowly to 3.7 mg

a.i./kg soil at 98 DAT, indicating a DT50 > 98 d. No explanation was given for the difference in dissipation times.

A third experiment was conducted with a sloping trough filled with silt loam soil and partitioned vertically into six compartments to distinguish vertical (leachate) and horizontal (surface run-off) movement (Fig. 3). Any chemical moving in the surface run-off would be found in the leachate collected from each of the six downslope compartments. Chlorfenvinphos was applied in the top compartment (Number 1) at the same rate as the field experiments to an initial concentration of 37 mg a.i./kg soil. The trough was then left outdoors exposed to the February (winter) weather. Approximately 20.1 L of leachate was collected but this was distributed unevenly among the various compartments. Leachate samples taken up to 119 DAT showed that 78% of all chlorfenvinphos found in the leachate occurred in the first 63 DAT and from the originally treated uppermost compartment. Soil residues were highest in the upper 7.5 cm in the first (treated) compartment at 28.0 mg a.i./kg soil at 70 DAT. No detections were made in soil from compartments 4-6 at any depth at 140 DAT and only 0.05 mg a.i./kg soil at 0-7.5 cm depth in compartment 3. This confirms the low surface run-off potential from the field plots. Approximately 5% of the chlorfenvinphos in the leachate was found at 70-119 DAT.

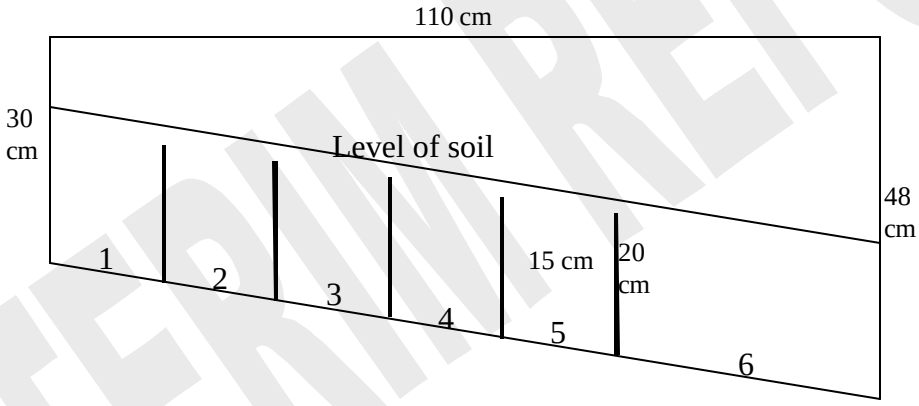


Fig. 3. Schematic diagram (side view) of the sloping trough used in Edwards et al. (1971).

2.8.2 ATSDR (1997) review

Williams (1975) found only 1-1.5% of the amount broadcast to a soil surface leached to a depth of 7.5-15 cm after 150 d, despite 120 mm of rainfall in the first 60 DAT. As well, little movement was detected below 10 cm when a granular formulation was applied at 7.5 cm depth. This was supported by Agnihotri et al. (1981) who found no leaching below 15 cm depth up to 120 DAT with a granular formulation (precipitation volume unspecified).

ATSDR (1997) concluded that surface water run-off of fields where chlorfenvinphos is applied is not likely to be a serious problem. This was based on a field study in which only 0.3-0.6% of the applied amount was found in run-off water after rain (Racke 1992). As well, monitoring reports (Braun and Frank 1980, Frank et al. 1991) of surface waters over eight (discontinuous) years in agricultural watersheds in Canada in which chlorfenvinphos had been used did not detect the compound (limit of detection (LOD) = 1 µg a.i./L). Even water and sediments in farm ditches were not found to contain chlorfenvinphos despite its detection in some soil samples (LOD = 0.01 µg a.i./L in water and 1 µg a.i./kg in sediment and soil, Wan et al. 1994).

2.8.3 MAFF (1994) review

MAFF (1994) calculated a GUS of 1.72 (Gustafson 1989) using a K_{OC} and soil half-life of 680 and 30 d, respectively, classifying chlorfenvinphos as a non-leacher.

2.9 Volatilisation

ATSDR (1997) considers chlorfenvinphos to volatilise slowly from water and therefore be essentially nonvolatile. The vapour pressure and Henry's Law Constant indicate that chlorfenvinphos has a low volatility and is unlikely to volatilise from water or moist soil surfaces (see Comments on Physico-Chemical Properties).

2.10 Field Dissipation

2.10.1 Plant surfaces

Beynon et al. (1973) reviewed other studies on the dissipation of chlorfenvinphos on plants following foliar application. The initial half-life was 2-3 d on cabbage foliage in the laboratory with a decreased rate of dissipation after this time (Beynon and Wright 1967), however, it was not stated how long the initial phase lasted. There was also "good evidence" for conversion (possibly by phototransformation) of the Z-isomer to the E-isomer, at an unspecified rate. Over 50% of the applied amount had presumably volatilised within 4-7 DAT although no evidence was provided for this route of dissipation. This was similar to potato and cabbage foliage in dry outdoor conditions (Beynon et al. 1968). No evidence for translocation of residues from treated leaves was observed. The major degradation product was a conjugate (probably with a sugar) of 2,4-dichloro-1-(1-hydroxyethyl)benzene (see Fig. 2) at an unspecified concentration.

2.10.2 Brassica plot 1

Rouchaud et al. (1991b, 1992) amended separate cauliflower plots in a Belgian sandy loam (pH 5.9, 2.0% OC) and silt loam (pH 5.9, 1.2% OC) with compost from mushroom cultivation, city refuse or cow manure at 100 t/ha or left as controls (Table 5). After incorporation into the soil and standing for one month in the spring, cauliflower seedlings in the 4-6 leaf stage were planted. Four days after planting, seedlings were treated with Birlane 25 EC (25% chlorfenvinphos) by pouring 100 mL of an emulsion around the stem of each plant for a dose of 50 mg a.i./plant. At various times up to harvest 2 months after treatment (MAT), samples of soil and foliage samples were taken for analysis by TLC, gas-liquid chromatography and mass spectrometry. In the sandy loam, a second crop was planted and the treatment, except for compost amendment, repeated in the summer.

Half-lives of chlorfenvinphos were 1.5-2.4X longer in soils which had been amended with organic compost, compared to control soils which had not been fertilised, at all sampling points. No parent or metabolites were detected in the cauliflower flower or soil deeper than 10 cm (LOD = 0.02 mg a.i./kg). The dissipation rate in control soils would classify chlorfenvinphos as non-persistent to slightly persistent (Goring et al. 1975). The authors attributed the slower degradation times in the summer sandy loam relative to the spring to increased adsorption to organic matter due to humification (slow oxidation into humus or humic acid) of the compost. However, this would not account for the same effect in the control. No indication was given as to the soil moisture content during cauliflower growth.

Table 4. Soil characteristics and half-lives of chlorfenvinphos in various treatments.

Type of Compost	pH	%OC	Half-lives (d)		
			Sandy loam, Spring	Sandy loam, Summer	Silt loam, Summer
Control (No compost)	NA	NA	9	23	18
Mushroom	7.8	12.2	21	53	43
City refuse	7.8	12.2	13	42	36
Cow manure	7.5-7.8	9.9	14	46	35

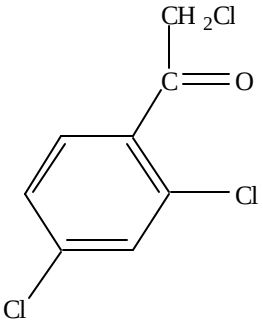
2.10.3 Brassica plot 2

Rouchaud et al. (1988) planted cauliflowers at the 4-6 leaf stage in the spring and/or summer at four different locations in Belgium (Table 5). Just after planting, an emulsion of Birlane WP (250 g a.i./kg) containing 50 mg of chlorfenvinphos was poured around the stem of each plant. Soil was sampled around the plant in a half sphere shape of radius 8 cm at various times up to 67 DAT. Maximum cumulative rainfall at any one site during growth was 132 mm. Analyses by thin layer chromatography, gas liquid chromatography and mass spectrometry were carried out with a limit of detection of 0.02 mg a.i./kg soil.

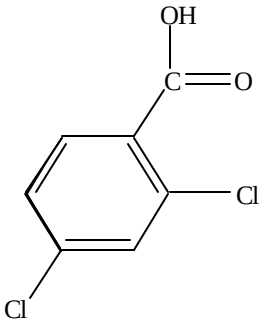
Table 5. Soil characteristics of cauliflower plots and half-lives of chlorfenvinphos.

Location	Soil Texture	pH	%OC	Half-life (d)
St Katelijne-Waver	sandy loam	5.6	1.9	18-33
Opdorp	sandy loam	5.9	1.6	17-34
Oppuurs	sandy loam	5.7	2.0	9-36
Gembloux	silty loam	5.5	1.4	23

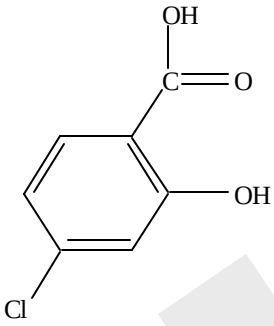
Initial concentrations were 21.5-26.4 mg a.i./kg soil dry weight at 0 DAT in the various plots. By harvest time at 43-67 DAT, residues were 0.4-7.9 mg a.i./kg soil. The relatively large range of half-lives could be due to variable environmental conditions during the spring and summer crops. The main soil metabolites were 2,4-dichloro-chloromethyl ketone (also called 2,4-dichlorophenacyl chloride) resulting from the hydrolysis of chlorfenvinphos, 2,4-dichlorobenzoic acid and 2-hydroxy-4-chlorobenzoic acid (Fig. 4) with peak concentrations of 3.3, 7.9 and 5.0 mg a.i./kg soil at 36, 18 and 36 DAT, respectively. The authors suggested the latter two products tended to accumulate in soil due to their relative stability although no data were presented to allow mass balance calculations. No parent or metabolites were detected in the flower of cauliflower.



2,4-dichloro-chloromethyl ketone



2,4-dichlorobenzoic acid



2-hydroxy-4-chlorobenzoic acid

Fig. 4. Soil metabolites detected in Rouchaud et al. (1988).

2.10.4 Brassica plot 3

Rouchaud et al. (1989a) planted cauliflower, brussel sprouts and chinese cabbage in the same soils as in the previous study (Rouchaud et al. 1988) and treated them with chlorfenvinphos in the same manner. Soils were sampled in a 10 cm radius from the stem of each plant and analysed by similar methods. Half-lives in the soils of the three crops were 13.5-27.9, 23.2 and 20.8-25.8 d, respectively. The plots in which cauliflower and brussel sprouts were grown had the same crops grown in them, and also the same chlorfenvinphos treatments, for 1-18 years. The authors suggest this history selected for a microbial population adapted to decomposing chlorfenvinphos and therefore may account for the sometimes shorter half-lives.

2.10.5 Brassica plot 4

Rouchaud et al. (1989b) conducted similar experiments using Birlane 25EC (250 g a.i./L emulsifiable concentration formulation) at 50 mg a.i./plant in cauliflower and Birlane 10G (100 g a.i./kg granular formulation) at 100 mg a.i./m in brussel sprouts in the same soils. Half-lives of parent biodegradation in the top 10 cm of soil ranged from 27.2 d in soils with 1 yr previous chlorfenvinphos history, to 20.1-25.7 d for soils with 2 yr history, to 10.8-18.7 d in a soil with 8 yr history. Half-lives for the collective dissipation of parent and five metabolites (including those of Fig. 4, Rouchaud et al. 1988) was relatively constant at 52.4-68.6 d in all these soils. Residue analyses of plant tissues indicated that chlorfenvinphos was absorbed from the soil and translocated into the foliage.

2.10.6 Carrot plot

Suett (1971) treated a sandy loam (pH 6.75, 1.1% OC) and peat loam (pH 7.40, 9.92% OC) with Birlane Granules (10% chlorfenvinphos) at 2.0 kg a.i./ha. Granules were incorporated to a 10 cm depth giving approximately 1.5 and 3.0 mg a.i./kg soil in the sandy loam and peat loam, respectively. Carrots were then planted and samples of soil (up to 20 cm deep) and carrots were taken for residue analysis up to 238 DAT. Chlorfenvinphos dissipated more quickly from the sandy loam than peat loam with about 21 and 41% of the originally applied amount remaining at 238 DAT, respectively (data were not provided to allow half-life calculations). At 182 DAT, only about 1% of the chlorfenvinphos had leached to the 10-15 cm layer in both soils and only traces were detectable below this. Peak concentrations in carrot root tissue occurred 21-35 DAT at about 5 and 1.5 mg a.i./kg in the sandy loam and peat loam, respectively, and had declined to 0.043 and 0.013 mg a.i./kg by 182 DAT. The author suggested that the high organic matter content of the peat loam

increased the adsorption of chlorfenvinphos to soil and reduced the rate of dissipation and uptake.

2.10.7 Bare soil

Beynon (1965) mixed chlorfenvinphos (as Birlane 50% EC) thoroughly into peat, sandy loam and medium loam soils to 6 mg a.i./kg soil wet weight. No other information was given on soil characteristics. Soils were then packed into wooden boxes and set into the ground with the soil surface level to that of the surrounding ground. Treated and control boxes were exposed to the environment with total rainfall during the trial of 287 mm but temperatures were not specified. Soils were sampled at 4, 10 and 21 weeks after treatment, extracted and analysed by gas-liquid chromatography.

Based on measured residues, Environment Australia calculated half-lives for chlorfenvinphos of 4.6 weeks for the sandy loam, 5.1 weeks for the medium loam and 22.6 weeks for the peat soil. The metabolite 2,6-dichloroacetonphenone was found at a maximum of 0.13 mg a.i./kg soil at 10 weeks after treatment in the medium loam soil.

2.10.8 General review

Beynon et al. (1973) reviewed other studies reporting degradation was fastest in a sand soil and slowest in peat and likely related to the degree of adsorption (Beynon and Wright 1967). On other soils in the UK, the initial half-life was usually in the wide range of 28-210 d, probably due to a slowing of degradation when temperatures fell below 6-7°C (Beynon et al. 1966, Suett 1971). Other data showed annual carryovers of 2.5-12.5% in field trials.

2.10.9 MAFF (1994) review

2.10.9.1 Cauliflower plots

Rouchaud et al. (1990) applied chlorfenvinphos to cauliflower and brussel sprouts at 50 mg a.i./plant in four soils (1.2-2.4% OC, pH 6.2-6.3) in Belgium. No residues were found deeper than 10 cm and field DT50 values were given as 12-45 d.

2.10.9.2 Canadian plots

Chisholm (1975) applied chlorfenvinphos to field plots (crop unspecified, 1.7% OC, pH 5) in June (summer) at 5.6 kg a.i./ha and incorporated to 15 cm depth. Analyses of soil samples in spring and autumn by GLC found 27% of the originally applied amount at 161 DAT and traces of both isomers (0.04 mg a.i./kg soil) 4 yr after treatment. No information was given on soil temperature or moisture.

2.10.9.3 Sandy loam plot 1

The fate of chlorfenvinphos applied to a sandy loam as granules or fluid gels at 50 mg a.i./m row was followed (Suett et al. 1981). Residues in the top 15 cm of soil were found at 41% of the originally applied amount remaining 84 DAT in the granular treatment and 65-76% in the gel treatments.

2.10.9.4 Sandy loam plot 2

Suett (1979) applied granular and liquid formulations of chlorfenvinphos to a sandy loam at 0.2-4.0 kg a.i./ha. No significant decrease in soil concentration was observed after 62 d in the granular treatment compared to a 20% decrease with the liquid treatment.

2.10.9.5 Peat blocks

Suett et al. (1982) incorporated chlorfenvinphos into peat blocks (containing 11 g peat dry weight and 80% water content) at 10 mg a.i./block. Blocks were covered in polythene film, watered appropriately and stored in glasshouses for 56 d. Analyses showed 85-90% of the applied dose remained when blocks were mixed in March, May and July, but that no degradation occurred in blocks mixed in January.

2.10.9.6 Onion plots

Chapman et al. (1984) treated onion plots in an organic soil for three consecutive Canadian springs at 1.18 kg a.i./ha. Soil analysis by GLC showed variable residue concentrations (0.77-11.1 mg a.i./kg soil) of parent compound but no overall accumulation after 4 yr of sampling.

2.10.9.7 Sorghum plots

Chlorfenvinphos was applied to sorghum in India at 2 kg a.i./ha and soil sampled up to 120 DAT (Sristava 1980). The DT50 was reported as 30-45 d with no residues found by the end of sampling.

2.10.9.8 Fallow field

The DT50 of chlorfenvinphos in a fallow Indian field treated at 1.5 kg a.i./ha was 33 d with no residues detected at 120 DAT (Jain et al. 1986).

2.10.9.9 Danish soils

Kirknel (1985) treated a find sand (1.9% OC, pH 5.6) and a silt loam (1.7% OC, pH 6.8) with chlorfenvinphos at 1, 4 or 8 kg a.i./ha and incorporated it to a depth of 8 cm. Soil analyses taken up to 127 DAT found DT50 values of 70-140 and 40-70 d for the sand and silt loam, respectively.

2.10.9.10 UK soils

Williams (1975) applied chlorfenvinphos on five sites in the UK at 2.3-7.2 kg a.i./ha. After 150 d, 70% of the originally applied amount remained on a peat soil (27.8% OC, pH 6.0). Degradation was much faster on the other four sand soils (0.93-1.3% OC, pH 6.0-7.5) with DT50 values of 2-60 d and 3-15% remaining 105 DAT. Persistence was generally higher when conditions were drier.

2.11 Uptake and Metabolism in Plants

2.11.1 Carrots, onions and cabbage

Beynon and Wright (1967) grew crops in a standardised compost (characteristics unspecified) and treated them at 3.4 and 4.5 kg a.i./ha for carrots and onions, respectively, and 4 mg a.i./plant for cabbages with radiolabelled technical chlorfenvinphos. Crops were harvested at maturity at 12-18

weeks from sowing or treatment. In cabbages, the majority of radioactivity was found in the soil at 0.32-0.36 mg a.i./kg soil. Equal amounts (0.26 mg a.i./kg plant) of radioactivity were found in the acetone extractable and unextractable portions of the cabbage stump and root; 95% of the extractable radioactivity was identified as parent compound. In the carrot plots, the majority of the radioactivity was identified as parent at 2.2 mg a.i./kg soil with 0.33 mg a.i./kg tissue in the leaf. Results in the onion plots were similar with the greatest residues of parent in the soil at 2.4 mg a.i./kg soil; residues in the leaf and bulb were =0.08 mg a.i./kg tissue.

2.11.2 Potato, cabbage and maize

In another set of experiments, Beynon and Wright (1968) treated potato, cabbage and maize plants grown in a glasshouse with ^{14}C-chlorfenvinphos and unlabelled material. The leaves were treated up to an approximate concentration of 30 mg a.i./kg plant and grown under unspecified conditions for up to 77 d. Plant tissue and soil samples were taken at various times, extracted and analysed by TLC, GLC and LSC. The half-life for parent compound in potatoes (above ground portion only, no detections in tubers, roots or soil) was 5.9 d over the entire 28 d sampling period with 39% of the originally applied radioactivity remaining in the plant at 28 DAT. However, degradation was initially rapid with a half-life of 1.9 d during the first week. Half-lives in cabbage and maize were 10.6 and 6.8 d, respectively, with 6.0 and 54% of the radioactivity remaining in the plant at 77 and 24 DAT. No translocation of chlorfenvinphos from treated to untreated leaves occurred. On cabbage foliage, the ratio of E- to Z-isomers changed from 1:9 to 1:1 over time, possibly due to greater persistence of the E-isomer or isomerisation due to phototransformation. The main metabolite was 2,4-dichloro-1-(1-hydroxyethyl)benzene (see Fig. 2) in the soil and as a conjugate in the crops at unspecified concentrations.

2.11.3 Carrots

Suett (1986) sowed carrots in pots and applied chlorfenvinphos at up to 1.25 mg a.i./seedling. Seedlings were transplanted into untreated sandy loam (1.3% OC, pH 6.4) or peat (34% OC, pH 5.9) after 19 d. Sampling of soil one week later showed 75% of the chlorfenvinphos in the seedlings had been transferred to the untreated soil.

2.12 Metabolism and Excretion in Mammals

2.12.1 ATSDR (1997) review

Male rats administered radiolabelled chlorfenvinphos orally at 2.5 mg a.i./kg bodywt excreted 67-73% of the dose in the urine within 82 h (Hutson and Wright 1980). At a higher dose of 13.3 mg a.i./kg bodywt, only 26-32% was recovered from the urine in 84 h. In female rats of a different strain, the daily dietary dose of 0.8 mg a.i./kg food for 30 d was excreted mostly in the urine (70-90%) and faeces (~16%) (Barna and Simon 1973).

2.12.2 MAFF (1994) review

A New Zealand white rabbit orally dosed with 9.7 mg of chlorfenvinphos rapidly excreted 65% of the radioactivity in the urine in 48 h (Donninger et al. 1992). Three major metabolites (2-chloro-1-(2,4-dichlorophenyl)vinyl ethyl hydrogen phosphate, [1,-(2,4-dichlorophenyl) ethyl ß-D-glucopyranosid] uronic acid and 2,4-dichloromandelic acid) accounted for 96% of this radioactivity.

Rats given a single oral dose of 2 mg a.i./kg bodywt also excreted radioactivity mainly in the urine (87%) and faeces (11%) in 96 h (Hutson et al. 1967). In the same experiment, dogs given a single oral dose of 0.3 mg a.i./kg bodywt excreted 89 and 4.5% of the radiolabel in the urine and faeces, respectively, in the same time frame. No indication was given of the amount of parent material excreted.

In a human study, a male volunteer given a single oral dose of 12.5 mg a.i. rapidly excreted 72% of the dose in the urine in the first 4.5 h (SC 8993/112). Within 26.5 h, 94% had been excreted in the urine. As only the two major metabolites were quantified, making up 48% of the applied radioactivity, it was impossible to determine the amount of parent compound excreted.

2.13 Bioconcentration

US EPA (1998) predicted a QSAR bioconcentration factor (BCF) of 332 if fathead minnow (*Pimephales promelas*) were exposed for 2-304 d. ATSDR (1997) reviewed other studies which reported BCF values of 37-460. These values, along with the log K_{OW} of 3.78-4.22, are moderate and do not indicate that bioconcentration is likely to be high (Connell 1990).

MAFF (1994) summarised study SC 8993/5 on the bioconcentration and metabolism of radiolabelled chlorfenvinphos (82.5% Z-isomer and 9.6% E-isomer) in rainbow trout (*Oncorhyncus mykiss*) in a flow through exposure. Fish of mean mass 0.7-0.8 g were exposed at measured concentrations of 0.019 and 0.183 mg/L for 80 h (uptake phase) followed by 160 h in clean water (depuration phase). Water was maintained at 16.0-17.0°C, pH 7.7-8.1 and dissolved oxygen of 8.5-10.5 mg/L. Fish were fed daily with excess food removed. At unspecified times, fish were sampled and tissue analysed by LSC and TLC. Mortality during both phases was 3.3% in controls and 4.2 and 4.8% in the low and high doses, respectively. Symptoms of toxicity such as hypoactivity, reduced feeding, loss of righting reflex, convulsion and enhanced respiratory rate were observed in the high dose treatment. Plateau concentrations of 1.9 and 12.1 mg/L in whole fish were found within 7 h after a rapid initial uptake. There was similarly an initial rapid depuration rate but this slowed with 22.2 and 21.8% of the residues present after 44 h in clean water in the low and high doses, respectively. These residue levels remained relatively constant for the duration of the study in the low dose treatment but declined somewhat in the high dose. The calculated depuration half-life of chlorfenvinphos was reported as 25.4-25.5 h in whole fish with BCF values of 66-103 calculated on total radioactivity. These values are indicative of only a limited tendency for bioconcentration.

2.14 Fate of Residues in Wool

AVCARE (1994) conducted a study on the fate of residues in greasy wool of merino sheep. Wethers with 9 months of growth that had been dipped about 6.5 months previously in diazinon, were handjetted with 3 L per sheep of Supona 200 (200 g a.i./L) at a measured concentration of 600 mg/L. Thorough wetting to skin was ensured by inspection and the volume of fluid retained on the fleece was measured by weighing each sheep before and after application. Samples of wool from treated and control animals were taken at various times up to 84 DAT. Analyses of wool extracts and jetting fluid (performed by GLC and reverse phase HPLC, respectively) found a half-life of chlorfenvinphos in greasy wool of 56.6 d, including accounting for dilution by wool growth. The peak concentration of 934.2 mg a.i./kg wool occurred at 42 DAT but had declined to 394.8 mg a.i./kg wool by 84 DAT. The reason for this sampling pattern is unknown. The report quoted other work (Rammell et al. 1988, Rammell and Bentley 1989) showing a half-life for chlorfenvinphos of

30-48 d in winter and 22-27 d in summer in romney sheep wool in New Zealand. As merino fleece is denser than romney, AVCARE (1994) considered these results consistent.

Savage (1998) reviewed the implications of pesticide residues of sheep ectoparasiticides, including chlorfenvinphos, in Australia. Residues in the fleece generally dissipate over time due to volatilisation, photodegradation (for those chemicals, unlike chlorfenvinphos, that photodegrade readily) and oxidation with higher rates of dissipation at higher temperatures and sunlight intensity. Dissipation is also faster for residues located near the surface of the fleece and on coarse open fleeces such as the carpet wool breeds. Generally, organophosphates degrade relatively quickly on sheep with half-lives of 28-35 d under Australian conditions. Once baled, however, little degradation occurs.

When raw wool is scoured, about 95% of pesticide residues are removed with the wool grease, dirt and other contaminants, and may be discharged to the environment in the liquid scouring effluent. Subsequent processing of the wool (eg. dyeing) may remove further residues and dye-house effluents may contain chlorfenvinphos. Wool scours recover =30% of the grease (containing >28.5% of pesticide residues) which is processed into various lanolin products. The remaining grease (containing about 60% of the residues) in the scouring effluent is usually treated in on-site systems or centralised sewage treatment plants before discharge to the environment. Treatment produces a sludge and liquid effluent both of which may contain residues.

Newer effluent treatment processes such as the CSIRO's Sirolan CF can extract a higher proportion of the grease and therefore lipophilic pesticide residues. The process adds a chemical flocculant to the strong flow liquors in an on-line mixing process to coagulate most of the dirt and wool wax in this principal waste stream. This mass, containing lipophilic pesticide residues, is then removed by a decanter centrifuge. Up to 80% of the residues can be removed from the effluent in this process; however, Sirolan CF is slow to be adopted in Australia due to its marginally higher costs (I. Russell, pers com).

The SimpleTreat model of the European Commission (1996) predicts the partitioning of chlorfenvinphos according to the following table if it were "inherently biodegradable" and passed through an activated sludge reactor with a 7.3 d retention time in the sludge, 10.4 h hydraulic retention time and surface aeration.

Compartment	**%**
Air	0
Water	32
Sludge	37
Degraded	31

2.15 Summary of Environmental Chemistry and Fate

2.15.1 Transformation

Chlorfenvinphos only slowly hydrolyses at environmentally relevant pH values (ie. pH 5-9) and this is not expected to be a major degradation pathway (Table 7). No studies were submitted on the phototransformation of chlorfenvinphos although a US review considered this to be a minor pathway

as the maximum wavelength for absorption is filtered out by the atmosphere. However, transformation due to hydroxyl radical reaction in the atmosphere is estimated to be rapid with a half-life of about 7 h. When an aerobic sandy loam was treated at 10 mg a.i./kg soil dry weight, incubation temperatures of 28, 15 and 3°C gave DT50 values of about 16, 42 and 98 d, respectively. Degradation in an organic muck was slower with DT50 values of 21 and 80 d at 28 and 15°C, respectively, and 63% remaining at 168 DAT in the 3°C treatment. The DT50 was uniform at about 11 d (nonpersistent) in the sandy loam at 20-60% MHC at 28°C, but was slower at about 63 d (moderately persistent) in air-dried sandy loam. Degradation in muck soil was more dependent on moisture with a DT50 of 13-58 d (nonpersistent-moderate) at 20-60% MHC; air-dried muck had a moderately persistent DT50 of about 91 d. The main soil metabolite was 2,4-dichloro-1-(1-hydroxyethyl)benzene which peaked at 11.2 and 27.7% of the originally applied amount at 63 DAT in a further experiment on four soils.

A US review reported that neither this nor any other metabolite retained any pesticidal characteristics and that adsorption to organic matter decreased the rate of degradation. A UK MAFF review reported the conflicting results of several studies: soil concentrations of chlorfenvinphos hardly declined over 126 d in carrots grown in a glasshouse; DT50 values in Belgian soils previously treated with chlorfenvinphos were 25-30 d but 50-56 d in "unadapted" soils; a natural sandy loam and an organic soil had DT50 values of <7 and 7 d, respectively, when incubated at 28°C and 60% FCM; 50-80% of the applied dose remained in eight soils incubated at 15°C and FCM for 56 d. No studies on anaerobic soil metabolism were submitted.

When natural sediment and pond water at 10°C were treated with ^{14}C-chlorfenvinphos, radioactivity slowly moved from the aqueous phase into the sediment with a half-life in water of about 70 d and in the whole system of 90.5 d. The major metabolite was 2,4-dichloro-1-(1-hydroxyethyl)benzene which peaked at 11.2 and 27.7% in the sediment and water, respectively, 63 DAT. At 25°C however, the half-life in water was about 7 d, reflecting more rapid movement to the sediment, with a whole system half-life of 27.0 d. At this temperature, no metabolites were found at >10%. In two other natural stream sediment-water systems held at 20°C, the half-life of parent compound was 38.0 and 40.3 d with the same major metabolite as in the previous study peaking at 17.4% of the originally applied amount at 61 DAT. Nonextractable radioactivity and evolved $^{14}CO_2$ peaked at 28.6 and 10.0% at 103 DAT. When a natural pond was treated at 74 kg a.i./ha in a field study, chlorfenvinphos dissipated from the water column with a half-life of 8.3 d while the concentration in sediment peaked at 0.32 mg a.i./kg sediment at 4.8 DAT and declined to 0.15 mg a.i./kg sediment by 33.9 DAT.

Table 6. Summary of environmental transformation studies.

Media	**Half-life or DT50**	
Atmospheric transformation	7 h due to hydroxyl radical reaction	
Soil		
-aerobic sandy loam	16 d at 28°C 42 d at 15°C 98 d at 3°C (all at 60% MHC)	11 d at 20-60% MHC 63 d in air dried soil (all at 28°C)
-organic muck	21 d at 28°C 80 d at 15°C >168 d at 3°C (all at 60% MHC)	13 d at 20% MHC 41 d at 40% MHC 58 d at 60% MHC 91 d in air dried soil (all at 28°C)

-carrots in a glasshouse	soil concentrations hardly declined over 18 weeks	
-previously treated Belgian soils -not previously treated	25-30 d 50-56 d	
-sandy loam -organic soil	<7 d at 28°C and 60% FCM 7 d at 28°C and 60% FCM	
-eight soils	50-80% of the applied dose remained at 56 DAT at 15°C and FCM	
Natural water/sediment systems		
-pond water -whole system	70 d (both at 10°C) 90.5 d	7 d (both at 25°C) 27.0 d
-stream water/sediment	38.0-40.3 d at 20°C	
-pond water -sediment	8.3 d peak concentration of 0.32 mg a.i./kg sediment at 4.8 DAT declining to 0.15 mg a.i./kg sediment by 33.9 DAT	

2.15.2 Mobility

The K_{OM} value for chlorfenvinphos of 170 with the equivalent K_{OC} of 293 indicates medium mobility. When chlorfenvinphos was applied to a sloping silty clay loam (about 8 m up slope from a pond) seeded with spring barley at 22 kg a.i./ha in the emulsifiable concentrate formulation, the highest concentration (8.7 mg a.i./kg soil 1 DAT) was found in the treated strip which dissipated with a half-life of about 28 d. Only at 28 DAT were detections of 0.03 mg a.i./kg soil found near the edge of the pond while all other samples (soil and water) were below the limits of detection. On a clay loam treated in a similar manner, the low mobility was confirmed as detections were only made in the treated strip to 25 cm depth and the adjacent strip (1.8 m down slope) to 15 cm; however, the DT50 was longer at >98 d. Another experiment was conducted with a sloping trough filled with silt loam and partitioned so that horizontal and vertical movement could be distinguished. When chlorfenvinphos was applied at 37 mg a.i./kg soil in the top compartment and the trough left outdoors for 140 d, 78% of all parent found in the leachate (20.1 L) occurred in the first 63 DAT and from the originally treated uppermost compartment; this confirmed the low surface run-off potential of chlorfenvinphos.

A US review reported low soil mobility with only 1-1.5% of the applied amount (formulation unspecified) leached to a depth of 7.5-15 cm in one study and no detections below 10 and 15 cm with a granular formulation in two other studies. Surface run-off was not significant as only 0.3-0.6% of the applied amount was found in run-off water after rain. Monitoring of surface waters over 8 yr in areas where chlorfenvinphos had been used also found no detections. As well, water and sediments in farm ditches did not contain chlorfenvinphos despite its detection in some soil samples.

A UK MAFF review calculated a GUS of 1.72 using a K_{OC} and soil half-life of 680 and 30 d, respectively, which classifies chlorfenvinphos as a non-leacher.

2.15.3 Volatilisation

The US review considered chlorfenvinphos to volatilise slowly from water and therefore to be essentially nonvolatile. Environment Australia agrees that the vapour pressure and Henry's Law Constant indicate that chlorfenvinphos has a low volatility and is unlikely to volatilise significantly from water or moist soil surfaces.

2.15.4 Field dissipation

When chlorfenvinphos was applied to cabbage foliage in the laboratory, the initial half-life was 2-3 d

but decreased after this time and >50% was said to have volatilised within 4-7 DAT (Table 8). There was some suggestion that phototransformation had isomerised the Z-isomer to the E-isomer. This was similar to potato and cabbage foliage in dry outdoor conditions. No translocation of residues from treated leaves was found and the major degradation product was a conjugate of 2,4-dichloro-1-(1-hydroxyethyl)benzene.

Table 7. Summary of field dissipation studies, including those of a UK MAFF report.

Media	**Half-life or DT50**
Cabbage foliage	initially 2-3 d but decreased after this time with >50% volatilisation in 4-7 DAT
Three soils -controls (no compost) -with organic compost	 9-23 d (non-persistent to slightly persistent) 13-53 d
Three sandy loams Silty loam	8.8-35.9 d All soils planted with cauliflower 23.0 d
Three sandy loams and a silty loam	Planted with -cauliflower 13.5-27.9 d -brussel sprouts 23.2 d -chinese cabbage 20.8-25.8 d
Cauliflower and brussel sprout plots with different chlorfenvin-phos histories	-1 yr history 27.2 d -2 yr history 20.1-25.7 d -8 yr history 10.8-18.7 d -parent + 5 metabolites 52.4-68.6 d in all soils
Sandy loam Peat loam	21% remaining at 238 DAT 41% remaining at 238 DAT
UK soils	28-210 d initial half-life possibly due to low temperatures over winter, annual carryovers of 2.5-12.5%
MAFF (1994)	
Four soils	12-45 d All soils planted with cauliflower and brussel sprouts
Field crops	27% of the applied amount detected in the soil at 161 DAT, traces of both isomers found 4 yr after treatment
Sandy loam	granules 41% remaining in the top 15 cm 84 DAT fluid gel 65-76% remaining in the top 15 cm 84 DAT
Sandy loam	granules no significant decrease in soil concentration after 62 d liquid 20% decrease 62 DAT
Peat blocks	85-100% remaining 56 DAT when stored in a glasshouse
Onion plots	variable residue concentrations (up to 11.1 mg a.i./kg soil) but no overall accumulation after treatment for 3 yr
Sorghum plots	30-45 d, no residues at 120 DAT
Fallow field	33 d, no residues at 120 DAT
Sand Silt loam	70-140 d 40-70 d
Four sand soils Peat	2-60 d 70% remained 150 DAT

Half-lives of chlorfenvinphos were 1.5-2.4X longer in three soils (13-53 d) which had been amended with organic compost and planted with cauliflower, compared to control soils which had

not been fertilised (9-23 d). The dissipation rate in control soils would classify chlorfenvinphos as non-persistent to slightly persistent. No parent compound or metabolites were detected in the cauliflower flower or soil deeper than 10 cm. In three sandy loams and a silty loam planted with cauliflower, the half-lives were 8.8-35.9 d and 23.0 d, respectively. Main metabolites were 2,4-dichloro-chloromethyl ketone, 2,4-dichlorobenzoic acid and 2-hydroxy-4-chlorobenzoic acid whose maximum concentrations were 3.3, 7.9 and 5.0 mg a.i./kg soil at 36, 18 and 36 DAT, respectively. When cauliflower, brussel sprouts and chinese cabbage were planted in the same soils and treated in the same manner, half-lives in the soils of the three crops were 13.5-27.9, 23.2 and 20.8-25.8 d, respectively. It was suggested the history of 1-18 years of previous treatment may have selected for a microbial population adapted to decomposing chlorfenvinphos and therefore account for the sometimes shorter half-lives. This was supported by half-lives of chlorfenvinphos in other cauliflower and brussel sprout plots of 27.2 d in soils with 1 yr previous chlorfenvinphos history, to 20.1-25.7 d for soils with 2 yr history, to 10.8-18.7 d in a soil with 8 yr history. Half-lives for the collective dissipation of parent and five metabolites was relatively constant at 52.4-68.6 d in all these soils. Residue analyses indicated that chlorfenvinphos was absorbed from the soil and translocated into the foliage.

In a sandy loam and peat loam treated with chlorfenvinphos granules and planted with carrots, dissipation was quicker from the sandy loam than peat loam with about 21 and 41% of the originally applied amount remaining at 238 DAT, respectively. At 182 DAT, only about 1% of the chlorfenvinphos had leached to the 10-15 cm layer in both soils and only traces were detectable below this. There was some suggestion that high organic matter content of the peat loam increased the adsorption of chlorfenvinphos to soil and reduced the rate of dissipation. On soils in the UK, the initial half-life was usually in the wide range of 28-210 d, probably due to a slowing of degradation when temperatures fell below 6-7°C. Other data showed annual carryovers of 2.5-12.5% in field trials.

2.15.5 Uptake and metabolism in plants

Carrots, onions (treated at 3.4 and 4.5 kg a.i./ha, respectively) and cabbages (treated at 4 mg a.i./plant) were harvested at maturity after 12-18 weeks. In carrot plots, the majority of the radioactivity was identified as parent at 2.2 mg a.i./kg soil with 0.33 mg a.i./kg tissue in the leaf. In the onion plots, the greatest residues of parent were in the soil at 2.4 mg a.i./kg soil; residues in the leaf and bulb were =0.08 mg a.i./kg tissue. The majority of the applied radioactivity (mostly as parent compound) to cabbage was found in the soil at 0.32-0.36 mg a.i./kg soil with equal amounts (0.26 mg a.i./kg plant) in the acetone extractable and unextractable portions of the cabbage stump and root.

The leaves of potato, cabbage and maize plants grown in a glasshouse were treated with 30 mg a.i./kg plant. The half-life for parent compound in potatoes was 5.9 d over the entire 28 d sampling period despite an initially rapid degradation with a half-life of 1.9 d during the first week. Half-lives in cabbage and maize were 10.6 and 6.8 d, respectively and no translocation from treated to untreated leaves occurred. The main metabolite was 2,4-dichloro-1-(1-hydroxyethyl)benzene in the soil and as a conjugate in the crops.

Carrot seedlings grown in treated soil were transferred to an untreated sandy loam or peat after 19 d and transferred 75% of the chlorfenvinphos in carrot seedlings to the untreated soil.

2.15.6 Bioconcentration

The relatively low bioconcentration factors of 37-460 (reported in other reviews) and 332 (estimated) for fathead minnow indicate that bioconcentration is likely to be low. This was confirmed by BCFs of 66-103 with depuration half-lives of 25-26 h in whole rainbow trout.

2.15.7 Residues in wool

Pesticide residues generally dissipate in fleece over time due to volatilisation and oxidation. A half-life for chlorfenvinphos in greasy wool of 56.6 d, including accounting for dilution by wool growth, was found in an Australian study when merino sheep were handjetted. Other studies indicate that dissipation of residues located near the surface of the fleece and on coarse open fleeces is faster and organophosphates generally degrade relatively quickly with half-lives of 28-35 d under Australian conditions.

Little degradation occurs when wool is baled; however, scouring removes about 95% of residues, >28.5% of which is recovered in the grease to be processed into various lanolin products. The remainder of the grease (containing residues) is usually treated before discharge to the environment in the liquid effluent and sludge. As chlorfenvinphos has a moderate solubility in water of 95 mg/L and a log K_{OW} of 3.1-4.2, it will partition mostly into the grease but still be found in the aqueous phase of the scour. Dye house effluents may also contain residues after processing the wool.

CSIRO's new Sirolan CF process can extract up to 80% of lipophilic pesticide residues from the effluent; however, not all scouring plants use this method. The SimpleTreat model predicts 37% of the chlorfenvinphos in treatment plant wastewater will partition to sludge and 32% to water with 31% degraded if it were inherently biodegradable.

2.15.8 Conclusions

Chlorfenvinphos is not expected to hydrolyse or volatilise to a great extent, although any amount in the atmosphere will transform quickly with a half-life of about 7 h. It biodegrades in aerobic soils with half-lives of about 11-98 d with more rapid degradation at higher temperatures and moistures, and lower organic matter content. Other reviews have reported variable soil biodegradation from DT50 values of <7 d to hardly any decline over 18 weeks. Dissipation from natural water-sediment systems was relatively quick with half-lives of 27-91 d, again with the rate proportional to the temperature. None of the major degradation metabolites was found to have insecticidal properties.

The K_{OM} and K_{OC} values for chlorfenvinphos of 170 and 293, respectively, indicate medium mobility. Field studies showed low to medium mobility with detections in soil made only in treated areas or at low concentrations 8 m downslope 28 d after treatment. This was confirmed by US and UK reviews.

Field dissipation DT50 values were also variable (9-53 d) depending on conditions but generally showed a rapid loss. However, the UK review reported some conflicting persistent results of 85-100% remaining 56 DAT of peat blocks stored in a glasshouse and a DT50 of 70-140 d in a sandy soil. A limited amount of chlorfenvinphos is taken up by plants grown in treated soil while no translocation was found from treated leaves. However, carrots grown in treated soil later transferred residues to untreated soil. Crops metabolised chlorfenvinphos with half-lives of 5.9-10.6 d. The relatively low bioconcentration factors of 37-460 (reported in other reviews), 332 (estimated) for

fathead minnow, and 66-103 in rainbow trout, indicate that bioconcentration is likely to be low.

Degradation of chlorfenvinphos in greasy wool on merino sheep is similar to that in aerobic soil with a half-life of 56.6 d, including accounting for dilution by wool growth. Dissipation is faster on coarse open fleeces but is severely restricted when wool is baled. About 95% of pesticide residues are transferred to wool scouring solutions which are usually treated before discharge to the environment. Chlorfenvinphos will partition mainly in the grease but may still be found in the aqueous phase of the scour.

3. ENVIRONMENTAL TOXICOLOGY

As with environmental chemistry and fate, many studies from the published literature were found in addition to those supplied by the registrants of chlorfenvinphos. As well, both ATSDR (1997) and MAFF (1994) reviewed studies which are summarised here but were not reviewed directly. The reviews of some of the studies contained very few details of experimental methodology and it is unknown if this was due to the quality of the original paper or the review report format. Those studies beginning with "SC 8993/" were presumed commercial-in-confidence data and were not referenced in the MAFF (1994) review.

As many of the studies were from the open literature, no indication was given of adherence to any standard protocol. Other studies (including some submitted by the registrants) were not recently completed and would not be acceptable to current guidelines. However, the collective weight of evidence indicates a general consensus which is discussed in each section. Studies which followed a particular protocol are identified as such.

3.1 Birds

The toxicity of chlorfenvinphos to several species of birds was examined in submitted studies, including those published in the scientific literature, which are summarised in Table 9. Chlorfenvinphos was very highly toxic to starlings with an acute LD50 < 10 mg a.i./kg bodywt, highly toxic to pigeons and blackbirds (LD50 of 10-50 mg a.i./kg bodywt) and moderately toxic to mallard ducks, chickens, pheasants and quail (LD50 of 50-500 mg a.i./kg bodywt) in acute exposures. The 28-d LOEC to pigeon, pheasant and Japanese quail was 100 mg a.i./kg food for depressed brain esterase activity and/or liver and kidney esterases. Feeding by various bird species on treated wheat seeds in recently planted fields resulted in no overt symptoms until after a second sowing 12 d later when 12 pigeon and dove carcasses were found. Annual reports of pigeon (a particularly susceptible species) mortality have been made around the time of sowing. The 8-h NOEC and LOEC for adult starlings was 3 and 6 mg a.i./kg bodywt, respectively, based on adverse brain AChE levels.

Table 8. Summary of chlorfenvinphos toxicity to birds.

Species	**Route**	**Duration**	**Parameter and Result (mg a.i./kg bodywt)****	**Reference**
Mallard ducks	NR*	NR*	LD50 = 85.5 (44.5, 164)	Stanley and Bunyan (1979)
Chickens			LD50 = 44-240	
Pigeons	Oral	Single dose + 3 d	LD50 = 16.4 (13.7, 25.8)	Bunyan et al. (1971)
Pheasant			LD50 = 107 (80, 145)	

Japanese quail		observation	LD50 = 148 (121, 229)	
Starling	Oral	NR	LD50 = 3.2	Schafer (1972)
Red-wing blackbird			LD50 = 10	
Pigeons, Pheasant and Japanese quail	Dietary	28 d	LOEC = 100 mg a.i./kg food for depressed brain, liver and kidney esterase function	Bunyan et al. (1971)
Field study - pigeons, chaffinch, yellow hammer, stock dove	Treated wheat seeds	6 d + 1 d	12 pigeon and dove carcasses found after resumption of feeding after 6 d on seed at 1.22 g a.i./kg seed	Anonymous (1975), MAFF (1994)
Simulated field study - starlings	Single oral dose	8 h observation	NOEC = 3, LOEC = 6 for increased resting time, response to singing	Hart (1993)
Cited from MAFF (1994)				
Starling	Oral	NR	LD50 = 3.16-23.7	Schafer et al. (1983)
Red-wing blackbird			LD50 = 10.0-13.3	
House sparrow Common pigeon Brown-headed cowbird			LD50 = 13.3	
Common grackle			LD50 = 17.8	
House finch			LD50 = 23.7	
Quail			LD50 = 17.8-178	
Golden-crowned sparrow			LD50 = 178	
Japanese quail	Oral	24 h	NOEC = 0, LOEC = 74 for brain AChE inhibition and mortality	Westlake et al. (1981)
Pheasant	NR	24 h	LD50 = 384.6	Janda (1974)
		Subchronic	LD50 = 204.6	

NR = not reported, *see notes in text, **mg a.i./kg bodywt unless otherwise specified.

Studies reviewed in MAFF (1994) confirmed the very high toxicity of chlorfenvinphos to starlings and high toxicity to red-wing blackbirds, house sparrows, common pigeons, brown-headed cowbirds, common grackles, house finches and quail and moderate toxicity to golden-crowned sparrows and pheasants. The 21-d NOEC and LOEC to Japanese quail were 0 and 74 mg a.i./kg bodywt, respectively, based on plasma and brain AChE inhibition.

3.1.1 Single oral dose - mallard duck and chicken

Stanley and Bunyan (1979) summarised the results of other studies on the LD50 values of chlorfenvinphos to mallards and chickens as 85.5 (44.5, 164) and 44-240 mg a.i./kg bodywt, respectively. As no methodology was given, these values, which classify chlorfenvinphos as moderately toxic, must be treated with caution.

3.1.2 Single oral dose - pigeon, pheasant and Japanese quail

Bunyan et al. (1971) dosed pigeons (*Columba livia*, 280-500 g body weight), pheasants (*Phasianus colchicus*, 1.09-1.47 kg) and Japanese quail (*Coturnix coturnix japonica*, 90-152 g) with technical chlorfenvinphos (93%) at doses up to 200 mg a.i./kg bodywt and observed them for 3 d. LD50 values were calculated by probit analysis (although these could not be confirmed due to lack of data) and reported as 16.4 (13.7, 25.8), 107 (80, 145) and 148 (121, 229) mg a.i./kg bodywt, respectively. These values classify chlorfenvinphos as highly toxic to pigeons and moderately toxic to pheasant and Japanese quail.

3.1.3 Single oral dose - starling and red-wing blackbird

Schafer (1972) reported the oral toxicities of several chemicals, including chlorfenvinphos, to starling (*Sturnus vulgaris*) and red-wing blackbird (*Agelaius phoeniceus*). Wild-trapped birds were preconditioned to captivity for 2-6 weeks before dosing by oral gavage with an unspecified formulation. No other details of methodology were given. The reported LD50 values for starling and blackbird were 3.2 and 10 mg a.i./kg bodywt, with no confidence limits, which classify chlorfenvinphos as very highly and highly toxic, respectively.

3.1.4 14-28 day dietary toxicity - pigeon, pheasant and Japanese quail

Bunyan et al. (1971) also examined the chronic toxicity of chlorfenvinphos in the diet to the same species as in the acute tests by exposing them for 14 and 28 d to 100 mg a.i./kg food. Although no birds showed any symptom normally associated with organophosphate poisoning such as weight loss, all three species had significantly depressed brain esterase activity compared to controls while only pigeons and pheasants had depressed liver and kidney esterases. Therefore the 28-d LOEC was considered to be 100 mg a.i./kg food.

3.1.5 Field study

The effects on birds of chlorfenvinphos applied to wheat seeds at two locations in Britain was examined (Anonymous 1975, MAFF 1994). Seeds were treated with Birlane Liquid Seed Dressing (325 g a.i./L) at 1.22 g a.i./kg seed and drilled into a field of medium calcareous clay loam in late February and then completed 12 d later in early March due to unfavourable weather. A second plot of stiff calcareous clay loam was seeded in March by depositing all treated seed (nominal concentration of 1.03 g a.i./kg seed) on the surface of the soil without subsequent harrowing to bury the seed. A large flock of about 150 pigeons was observed feeding in this plot on the recently sown seed as well as debris from the previously abandoned potato crop.

Bird surveys conducted at both locations before treatment at various times of the day showed a broad range of species (29) dominated by pigeons (*Columba palumbus*) and chaffinch (*Fringilla coelebs*). Further surveys and searches of the sites (including surrounding woods and fields) up to 6 d after sowing found an increase in granivorous birds. At the site where treated seeds were left on the soil surface, continual feeding by birds resulted in no overt intoxication or mortalities (and the crop did not establish due to heavy feeding). This may have been due to the delayed feeding caused by a snow fall 12 h after seeding which covered seed for 24 h. In the 4 d period after initial sowing, residue analyses of seeds found a 64% decrease in chlorfenvinphos concentration from 0.85 to 0.31 g a.i./kg seed potentially caused by leaching from rain and snow. At the plot where seeds were buried, surveys and searches up to 6 d after seeding found =6 species of grain eaters in the sown areas (mostly pigeons, chaffinch and yellow hammer (*Emberiza citrinella*)) with no adverse effects noted until 24 h after seeding recommenced 12 d later when 12 pigeon and stock dove (*Columba cenas*) carcasses were recovered. Post mortem and tissue residue analyses found treated grain in the crop/gizzard and chlorfenvinphos in the muscle and skin. These were said to be approaching the LD50 to pigeons of approximately 16 mg a.i./kg bodywt. The author speculated that the first exposure had depressed acetylcholinesterase levels but not sufficiently enough to be symptomatic. However, the resumption of feeding on freshly treated seed compounded or added to the previous effect, resulting in mortality.

3.1.6 Simulated field study - starling

Hart (1993) dosed adult starlings (*Sturnus vulgaris*) at up to 15 mg a.i./kg bodywt with technical

chlorfenvinphos (89.2% Z-isomer) and measured several behavioural and physiological parameters in separate experiments in outdoor aviaries. Observers were hidden behind one-way windows and recorded behaviour using double-blind techniques. When orally dosed with corn oil in gelatin capsules containing up to 9 mg a.i./kg bodywt, all birds treated in the morning and sacrificed 8 h later had significantly depressed brain acetylcholinesterase (AChE) activity relative to controls which received only corn oil in capsules. Although no overt symptoms of intoxication were observed, higher doses were associated with increased time spent resting and decreased time preening or standing on one leg. Ataxia (loss of muscular control) or vomiting were noted in birds treated at 15 mg a.i./kg bodywt with brain AChE activities of 54-68% of controls. Doses of 10 and 15 mg a.i./kg bodywt caused significant reductions in time spent feeding with resultant losses in body weight. All birds dosed at =6 mg a.i./kg bodywt in one experiment exhibited vomiting while controls did not. All birds with lowered brain AChE failed to respond to a singing stimulus for a longer time after dosing and showed a more gradual return to normal response levels. Foraging ability was not affected at the highest treatment of 9 mg a.i./kg bodywt. Based on these results, the NOEC and LOEC were 3 and 6 mg a.i./kg bodywt, respectively.

3.1.7 Pigeons

Greig-Smith (1988) qualitatively reported that chlorfenvinphos was less toxic to geese, but carried a higher hazard to pigeons which are particularly susceptible. There have been some annual reports of feral pigeon and woodpigeon mortality around the time of sowing (presumably with a seed dressing formulation of chlorfenvinphos) although these were not considered serious enough to adversely affect their populations.

3.1.8 MAFF (1994) review

3.1.8.1 Acute oral LD50 to birds

Schafer et al. (1983) acclimated wild-trapped birds (Table 9) for 2-6 weeks to laboratory conditions before dosing by gavage with chlorfenvinphos (formulation unspecified). No further details on methodology were given. LD50 values reported for the various species are presented in Table 9.

Table 9. Acute oral LD50 values for birds in Schafer et al. (1983).

Common Name	Species Name	LD50 (mg a.i./kg bodywt)	Toxicity Classification
Starling	*Sturnus vulgaris*	3.16-23.7	Very highly to highly toxic
Red-wing blackbird	*Agelaius phoeniceus*	10.0-13.3	Highly toxic
House sparrow	*Passer domesticus*	13.3	Highly toxic
Common pigeon	*Columba livia*	13.3	Highly toxic
Brown-headed cowbird	*Molothrus ater*	13.3	Highly toxic
Common grackle	*Quiscalus quiscula*	17.8	Highly toxic
House finch	*Carpodacus mexicanus*	23.7	Highly toxic
Quail	*Coturnix coturnix*	17.8-178	Highly to moderately toxic

Golden-crowned sparrow	*Zonotrichia atricapella*	178	Moderately toxic

3.1.8.2 Japanese quail

Westlake et al. (1981) treated 21-d old Japanese quails (*Coturnix coturnix japonica*) with chlorfenvinphos (93%) in gelatine capsules at 0, 74, 148 or 296 mg a.i./kg bodywt (LD50 = 148.0 mg a.i./kg bodywt). Birds were housed at 19°C, 60% relative humidity and 16 h daylight for 21 d before dosing and during the 24 h observation period. Blood and brain samples were taken at various times and analysed for AChE, cholinesterase (ChE) and α-naphthyl acetate esterase activity. All birds in the highest treatment died within 70 min of dosing while 83 and 33% of those in the middle and low treatment died at 2 HAT, respectively. No explanation was given for the higher and sooner than expected mortality at the LD50 treatment of 148 mg a.i./kg bodywt. All doses induced significant plasma AChE and ChE inhibition within 2 h although the lowest treatment group (74 mg a.i./kg bodywt) recovered to within the control range at 24 HAT. Brain AChE was severely inhibited in all dosed birds with >88% inhibition in those that died within 2 HAT. Based on these results, Environment Australia considered the NOEC and LOEC to be 0 and 74 mg a.i./kg bodywt, respectively.

3.1.8.3 Pheasant

Chlorfenvinphos formulated as Birlane EC was not found to be repellent to pheasants (Janda 1974). The 24-h LD50 was 384.6 mg a.i./kg bodywt indicating moderate toxicity. The subchronic LD50 was given as 204.6 mg a.i./kg bodywt but no time period was reported.

3.2 Fish

Toxicity studies from the company and scientific literature on a range of fish species were assessed (Table 10). Chlorfenvinphos, in various formulations, was found to be very highly toxic to *Tilapia nilotica* and common carp (LC50 < 0.1 mg/L) and highly toxic to rainbow trout (LC50 of 0.1-1 mg/L) in acute exposures. It was moderately (LC50 of 1-10 mg/L) to highly toxic to the guppy in two experiments but highly to very highly toxic to the guppy and Harlequin fish in another. Juvenile carp placed in cages in a rice paddy showed 97% mortality within 7 d after treatment with 1.2 kg a.i./ha of a granular formulation. Many dead perch and roach were reported anecdotally when a pond was treated at 74 kg a.i./ha. Unfortunately, details on methodology were lacking in several of these studies and the results should be treated with caution.

Table 10. Summary of chlorfenvinphos toxicity to fish.

Organism	Life Stage	Test Type	Time	Parameter and Result	Formulation (% a.i.)	Reference
Rainbow trout	0.8-2.5 g	Static	96 h	60-100% mortality at 1,000 µg a.i./L, 70% mortality at 300 µg a.i./L	Birlane EC (240 g a.i./L), WP (250 g a.i./kg) or ME (100 g a.i./kg)*	Shires (1982)
Tilapia nilotica	2.2-6.7 g			LC50 = 40-55 µg a.i./L, 100% mortality at 300 µg a.i./L		
Carp	8.0-20 g			70% mortality at 300 µg a.i./L	Birlane EC (240 g a.i./L)	
Fathead minnow	0.7-1.9 g			No mortality at 300 µg a.i./L		
Tench	0.6-1.9 g			90% mortality at 300 µg a.i./L		
Carp	5.5 cm, 2.1 g	Static renewal	48 h	LC50 = 44.6 (20.6, 93.6) µg a.i./L	Birlane granular (30 g a.i./kg)	Stephenson (1982)
Guppy	NR	NR	96 h	EC50 = 1560 µg a.i./L (confidence limit not reported)	Technical (94.4%)	Lejczak (1977)
Guppy	32-35 mg	NR	96 h	LC50 = 600 µg a.i./L	Technical (98%)	Wroblewski (1979)
T. nilotica	0.4-1.3 g	Static	80 h	LC50 < 34.5 µg a.i./L	Birlane granular (49.0 g a.i./kg)	Stephenson (1981)
T. nilotica	0.6-0.8 g	Flow-through	96 h	LC50 = 45.9 (30.1, 67.3) µg a.i./L	Technical (91.3%)	Stephenson (1980)
Harlequin fish, guppy	NR	NR	96 h	100% mortality of Harlequin fish and 60% mortality of guppies at 316 µg a.i./L	Technical	Anonymous (1969)
				316 < LC50 < 1000 µg a.i./L for guppies, NOEC = 1000 µg a.i./L for Harlequin fish	1.44 g a.i./kg dust	
				240 < EC50 < 760 µg a.i./L for both species	240 g a.i./kg EC	
Harlequin fish	1.3-3 cm	Flow-through	48 h	LC50 = 270 µg a.i./L	Technical (92%)	Alabaster (1969)
				LC50 = 3550 µg EUP/L	Cooper's Fly dip formulation	
Spot	NR	NR	24 and 48 h	loss of equilibrium at 1000 µg a.i./L	Unspecified	Butler (undated)
Guppy	17 d	NR	12 d	NOEC = 0, LOEC = 500 µg a.i./L based on reduced food consumption	Technical (98%)	Wroblewski (1979)
Carp	7.7 cm, 4.6 g	Caged in rice paddy	7 d	97% mortality at 1,200 g a.i./ha	Birlane granular (30 g a.i./kg)	Stephenson (1982)
Perch and roach	NR	Treated pond	NR	Many dead perch and roach reported but not quantified	24% EC	Beynon et al. (1970, 1971)

*See comments in text. NR = not reported

The review by MAFF (1994) found some differences in the acute toxicity of chlorfenvinphos to fish (Table 12). It was listed as only highly toxic to carp, goldfish, *Orizias latipes* and guppy, and moderately toxicity to rainbow trout. The very high toxicity of chlorfenvinphos to *Tilapia nilotica* and carp was confirmed in one study, but another found only moderate toxicity to carp. The chronic 7-d NOEC and LOEC to rainbow trout were 10 and 100 µg a.i./L, respectively, based on brain acetylcholinesterase inhibition. For reproductive physiology endpoints in the striped catfish, the 84-d NOEC and LOEC were 0 and 3.02 µg a.i./L respectively. Chlorfenvinphos applied at 0.9 kg

a.i./ha to a pond still caused 30% mortality to mosquito fish when introduced 15 DAT. It is apparent that there is a range of toxicity among and within a species presumably dependent upon differences in methodology.

Table 11. Summary of chlorfenvinphos toxicity to fish as reviewed by MAFF (1994).

Organism	Life Stage	Test Type	Time	Parameter and Result	Formulation	Reference
Rainbow trout	1.1 g, 3.8 cm	Static renewal	96 h	LC50 = 1120 (880, 1460) µg a.i./L	EC (240 g a.i./L)	SC 8993/53
Carp	1.10 g, 4.5 cm	Static	48 h	LC50 = 270 µg a.i./L	Technical	Nishiushi and Hashimoto (1967)
Goldfish	1.04 g, 4.01 cm			LC50 = 340 µg a.i./L		
Orizias latipes	0.16 g, 2.54 cm			LC50 = 230 µg a.i./L		
Tilapia nilotica	0.6-3.0 g	Flow-through	96 h	LC50 = 39 µg a.i./L	Granular	Stephenson et al. (1984)
		Static		LC50 < 30 µg a.i./L		
Carp	2.1 g	Static renewal	48 h	LC50 = 45 µg a.i./L		
Carp	0.6 g, 3.3 cm	Static renewal	96 h	LC50 = 1900 (1490, 2770) µg a.i./L	EC	SC 8993/54
Guppy	NR	NR	24 h	LC50 = 540 (520, 560) µg a.i./L	Technical	Mathis and Pant (1974)
Rainbow trout*	0.6 g, 3.9 cm	Flow-through	21 d	NOEC = 38 µg a.i./L LOEC = 154 µg a.i./L	EC 240 g a.i./L	SC 8993/55
Rainbow trout*	NR	NR	7 d	NOEC = 10 µg a.i./L LOEC = 100 µg a.i./L	NR	Groba and Trzcinska (1979)
Mosquito fish*	NR	Cages in ponds	24 h	August and September treatments 0.22 kg a.i./ha: 100% mortality at 0 DAT, 0% at 8 DAT. 0.9 kg a.i./ha: 100% mortality at 0 DAT, 98% at 8 DAT, 30% at 15 DAT	500 g a.i./L EC	Mulla and Isaak (1961)
			48 h	October and November treatment 0.11 kg a.i./ha: 12% mortality at 0 DAT, 0% at 7 DAT. 0.45 kg a.i./ha: 100% mortality at 0 DAT, 0% at 7 DAT but 48% moribund, no effect by 14 DAT		
Striped catfish	12 g	NR	84 d	NOEC = 0 µg a.i./L LOEC = 3.02 µg a.i./L	Birlane 240 g a.i./L	Haider and Upadhyaya (1985)

*See comments in text. NR = not reported

3.2.1 Acute studies

3.2.1.1 Rainbow trout, *Tilapia nilotica*, carp, fathead minnow and tench

Shires (1982) exposed juvenile rainbow trout (*Oncorhyncus mykiss*), *Tilapia nilotica*, carp (*Cyprinus carpio*), fathead minnow (*Pimephales promelas*) and tench (*Tinca tinca*) to 300 µg a.i./L of an emulsifiable concentrate formulation of chlorfenvinphos (Birlane 240 g a.i./L) in 96-h static experiments at 22±1°C. Additionally, a wettable powder (250 g a.i./kg) and micro-encapsulated suspension concentrate (100 g a.i./kg) were tested on trout and *T. nilotica*. Trout showed similar sensitivity to all formulations with 60-100% mortality at 1,000 µg a.i./L (at least

highly toxic) and no mortality at other nominal concentrations. *T. nilotica* were more sensitive with 96-h LC50 values of approximately 40-55 µg a.i./L for the three formulations (very highly toxic). In relation to the other fish species tested, *T. nilotica* were the most sensitive (100% mortality at 96 h) followed by tench (90%), carp (70%), trout (70%) and minnow (0%) at 300 µg a.i./L and 22°C.

3.2.1.2 Carp

Stephenson (1982) conducted acute toxicity tests of chlorfenvinphos on common carp (*Cyprinus carpio*). The 48-h static exposure with renewal in the lab used water of 22-26°C, pH 6.7-6.9 and 20-25 mg $CaCO_3$/L. Juvenile carp (mean length and mass of 5.5 cm and 2.1 g) were placed in nominal concentrations of up to 200 µg a.i./L using a granular formulation of Birlane (30 g a.i./kg). The 48-h LC50 was calculated by probit analysis to be 44.6 (20.6, 93.6) µg a.i./L classifying chlorfenvinphos as very highly toxic.

3.2.1.3 Guppy 1

Lejczak (1977) examined the toxicity of technical chlorfenvinphos (94.4%) to the guppy (*Poecilia reticulata*) in 96-h exposures using river water. Details on methodology and water quality characteristics were sparse and 10 fish were placed in only 100 mL of each treatment solution. As no raw data were reported, The 96-h EC50 (endpoint of paralysis) of 1560 µg a.i./L, which would indicate moderate toxicity could not be verified.

3.2.1.4 Guppy 2

Wroblewski (1979) studied the effects of chlorfenvinphos (98%) on juvenile guppy (*Lebistes reticulatus*) of 8-72 mg wet weight. LC50 determinations were conducted in aerated dechlorinated tap water at 22±0.1°C for 96 h according to weight groups. Fish of about 32-35 mg weight were the most susceptible in 24-h exposures with an LC50 of 1400 µg a.i./L. This higher sensitivity was also evident in longer exposures with a 96-h LC50 of 600 µg a.i./L indicating high toxicity compared to 900 µg a.i./L for fish of 1-8 mg weight.

In other experiments, guppies exposed continuously to various concentrations of 300-5060 mg/L eventually showed mortality after different periods of time. A relatively quick mortality response was observed at the highest concentration with 50% mortality after about 4 h whereas 300 µg a.i./L caused the same mortality after about 135 h exposure; there was no concentration tested at which 50% mortality was not reached. In 12 d exposures of fish starting at 17 d old, food consumption was lower than controls in the lowest treatment of 500 µg a.i./L making this the LOEC.

3.2.1.5 *Tilapia nilotica*, static exposure

Stephenson (1981) investigated the acute toxicity of chlorfenvinphos (Birlane "stick on" granular formulation at 49.0 g a.i./kg) to *Tilapia nilotica* (2.9-4.5 cm, 0.4-1.3 g). Fish were incubated in water of 23-26°C, pH 7.4-7.8 and hardness of 240-260 mg $CaCO_3$/L for 80 h. Granules were applied evenly to the surface of all aquaria at the beginning of the experiment. Nominal concentrations were up to 670 µg a.i./L but measurements showed concentrations increasing from 11.6-45.5% of nominal at 3 h after treatment (HAT) to 95.6-109% at 80 HAT. By 24 HAT, all fish in measured concentrations up to 115 µg a.i./L had died and at 80 HAT only 10% were alive in the lowest treatment of 34.5 µg a.i./L. No LC50 could be calculated but it was clearly <34.5 µg a.i./L at 80 HAT classifying chlorfenvinphos as very highly toxic.

3.2.1.6 *Tilapia nilotica*, flow-through exposure

Stephenson (1980) exposed *Tilapia nilotica* (1.8-2.0 cm, 0.6-0.8 g) to technical chlorfenvinphos (91.3%). Exposure to water of 26±1°C, pH 8.0±0.1 and hardness 265-270 mg $CaCO_3$/L under flow-through conditions was maintained for 96 h. Mean measured concentrations were used to calculate the 96-h LC50 of 45.9 (30.1, 67.3) µg a.i./L by probit analysis. This value classifies chlorfenvinphos as very highly toxic.

3.2.1.7 Harlequin fish and guppy

Anonymous (1969) conducted a poorly documented study on the toxicity of the technical (11.2% α-isomer, 84.1% β-isomer), emulsifiable concentrate (240 g a.i./kg) and field-strength dust (1.44 g a.i./kg) to Harlequin fish (*Rasbora* spp) and the guppy (*Lebistes* spp). No information was given on the maintenance or characteristics of the fish, experimental procedures, use of controls or replicates except that aquaria were kept at 20±1°C and aerated.

In 2-h exposures, 0 and 100% mortality was found at 3160 and 10,000 µg a.i./L, respectively, for both species. Technical grade material at the lowest concentration of 316 µg a.i./L caused complete mortality of Harlequin fish after 96 h, but only 60% mortality of guppies under the same conditions. The approximate 96-h LC50 of the EC formulation was between 240 and 760 µg a.i./L for both species. The dust formulation had variable results with an approximate 96-h LC50 of 316-1000 µg a.i./L for guppies but a NOEC of 1000 µg a.i./L for Harlequin fish. Although these values generally classify chlorfenvinphos as highly to very highly toxic to these fish, these results must be treated with extreme caution because of the many deficiencies in this study.

3.2.1.8 Harlequin fish

Alabaster (1969) reported the results of toxicity testing on harlequin fish (*Rasbora heteromorpha*) to technical (92%) and formulated (Cooper's Fly dip, formulation and guaranteed content not specified) chlorfenvinphos. Fish were 1.3-3 cm in length and exposed in flow-through solutions of 20 mg $CaCO_3$/L hardness at 20°C at pH 7.2. The 48-h LC50 values were graphically determined at 270 µg a.i./L and 3550 µg EUP/L. These values classifying chlorfenvinphos as highly toxic must be treated with caution as confidence limits and raw data were not presented.

3.2.1.9 Spot

Butler (undated) summarised a study on the toxicity of chlorfenvinphos (formulation unspecified) to the estuarine fish spot (*Leiostomus xanthurus*) in a mean water temperature of 14°C. In 24 and 48-h exposures, fish (quantity not stated) lost equilibrium at 1000 µg a.i./L. As no other experimental details were provided, these results should be treated with caution.

3.2.2 MAFF (1994) review - acute studies

3.2.2.1 Rainbow trout

The study identified only as SC 8993/53 exposed rainbow trout (*Oncorhyncus mykiss*, mean mass 1.1 g, mean length 3.8 cm) to solutions of the 240 g a.i./L emulsifiable concentrate formulation of chlorfenvinphos in static conditions with renewal every 24 h. Water quality conditions were 13.0-

14.5°C, pH 7.7-8.3, dissolved oxygen 8.6-10.7 mg/L and a fish loading of 0.6-1.0 g body weight/L. Symptoms of hypoactivity, remaining at the top or bottom of the tank and enhanced respiratory rate were observed in the lowest nominal treatment of 234 µg a.i./L. The 96-h LC50 estimated by the logit method was 1120 (880, 1460) µg a.i./L indicating moderate toxicity.

3.2.2.2 Carp, goldfish and *Orizias*

Nishiushi and Hashimoto (1967) exposed fish to technical chlorfenvinphos for 48 h at 23-24°C. *Cyprinus carpio* (4.5 cm long and 1.10 g), *Cyprinus auratus* (4.01 cm and 1.04 g) and *Orizias latipes* (2.54 cm and 0.16 g) were held in 10 L jars at loadings of 0.55, 0.52 and 0.16 g/L, respectively, with at least 10 fish per dose. The 48-h LC50 values were graphically determined from nominal concentrations to be 270, 340 and 230 µg a.i./L indicating high toxicity. These values must be treated with caution, however, as there were numerous inconsistencies in methodology.

3.2.2.3 *Tilapia nilotica* and carp

Stephenson et al. (1984) exposed *Tilapia nilotica* (0.6-3.0 g) to solutions of a granular formulation of chlorfenvinphos in 96-h flow-through tests with a fish loading of about 0.23 g bodywt/day. Water quality parameters were dechlorinated tapwater, 25±2°C, hardness 230-270 mg $CaCO_3$/L, pH 7.1-8.1 and dissolved oxygen of 7.5-8.5 mg/L. The 96-h LC50 was reported as 39 µg a.i./L (very highly toxic) determined by probit analysis or graphically from the measured concentrations; no confidence limits were given.

In another experiment, tapwater of pH 6.9-8.2, hardness 240-280 mg $CaCO_3$/L and dissolved oxygen 6.2-8.3 mg/L were allowed to stand for 48 h at 24±2°C. *T. nilotica* were added (loading of 0.02 g body weight/L) and after 24 h a 50 g a.i./kg granular formulation of chlorfenvinphos was added to give nominal concentrations up to 670 µg a.i./L. The 96-h LC50 was given as <30 µg a.i./L calculated by probit analysis or graphical interpolation on nominal concentrations indicating very high toxicity.

Carp (*Cyprinus carpio*, 2.1 g) were placed in aerated water of pH 6.3-6.9, hardness 20-25 mg $CaCO_3$/L, dissolved oxygen 4.5-6.5 mg/L and 22-26°C. A dispersion of granular chlorfenvinphos was added to the tanks of loadings of 1.3 g body weight/L. Treatment solutions were renewed after 24 h. The 48-h LC50 was given as 45 µg a.i./L (very highly toxic) calculated by probit analysis or graphical interpolation (no confidence limits reported).

3.2.2.4 Carp

A study identified only as SC 8993/54 reported a 96-h static renewal exposure of carp (*Cyprinus carpio*) to the 240 g a.i./L emulsifiable concentrate formulation of chlorfenvinphos at nominal doses up to 2460 µg a.i./L. Fish of mean mass and length of 0.6 g and 3.3 cm, respectively, were incubated in deionised water of 18.0-18.5°C, pH 7.9-8.3 and dissolved oxygen 8.7-9.9 mg/L with an average loading of 0.4 g body weight/L. Clinical symptoms of remaining at the top of the tank and an enhanced respiratory rate were observed at the lowest dose of 222 µg a.i./L. The 96-h LC50 was calculated by the logit method as 1900 (1490, 2770) µg a.i./L indicating moderate toxicity.

3.2.2.5 Guppy

Mathis and Pant (1974) exposed field-collected female guppies (*Poecilia reticulata*) to technical chlorfenvinphos in serial dilutions and assessed mortality after 24 h. No further details were given on methodology. The 24-h LC50 was calculated as 540 (520, 560) µg a.i./L (highly toxic) based on information provided, however, this value should be treated with caution given the scarce details on methods.

3.2.3 Chronic studies

3.2.3.1 Carp

Stephenson (1982) also conducted a 7-d field study in rice paddies in Korea. These were planted with 6-wk old seedlings and then treated with the same granular formulation of chlorfenvinphos by hand casting approximately 11 weeks later at 1,200 g a.i./ha. The concentration of chlorfenvinphos was not stated although it would be equivalent to 1.2 mg/L if the water was 10 cm deep. Two days prior to pesticide application, juvenile carp (mean length and mass of 7.7 cm and 4.6 g) were placed in cages in the paddies. Water temperature during the 7 d observation period was 21-30°C with a pH of 5.6-6.8, hardness of 43-57 mg $CaCO_3$/L and suspended solids of 66-440 mg/L. At 3 DAT, >50% mortality was found in caged fish which increased to 97% by 7 DAT. This was significantly higher (p<0.001) than the control mortality of 6.6%.

3.2.4 Natural pond field study

Beynon et al. (1970, 1971) treated a natural pond in the UK with chlorfenvinphos, formulated as a 24% emulsifiable concentrate, at 74 kg a.i./ha giving an initial measured concentration of 6.1 mg/L (also reported in Dissipation in Natural Sediment/Water Field Study, page 281). Water and sediment were sampled before and after treatment up to 33.9 DAT. Details on methodology were scant and the authors concluded that insufficient invertebrates were sampled to show any significant effect. Although not quantified, the authors reported many dead perch and roach floating on the surface soon after treatment.

3.2.5 MAFF (1994) review - chronic studies

3.2.5.1 Rainbow trout 1

SC 8993/55 reported the chronic 21-d toxicity of the 240 g a.i./L EC formulation of chlorfenvinphos to *Oncorhyncus mykiss* (mean mass 0.6 g, mean length 3.9 cm). Fish were held in flow-through conditions with 100 L replacement every 24 h and a loading of <0.1 g/L/day. Water quality parameters were 15.0-16.5°C, pH 7.7-8.3 and dissolved oxygen 9.1-11.0 mg/L. Mean measured concentrations of 2-615 µg a.i./L were 73-163% of nominal which MAFF (1994) regarded as unacceptable along with the 20% control mortality (Environment Australia concurs). The NOEC and LOEC were 38 and 154 µg a.i./L, respectively.

3.2.5.2 Rainbow trout 2

Brain AChE was measured in trout (age and size unspecified) exposed to nominal chlorfenvinphos concentrations of 0.001-1.0 mg/L (Groba and Trzcinska 1979). After 7 d in unspecified conditions, considerable inhibition of the AChE activity relative to the controls was observed at both lethal and sublethal doses. Although no statistical significance was stated, it appears that the NOEC and LOEC were 10 and 100 µg a.i./L, respectively. These results must be treated with caution.

3.2.5.3 Mosquito fish

Mulla and Isaak (1961) treated several ponds with the 500 g a.i./L EC formulation of chlorfenvinphos to nominal doses of 0.11-0.9 kg/ha (unspecified as EUP or a.i.) at various times over several months. Water had a pH of 7.5-8.0 and depth of 10-20 cm. Wild-collected mosquito fish (*Gambusia affinis*) were placed in cages in each pond and assessed after 72 h. During August and September when the pond temperature was 25.5-34.5°C, complete mortality was observed within 24 h of exposure in the 0.22 and 0.9 kg/ha treatments. At 8 DAT, fresh fish introduced into the ponds showed mortality in the two treatments of 0 and 98% (which declined to 30% by 15 DAT with the introduction of more new fish), respectively. In October and November with water temperatures of 17-29°C, there was 12 and 100% mortality after 48 h in the 0.11 and 0.45 kg/ha treatments, respectively. When new fish were introduced at 7 DAT, there was no mortality in either treatment but 48% of the fish in the 0.45 kg/ha treatment were moribund. By 14 DAT, there was no residual activity on new fish.

3.2.5.4 Striped catfish

Haider and Upadhyaya (1985) examined the effect of chlorfenvinphos (formulated as Birlane 240 g a.i./L) on the midvitellic ovaries of wild-caught *Mystus vittatus*, a freshwater catfish. Fish (mean mass 12 g) with ovaries in the first half vitellogenic phase were held in either tap water controls or at 3.02 µg/L (presumed a.i.) for 84 d. Water was kept at room temperature of 26.2-36.9°C, pH 7.2 under natural photoperiod (unspecified location or time of year) and the fish fed daily. At the end of the exposure, sacrificed fish were examined histopathologically and showed a loss of stage II and III oocytes with some stage I oocytes degenerating relative to controls. The ratio of the ovary mass to whole body mass (gonadosomatic index) was significantly reduced along with some enzyme activities indicating a NOEC and LOEC of 0 and 3.02 µg a.i./L respectively.

3.3 Aquatic Invertebrates

Submitted studies and those summarised from MAFF (1994) on the freshwater invertebrate *Daphnia magna* showed conflicting results ranging from moderate (LC50 of 1-10 mg/L) to very high (LC50 <0.1 mg/L) acute toxicity (Table 12). Chlorfenvinphos was highly toxic to another species of water flea (*Ceriodaphnia dubia*) and the eastern oyster but moderately toxic to the scud. Only slight toxicity was found to protozoa which may be expected of a neurotoxin on a prokaryote. As experimental details were lacking in several of these studies, these results should be treated with caution.

The 21-d LOEC to *D. magna* was the lowest dose tested of 0.3 µg a.i./L based on adverse reproductive effects of reduced number of live young and the number of young per adult.

Table 12. Summary of chlorfenvinphos toxicity to aquatic invertebrates.

Organism	Test Type	Time	LC50* and 95% confidence limits (µg a.i./L)	Formulation (% a.i.)	Reference
Water flea	Static	48 h	EC50 = 0.25 (0.21, 0.30)	Technical (92.0%)	Stephenson (1983)
	NR	96 h	3750 (confidence limit not reported)	Technical (94.5%)	Lejczak (1977)

Eastern oysters	Shell growth	96 h	EC50 = 600 (confidence limit not reported)	NR	Butler (undated)
MAFF (1994) review					
Water flea	Static	48 h	2270 (170, 7390)	EC 240 g a.i./L	SC 8993/56
Water flea - *D. pulex*	NR	3 h	11 (confidence limit not reported)	Technical	Nishiushi and Hashimoto (1967)
- *M. macrocarpa*			23 (confidence limit not reported)		
Water flea	NR	48 h	0.1 (0.09, 0.11)	NR	Bogacka and Groba (1980)
Ceriodaphnia dubia	Static	48 h	0.40 (0.32, 0.50)	NR	Ankley et al. (1991)
Scud	Static	96 h	9800 (8600, 11000)	NR	Sanders (1969)
Protozoa	NR	96 h	59,200 (confidence limit not reported)	NR	Lejczak (1977)
Water flea	Static renewal	21 d	NOEC = 0, LOEC = 0.3 based on reproductive effects	EC 240 g a.i./L	SC 8993/57
Chironomids	Rice paddy	20 d	Mortality <5% at 20 DAT	NR	Stevens (1991)

*LC50 unless stated otherwise. NR = not reported.

3.3.1 Acute studies

3.3.1.1 Water flea 1

Stephenson (1983) exposed juvenile (<24 h old) water flea (*Daphnia magna*) to technical chlorfenvinphos (92.0%) in static exposures. The water temperature was 20±2°C with a pH of 8.1-8.4 and hardness of 168 mg $CaCO_3$/L. The 48-h EC50 (endpoint of immobilisation) was 0.25 (0.21, 0.30) µg a.i./L based on nominal concentrations classifying chlorfenvinphos as very highly toxic to daphnids.

3.3.1.2 Water flea 2

Lejczak (1977) exposed daphnids to chlorfenvinphos in similar conditions as with guppies (see Guppy 1, page 303). Twenty animals of unspecified age were placed in 10 mL of treatment solution for 96 h. As with other experiments, few details on methods were reported and no raw data were available to allow verification of the 96-h LC50 of 3750 µg a.i./L. This value is markedly higher (15,000X) than the previous study and would classify chlorfenvinphos as only moderately toxic but should be treated with caution.

3.3.1.3 Eastern Oysters

Butler (undated) summarised the results of testing chlorfenvinphos (formulation unspecified) on the shell growth rate of marine eastern oysters (*Crassostrea virginica*) in 96-h exposures. The EC50 at 16°C was 600 µg a.i./L (confidence limits unspecified). The author also reported a 1 week recovery period was required for the growth rate to match that of controls. This result, which classifies chlorfenvinphos as highly toxic, must be treated with caution as no other water quality parameters or methodology details were reported.

3.3.2 MAFF (1994) review - acute studies

3.3.2.1 Water flea 1

Daphnia magna were exposed to solutions of the 240 g a.i./L emulsifiable concentrate formulation of chlorfenvinphos under 48 h static conditions (SC 8993/56). Daphnids were kept at 21.5-22.0°C, pH 8.0-8.3, 8.7-8.8 mg/L dissolved oxygen and a 16 h light photoperiod. The 48-h LC50 calculated by the logit method based on nominal concentrations was reported as 2270 (170, 7390) mg/L which classifies chlorfenvinphos as moderately toxic.

3.3.2.2 Water flea 2

Technical chlorfenvinphos was used to make up an unspecified range of solutions in which *Daphnia pulex* and *Moina macrocarpa* adults were exposed for 3 h at 24-26°C (Nishiushi and Hashimoto 1967). The 3-h LC50 values for these nonstandard experiments were graphically derived as 11 and 23 µg a.i./L. However, based on the lack of experimental details provided, these results should be treated with caution.

3.3.2.3 Water flea 3

A summary (Bogacka and Groba 1980) reported the 48-h LC50 to *Daphnia magna* to be 0.1 (0.09, 0.11) µg a.i./L classifying chlorfenvinphos as very highly toxic. As no experimental details were given, this result should be treated with extreme caution.

3.3.2.4 Water flea 4

Ankley et al. (1991) determined the toxicity of chlorfenvinphos to =48 h old *Ceriodaphnia dubia* in static exposures at 25°C. Using the trimmed Spearman-Karber method, the 48-h LC50 was calculated as 0.40 (0.32, 0.50) µg a.i./L which is very highly toxic.

3.3.2.5 Scud

Sanders (1969) exposed 2-month old amphipods (*Gammarus lacustris*) to unspecified doses at pH 7.1 and 21.1°C for 96 h in static systems. The 96-h LC50 at 21.1°C was reported as 9800 (8600, 11000) µg a.i./L which classifies chlorfenvinphos as moderately toxic. All animals showing symptoms of poisoning died after transfer to clean water.

3.3.2.6 Protozoa

Lejczak (1977) exposed *Paramecium caudatum* to chlorfenvinphos (94.4%) solutions at 20°C for 96 h. The 96-LC50 was reported as 59.2 mg/L which is slightly toxic.

3.3.3 Chronic studies

No chronic studies on the toxicity of chlorfenvinphos to aquatic invertebrates were submitted.

3.3.4 MAFF (1994) review - chronic studies

3.3.4.1 Water flea

SC 8993/57 conducted a 21-d static renewal test on *Daphnia magna* using the 240 g a.i./L EC formulation of chlorfenvinphos at measured concentrations of 0.3-25 µg a.i./L. These were 64-250% of nominal concentrations. Daphnids (=24 h old) were kept at 20.5-22.0°C, pH 8.1-8.7,

dissolved oxygen 8.2-9.1 mg/L and under a 16 h photoperiod. It was not stated if any protocols were followed in conducting this experiment. F1 generation mortality was 100% by day 4 in the =2.5 µg a.i./L treatments and by day 16 at 0.8 µg a.i./L. Only the lowest dose of 0.3 µg a.i./L was not significantly different from control mortality (10%) at day 21. However, based on the reduced number of live young and the number of young per adult, the lowest dose (0.3 µg a.i./L) was significantly different from the control and was therefore the LOEC.

3.3.4.2 Chironomids

Stevens (1991) applied chlorfenvinphos to rice paddy water (25-30°C, pH 6.8) at 0.27 mg/L. Bioassays with rice bloodworms (*Chironomus tepperi*) found mortality declined to <5% only 20 DAT. No other details were specified and this result must be treated with caution.

3.4 Aquatic Plants

One toxicity study was submitted on a freshwater alga while other studies on algae and macrophytes were summarised from MAFF (1994) (Table 13). Chlorfenvinphos was moderately toxic (IC50 of 1-10 mg/L) to *Selenastrum capricornutum*, *Scenedesmus subspicatus*, and moderately to slightly (LC50 of 10-100 mg/L) toxic to *S. quadricauda*. Concentrations as low as 600 µg a.i./L reduced the biomass and chlorophyll content of *Lemna minor* at an unspecified exposure duration. The bacteria *Sphaerotilus natans* showed decreased growth at 1.0-100 mg/L but increased growth at 10,000 mg/L.

Table 13. Summary of chlorfenvinphos toxicity to plants.

Organism	Test Type	Time	IC50 and 95% confidence limits (µg a.i./L*)	Formulation (% a.i.)	Reference
Alga (*Selenastrum capricornutum*)	Shaker	96 h	1600 (450, 2800)	92.0	Stephenson (1983)
MAFF (1994) review					
Alga (*Scenedesmus subspicatus*)	Static	96 h	1360 (1340, 1430)	EC	SC 8993/58
Alga (*Scenedesmus quadricauda*)	NR	NR	10000 < IC50 < 32000	NR	Bogacka and Groba (1980)
Duckweed (*Lemna minor*)			LOEC = 600 based on reduced biomass and chlorophyll content		
Alga (*Scenedesmus quadricauda*)	NR	10 d	1,045 (no confidence limits)	Technical 94.4	Lejczak (1977)
Bacteria (*Sphaerotilus natans*)		72 h	23-63% decreased growth at 1-100 mg/L, 719% increased growth at 10,000 mg/L		

*µg a.i./L unless otherwise specified. NR = not reported.

3.4.1 Green alga

In addition to testing chlorfenvinphos on daphnids, Stephenson (1983) examined its toxicity to *Selenastrum capricornutum* in a 4-d exposure. Incubation conditions were identical to those for daphnids (see Water flea 1, page 308) except algae were grown under constant illumination. The 96-h IC50 was 1600 (450, 2800) µg a.i./L classifying chlorfenvinphos as moderately toxic.

3.4.2 MAFF (1994) review

3.4.2.1 Alga

Scenedesmus subspicatus was exposed to solutions of chlorfenvinphos (EC formulation) of 8-24,600 µg a.i./L for 96 h in static tests in a report identified only as SC 8993/58. Mean measured concentrations varied widely from nominal (23.5-120.7%). Treated flasks were held at 23-24°C and pH 6.4-7.6 under continuous illumination. The 96-h IC50 was reported as 1360 (1340, 1430) µg a.i./L calculated by logit analysis of nominal concentrations which indicates moderate toxicity. The reported NOEC and LOEC were 246 and 788 µg a.i./L, respectively.

3.4.2.2 Alga and macrophyte

Bogacka and Groba (1980) summarised the toxicity of chlorfenvinphos to *Scenedesmus quadricauda* and *Lemna minor* at unspecified exposure durations and nominal concentrations of 600-112,500 µg a.i./L. All treatments were reported to inhibit reproduction and reduce the biomass and chlorophyll content of *L. minor* although no IC50 value was given. Algal inhibition was reported at 30 and 70% at 10,000 and 32,000 µg a.i./L, respectively, which likely brackets the IC50 and indicates slight toxicity. As no experimental details such as duration of exposure were provided, these results should be treated with caution.

3.4.2.3 Alga and bacteria

Lejczak (1977) investigated the toxicity of chlorfenvinphos (94.4%) to *Scenedesmus quadricauda* and the filamentous bacteria *Sphaerotilus natans*. The alga was incubated at nominal concentrations of 0.1-1000 mg/L at 20°C and constant light for 10 d. An IC50 of 1.045 mg/L (no confidence limits) was calculated. The bacterium was incubated at 1-10,000 mg/L at 20°C for 72 h and showed decreased growth (as measured by dry weight) at 1.0-100 mg/L by 23-63% but increased growth of 719% at 10,000 mg/L. The MAFF (1994) report stated that methods were not done to modern standards and that the highest dose was greater than the solubility of chlorfenvinphos in water, therefore these results should be treated with caution.

3.5 Terrestrial Invertebrates

Several studies were submitted which showed chlorfenvinphos was generally nontoxic to most terrestrial invertebrates at the maximum rate registered in Australia of 500 g a.i./ha. Earthworms were generally unaffected by chlorfenvinphos with 14-d LC50, NOEC and LOEC values of 204, 123 and 234 mg a.i./kg soil, respectively, in a laboratory experiment, and no mortality claimed in a 21-week field study (although up to half the worms were not recovered). Various studies reported a wide range of responses with chlorfenvinphos relatively nontoxic (oral LD50 = 14.9 µg a.i./bee) to highly toxic (topical LD50 = 0.41 µg a.i./bee) to bees although a midvalue of 4.1 µg a.i./bee (moderately toxic) for contact toxicity seems fairly reliable. Mortality of larval and adult ladybird beetles appears high at 76 and 88% 72 h after being sprayed with 500 mg/L, however, no EC50 could be calculated from the data provided. Rove beetles showed contrasting results with initially reduced parasitisation efficiency to eventual greater efficiency compared to controls when treated with =4 kg a.i./ha but only adverse effects at 16 kg a.i./ha. More carabid beetles were caught in traps in spring wheat plots treated at 9-22 kg a.i./ha than in controls possibly due to increased activity. In this report, the 48-h LC50 was reported as 2.3 mg/L in topical exposures while another reported 24-h LD50 values of 600-2000 mg a.i./kg soil for three different species of carabids.

Summaries reported high doses of 100 kg a.i./ha significantly decreased nematode numbers, 4.5 and

9.0 kg a.i./ha greatly decreased predatory mites and temporarily increased oribatid mites, respectively, and slugs and beetles concentrated chlorfenvinphos to 280 and 1.33 mg a.i./kg bodywt, respectively. Spiders and natural predators of rice pests were not affected by 750 g a.i./ha applied three times at 10-15 d intervals. Mortality was higher to springtails at 24°C than at 13°C when other factors were constant with a 24-h LC50 of 0.5-1.0 mg a.i./kg soil. Predatory beetles and earthworms were reduced by up to 32 and 50%, respectively, at 1.8-2.2 kg a.i./ha.

The numbers of carabids caught in the field was slightly higher than controls when treated at the equivalent of up to 15 kg a.i./ha, although the statistical significance is unknown. In the laboratory, beetles were relatively resistant to treatments of 40 mg a.i./kg soil after 7 d. Complex interactions were found in another field study with springtails greatly diminished initially but recovering within 4-7 months of treatment with up to 9.0 kg a.i./ha. However, one family of springtails and oribatid mites were increased even at 6 MAT possibly due to reduced predators. Wireworms experienced up to 70% reductions although the authors regarded this as not very lethal. Fly larvae decreased by 50-80% initially but recovered as chlorfenvinphos dissipated while microarthropods (eg predatory mites) were decreased even after residues had almost disappeared.

Table 14

Organism	Test Type	Time	Parameter and Result	Formu-lation	Reference
Earthworm (*Eisenia foetida*)	Artificial soil	14 d	LC50 = 204 (176, 232), NOEC = 123, LOEC = 234 mg a.i./kg soil	93.2%	Weyman (1997)
Earthworm (*Lumbricus terrestris , Allolobophora caliginosa, A. longa, A. rosea*)	Boxes of peat, sandy loam and medium loam soils	147 d	Parent and metabolite residues <LOD of 0.02 mg a.i./kg tissue except in peat when equal to LOD, author claims no mortality but up to half the worms not recovered	NR	Beynon (1965)
Honey bee	Caged in red clover field	24 h	100% mortality at 560 g a.i./ha, 14 and 1% mortality when exposed to treated foliage 3 and 24 h after application, respectively	NR	Johansen and Hutt (1963)
	Topical spray	18 h	1 < LC50 < 10 g a.i./L	=95%	Harris and Svec (1969)
	Oral and contact	NR	Oral LD50 = 0.55 µg a.i./bee Contact LD50 = 4.1 µg a.i./bee	=95%	Stevenson (1978)
	Oral and topical	NR	Oral LD50 = 14.9 µg a.i./bee Topical LD50 = 0.41-9.78 µg a.i./bee	Birlane	Beran (1970) Batista et al. (1975)
Ladybird beetle	Topical	72 h	75.6% mortality of 3rd instar larvae 87.9% mortality of 1-d old adults when sprayed with 500 mg/L	NR	Makar and Jadhav (1981)
Rove beetle	Sprayed on sandy loam	305 d	2-16 kg a.i./ha reduced parasitisation by >80% 7 DAT but was reversed at 60-305 DAT for treatments =4 kg a.i./ha	Birlane 24 EC	Kirknel (1978)
	and sand		Parasitisation reduced except at 120 DAT		
Carabid beetles (3 species)	Spring wheat plots	4 yr	More beetled caught in treated plots than controls in most treatments	EC and granula r	Edwards and Thompson (1975)
	Contact	48 h	LC50 = 2.3 mg/L (no confidence limits reported)	NR	
Carabid beetles (3 species)	Treated medium sandy loam	24 h	LD50 = 600-2000 mg a.i./kg soil with toxicity generally proportional to soil moisture	Birlane	Mowat and Coaker (1967)
Nematodes, mites, slugs and beetles	NR	NR	100 kg a.i./ha significantly decreased nematode numbers	NR	Whitehead and Storey (1970)
	NR	NR	4.5 kg a.i./ha decreased predatory mite numbers and 9.0 kg a.i./ha temporarily increased oribatid mites	NR	Thompson (1968)
	NR	NR	Slugs accumulated chlorfenvinphos to 280 mg a.i./kg bodywt, beetles concentrated to 1.33 mg a.i./kg bodywt when treated at =8800 g a.i./ha	NR	Edwards (unpublished data)
Spiders	Rice paddy	=45 d	NOEC = 750 g a.i./ha	20% EC	Reissig et al. (1982)
Springtails (*Folsomia candida*)	Sprayed directly	24 h	100 < LC50 < 1000 mg/L	=95%	Thompson and Gore (1972)
	Sprayed sand		13°C: 1.0 < LC50 < 5.0 24°C: 0.5 < LC50 < 1.0 mg a.i./kg soil		
Springtails (3 species)	Sprayed sand soil	24 h	0.5 < LC50 < 1.0 mg a.i./kg soil for the most sensitive species *F. candida*	95-97%	Tomlin (1975)
Beetles and earthworms	Sandy loam fields	5 mont hs	English plots: 12% reduced beetle numbers 50% reduced earthworms, Canadian plots: 32% reduced beetles at 1.8-2.2 kg a.i./ha	Granu-lar	Finlayson et al. (1975)

Carabid and staphylinid beetles	Treated silt loam	7 d	8% mortality at 40 mg a.i./kg soil No significant field effect in 3 yr. 0% mortality at 20 mg a.i./kg soil	Granular 10%	Finlayson et al. (1980)
Soil invertebrates	Potato and spring wheat field	11 months	Springtails greatly reduced but recovered within 4-7 months, wireworms reduced by =70%, dipteran larvae reduced 50-80% but recovered, microarthropods (eg mites) and pauropods decreased up to 6 MAT when treated at =4500 g a.i./ha	50% EC or 10% granular	Edwards et al. (1968)

NR = not reported, EC = emulsifiable concentrate

The MAFF (1994) review (Table 15) reported 100% mortality to honey bees when treated at 0.56 kg a.i./ha when caged in clover and lucerne fields. When exposed to foliar residues, 41% were killed when leaves had been sprayed 3 h previously, but only 1% when residues were 24 h old. The maximum LD50 risk zone was estimated as within 1 m of a spray nozzle based on an LD50 of 4.1 µg a.i./bee and a surface area of 1 cm^2. Chlorfenvinphos was not harmful to a carabid beetle at up to 40 mg a.i./kg soil.

Table 15. Summary of MAFF (1994) on chlorfenvinphos toxicity to terrestrial invertebrates.

Organism	**Test Type**	**Time**	**Parameter and Result**	**Formulation**	**Reference**
Honey bee	Cages in clover, lucerne	24 h	100% mortality at 0.56 kg a.i./ha	EC	SC 8993/30
	Foliar residues		41 and 1% mortality on leaves sprayed 3 and 24 h previously, respectively		
	Mathematical modelling	NA	Maximum LD50 risk zone of <1 m at wind speeds of 9-14 km/hr given a topical LD50 of 4.1 µg a.i./bee	NA	Davis and Williams (1990)
Carabid beetle	Treated soil	7 d	0 and 5% mortality at 10 and 40 mg a.i./kg soil, respectively	Granular 10%	Obadofin and Finlayson (1977)

EC = emulsifiable concentrate, NA = not applicable

3.5.1 Earthworm

3.5.1.1 14-d toxicity

Weyman (1997) followed OECD protocols in determining the 14-d LC50 of technical chlorfenvinphos (93.2%) to *Eisenia foetida*. Worms were sexually mature, =2 months old and weighing 300-620 mg prior to the 24 h acclimation period. They were incubated in measured concentrations up to 832 mg a.i./kg soil at 19.7-21.6°C under continuous light. Observations of burrowing, appearance and survival were made at initiation and at various intervals during the experiment. The author's 14-d LC50 value confirmed the probit analysis calculations of 204 (176, 232) mg a.i./kg soil. This classifies chlorfenvinphos as slightly toxic according to Mensink et al. (1995). The NOEC and LOEC for adverse effects on weight change were 234 and 423 mg a.i./kg soil, respectively. However, the NOEC and LOEC for mortality were more sensitive at 123 and 234 mg a.i./kg soil, respectively. Behavioural observations showed immobility and abnormal curling in all worms at even the lowest treatment of 62 mg a.i./kg soil.

3.5.1.2 21-week uptake

Beynon (1965) (also reported in Edwards et al. 1968) exposed worms (*Lumbricus terrestris*,

Allolobophora caliginosa, *A. longa* and *A. rosea*) to 6 mg a.i./kg soil wet weight in peat, sandy loam and medium loam soils as described in Bare soil. No information was given on the age/size of the worms. Seven worms of each of the deep-living (*L. terrestris* and *A. longa*) and seven of the shallower-living (*A. caliginosa* and *A. rosea*) species were placed in the boxes fitted with permeable (gauze) tops and bottoms to allow water flow. Worms were sampled at 28, 70 and 147 DAT, washed with water and allowed to expel gut contents for 2-4 d before analysis for chlorfenvinphos and metabolites by gas-liquid chromatography.

Parent compound or metabolite residues in the worms at 147 DAT were below the limit of detection (LOD) of 0.02 mg a.i./kg tissue in all cases except the peat soil at 21 weeks after treatment when they were at the LOD. Although the author claims no mortality was observed, up to half the original number of worms were not recovered from some boxes.

3.5.2 Honey bee 1

Johansen and Hutt (1963) summarised the effect of chlorfenvinphos in an unspecified formulation. Caged honey bees were placed in a red clover field and treated by hand sprayer at 560 g a.i./ha. Complete mortality of all bees was observed after 24 h. Other bees exposed for 24 h to treated foliage 3 and 24 h after application showed 14 and 1% mortality, respectively.

3.5.3 Honey bee 2

The toxicity of analytical chlorfenvinphos (=95%) to honeybees (*Apis mellifera*) was determined by Harris and Svec (1969). Adult workers were sprayed with solutions of up to 10 g a.i./L and observed for 18 h. The 18-h LC50 was between the concentrations of 1 and 10 g a.i./L which caused 17 and 100% mortality, respectively. As insufficient information was given to calculate an equivalent dose in µg a.i./bee, the relative toxicity is unknown.

3.5.4 Honey bee 3

Stevenson (1978) tested the oral and contact toxicity of chlorfenvinphos (=95%) to worker honey bees (*A. mellifera*). Single doses were given but no observation period was specified. The oral and contact LD50 values were 0.55 and 4.1 µg a.i./bee classifying chlorfenvinphos as highly and moderately toxic, respectively.

3.5.5 Honey bee 4

Clements (1980) reviewed and summarised the results of others. The oral and topical LD50 values of Birlane (formulation unspecified) were 14.9 and 9.78 µg a.i./bee, relatively nontoxic and moderately toxic respectively, while the LD50 of residues (presumably surface exposure) was 312 g a.i./ha; no time period or confidence limits were specified (Beran 1970). Batista et al. (1975) found the topical LD50 of Birlane was 0.41 µg a.i./bee (highly toxic). As no details of methodology were presented for either study, these results must be treated with caution.

3.5.6 Ladybird beetle

Makar and Jadhav (1981) conducted a simple toxicity experiment by spraying 500 mg/L solutions of chlorfenvinphos (formulation and dose per individual unspecified) on third instar larvae and 1-d old adults of the ladybird beetle (*Menochilus sexmaculatus*). Treated animals were left for 1 h before transfer to noncontaminated containers where they were observed for a total of 72 h. No incubation

conditions were given except that they were fed on cotton aphids (*Aphis gossypii*) during this time. Mortality of larvae and adults after 72 h was reported as 75.6 and 87.9%, respectively, after correction for control mortality by Abbott's formula. Although no EC50 can be calculated from these data, chlorfenvinphos would be classified as slightly to moderately harmful according to Mensink et al. (1995).

3.5.7 Rove beetle

Kirknel (1978) examined the effect of chlorfenvinphos application to soil on the parasitisation efficiency of rove beetle larvae (*Aleochara bilineata*) on turnip root fly pupae (*Hylemya floralis*). A sandy loam (pH 5.6, 1.6% OC) and sand (pH 6.3, 0.06% OC) were treated at up to 16 kg a.i./ha with Birlane 24 EC (24% a.i.). Prey pupae and beetle eggs were added and microcosms incubated in a moist environment for up to 305 d at 23°C. At the first sampling date at 7 DAT in the sandy loam, the lowest treatment of 1 kg a.i./ha caused approximately 5% lower parasitisation of prey eggs relative to controls, but the higher treatments of 2-16 kg a.i./ha had >80% reductions (moderately harmful). By the next sampling 60 DAT, all treatments =4 kg a.i./ha showed greater parasitisation than controls (ie. a reverse effect), which continued until the final sample at 305 DAT. Parasitisation efficiency was severely depressed in the highest treatment for the duration of the experiment. In the sandy soil, efficiency was always lower than controls except at 120 DAT.

3.5.8 Carabid beetle 1

Edwards and Thompson (1975) treated predatory carabid beetles (*Feronia melanaria, F. madida* and *Harpalus rufipes*) isolated in fenced plots of spring wheat with chlorfenvinphos as emulsifiable concentrates or granules at 9.0 or 22.4 kg a.i./ha. Pitfall traps were set in each plot and the catches identified to species and counted every second day until beetle activity ceased (approximately 3 months). This treatment and sampling were repeated annually for 4 yr. In most of the treatments (except *F. madida* in the first 2 yr), more beetles were caught in treated plots than in control plots (statistical significance unspecified). The authors postulated that treatment increased their activity and chances of being caught.

Laboratory toxicity experiments were also conducted on *F. melanaria* to determine an LD50. Beetles were randomly treated with chlorfenvinphos (formulation unspecified) in 5 µL of acetone on the ventral surface of the abdomen and observed for 48 h. The LC50 was reported as 2.3 mg/L (no confidence limits reported) but could not be confirmed by Environment Australia as no data were presented.

3.5.9 Carabid beetle 2

Mowat and Coaker (1967) conducted extensive toxicity testing of chlorfenvinphos (formulation specified only as Birlane) on adult carabid beetles *Trechus quadristriatus, Agonum dorsale* and *Feronia melanaria* of mean mass 2.9, 14.9 and 168.0 g, respectively, collected from the field. A medium sandy loam (details not reported) was treated at unspecified concentrations and soil moisture levels of 2-16% (wt/wt). Beetles were placed on treated soils and observed for 24 h at 20°C and =65% relative humidity. The authors reported 24-h LD50 values of about 600-2000 mg a.i./kg soil with the greatest toxicity to *A. dorsale* and the least toxicity to *F. melanaria*. Increased toxicity was generally found at higher moisture levels possibly due to increased bioavailability in soil water.

3.5.10 Nematodes, mites, slugs and beetles

Edwards and Thompson (1973) reviewed the results of several other authors. Whitehead and Storey (1970) found that high doses of 100 kg a.i./ha significantly decreased nematode numbers. Thompson (1968) found that chlorfenvinphos greatly decreased predatory mite numbers and temporarily increased oribatid mite number at 4.5 and 9.0 kg a.i./ha, respectively. Edwards (unpublished data) reported that slugs accumulated chlorfenvinphos to 280 mg a.i./kg bodywt after several months on soils treated with 8800 g a.i./ha. Beetles concentrated residues only to 1.33 mg a.i./kg bodywt after an unspecified time when treated at 9.6 kg a.i./ha.

3.5.11 Spiders

The effect of chlorfenvinphos on natural predators of rice pests was examined by Reissig et al. (1982). A 20% EC formulation was applied three times at 10-15 d intervals at 750 g a.i./ha by knapsack sprayer. The predators *Microvelia atrolineata*, *Cyrtorhinus lividipennis* and three species of spiders were sampled before and after each treatment. Statistical analysis by ANOVA showed no significant difference with controls at any sampling date thus indicating a NOEC of 750 g a.i./ha.

3.5.12 Springtails 1

Thompson and Gore (1972) studied the effect of chlorfenvinphos (=95%) on springtails (*Folsomia candida*) when sprayed directly or exposed to treated soil. Insects were cultured in darkness at 24±1°C and fed on brewer's yeast. Individuals were acclimated to either 13 or 24°C for 1 week prior to being sprayed for 15 s or exposed to a treated sand (0.4% OC, pH unspecified) at various concentrations. Insects were kept at the acclimated temperature for 24 h before mortality was assessed. Of those sprayed directly, temperature had little effect as 25-30 and 100% mortality was observed at 100 and 1,000 mg/L treatments, respectively. Mortality was greater with the soil exposure at higher temperature (24°C) as 0 and 100% mortality occurred at 0.5 and 1.0 mg a.i./kg soil (equivalent to 0.75 and 1.5 kg a.i./ha, respectively, assuming 10 cm soil depth) compared to the same mortality at 1.0 and 5 mg a.i./kg soil in the lower temperature (13°C).

3.5.13 Springtails 2

Tomlin (1975) conducted a similar study as Thompson and Gore (1972) on the toxicity of technical chlorfenvinphos (95-97%) to the springtails *Folsomia candida*, *Onychiurus justi porteri* and *Hypogastrura armata.* The same sand soil was treated at various concentrations and insects were incubated on them for 24 h in the dark at 21±1°C. Control mortality was accounted for by Abbott's formula. The most susceptible species *F. candida* had 9 and 100% mortality at 0.5 and 1.0 mg a.i./kg soil, respectively (equivalent to 0.75 and 1.5 kg a.i./ha), indicating the LC50 was between these two values.

3.5.14 Beetles and earthworms, field study

Finlayson et al. (1975) treated a sandy loam in England (1.2% OC, pH 6.0-6.2) and in Canada (2.0% OC, pH 5.3) with a granular formulation of chlorfenvinphos at 1.83-2.20 kg a.i./ha. Plots in each country were simultaneously seeded with cauliflower and then sampled for invertebrates at various times up to 5 MAT. Predatory beetle abundance was reduced by 12 and 32% in England and Canada, respectively, compared to control plots while earthworms showed a 50% reduction in

the British plots; no data were provided for Canadian plots.

3.5.15 Carabid and staphylinid beetles, field study

Finlayson et al. (1980) treated silt loam plots containing cauliflower transplants with chlorfenvinphos (10% granular formulation) at about 35 mg a.i./kg soil (equivalent to 13 kg a.i./ha). The granules were manually applied around the base of each plant and incorporated into the top 2.5 cm of soil. Pitfall traps were placed in treated and control plots to monitor the effect on predatory carabid (mainly *Bembidion lampros*) and staphylinid (mainly *Aleochara bilineata*) beetles. The adults of these beneficial short-winged beetles predate on dipteran eggs and larvae while the beetle larvae parasitise the pupae. The experiment was carried out for 3 yr. These two main species of beetles were also exposed in the laboratory in a silt loam (3.0% OC, pH 5.8) that had been treated at various concentrations up to 40 mg a.i./kg soil (equivalent to 15 kg a.i./ha) with granular chlorfenvinphos. Prey onion maggot larvae (*Hylemya antiqua*) were added as food and mortality was assessed after 7 d.

In the three years of the field study, the numbers of carabids caught in treated plots was slightly higher than controls by 4.0-16%, however, the statistical significance is unknown. In the laboratory, *B. lampros* were relatively resistant to chlorfenvinphos treatment as only 8% mortality was observed at the highest treatment of 40 mg a.i./kg soil after 7 d. Similarly, *A. bilineata* had no mortality at the highest treatment of 20 mg a.i./kg soil.

3.5.16 Soil invertebrates, field study

Edwards et al. (1968) conducted several experiments in potato and spring wheat fields and with invertebrates contained in boxes placed outdoors. Potatoes were planted in sandy loam and loam over clay while spring wheat was planted in clay loam with flints and clay loam. No other details of the soils were provided. Chlorfenvinphos was applied at 4.5 or 9.0 kg a.i./ha as a 50% emulsifiable concentrate (EC) or 10% granular formulation and tilled into the soil. Samples of soil and invertebrates were taken at various times up to 11 MAT and analysed for parent residues. Half-lives in soils were found to be 11-30 d. Earthworm and macroarthropod numbers (assessed with pitfall traps and quadrat sampling) showed complex interactions which were generally consistent among the different sites. Some families of Collembola (springtails) were greatly diminished in number but recovered within 4-7 months and sometimes exceeded pretreatment abundance. At all sites, one family of Collembola (Entomobryidae) and oribatid mites were more numerous in treated than control plots, even at 6 MAT, possibly due to reduced predator numbers. Wireworms (Coleoptera) were decreased by up to 70% although the authors regarded this as “not...very lethal”. Dipteran (fly) larvae decreased by 50-80% in the first few months following treatment but recovered as chlorfenvinphos dissipated from the soil. This was in contrast to microarthropods (eg. predatory mites) which had decreased populations long after the residues had almost disappeared, and significant reductions of pauropods 6 MAT. Treatment was considered to have had only a slight effect on earthworms as cultivation often kills many of the surface-dwelling forms.

3.5.17 MAFF (1994) review

3.5.17.1 Honey bee 1

MAFF (1994) summarised study SC 8993/30 testing the EC formulation at 0.56 kg a.i./ha applied to caged bees in fields of clover or lucerne. Mortality of the 25-50 bees at various plots was 100%

after 24 h. When bees were exposed to foliar residues of the same treatment in the lab (plant species not specified but presumed clover and lucerne), 41% of bees were killed when leaves had been sprayed 3 h previously, but only 1% when residues were 24 h old.

3.5.17.2 Honey bee 2

Davis and Williams (1990) estimated the relative hazard to honey bees from chlorfenvinphos application due to spray drift using a mathematical model. Using a topical LD50 of 4.1 µg a.i./bee and an estimated bee surface area of 1 cm^2, they calculated a maximum LD50 risk zone of within 1 m of a spray nozzle at wind speeds of 9-14.4 km/hr. For carrots with an application rate of 2.35 kg a.i./ha, a hazard index of 5.7 was calculated indicating the extent by which the application rate exceeds the LD50. The reciprocal value of 0.18 is the fraction of the application rate required to produce the LD50.

3.5.17.3 Carabid beetle

Obadofin and Finlayson (1977) exposed the carabid beetle *Bembidion lampros* to soil mixed with a 10% granular formulation of chlorfenvinphos to final concentrations of 10 and 40 mg a.i./kg soil. Beetles were fed on *Drosophila melanogaster* larvae and observations for 7 d showed 0 and 5% mortality at the low and high treatment concentrations. The authors concluded that chlorfenvinphos was not harmful to this beetle.

3.6 Terrestrial Plants

No studies were submitted on the toxicity of chlorfenvinphos to terrestrial plants.

3.7 Soil Microorganisms

Studies generally showed chlorfenvinphos to be nontoxic to soil microbial processes at the maximum application rate in Australia of 500 g a.i./ha. However, the processes of respiration, ammonification and denitrification are not good indicators of toxicity to individual species. These processes can be maintained in the face of significant toxic impacts as resistant microbes increase their populations at the expense of sensitive species (van Beelen and Doelman 1997).

Nitrogen fixation (as measured by nitrogenase activity of the rhizosphere soil around rice plant roots) was somewhat slowed by application of 0.5 kg a.i./ha but this effect was inconsistent throughout the sampling period. When this process was measured by acetylene reduction, treatments of up to 10 mg a.i./kg soil (equivalent to 15 kg a.i./ha presuming 10 cm soil depth) decreased reduction after 2 d but not 6 d. The activity of some microbial enzymes was different from controls when treated at 10 mg a.i./kg soil, however the environmental significance is unknown. Entomopathogenic fungi were affected with a LOEC of 5 mg/L but showed inconclusive results at the field rate of 100 mg a.i./kg soil when soil amended with chlorfenvinphos-exposed fungi caused somewhat increased toxicity of Colorado potato beetle pupae in the winter but not summer. Total soil biomass, consisting of bacterial and fungal counts, were not affected by treatments up to 1.52 kg a.i./ha. Chlorfenvinphos treatment at 2 kg a.i./ha increased the number of spores (by 41%) of a beneficial fungi. Preliminary work has shown that composting under favourable conditions can biodegrade chlorfenvinphos in dip sludges.

3.7.1 Nitrogen fixation

The influence of chlorfenvinphos (formulated as Birlane EC) on nitrogen fixation as measured by nitrogenase activity was investigated by Rao et al. (1982). Rice plants were sprayed at 0.5 kg a.i./ha (equal to the maximum field rate in Australia) at 30-60 d after transplanting into the field. At 65-86 d after transplanting, plants were uprooted and the rhizosphere soil was assessed for nitrogen fixation. Peak rhizosphere nitrogenase activity in the controls was observed at 79 d after transplanting, while that with treated soil occurred at 86 d after transplanting and was significantly higher. However, this effect was not consistent throughout the sampling period with higher activity in treated soil on the first and last sampling days only.

3.7.2 Nitrification and respiration

No study was submitted on this subject.

3.7.3 Acetylene reduction

Tu (1978, 1979) treated a sandy loam (1.7% OC, pH 7.8) and organic soil (29% OC, pH 7.6) with chlorfenvinphos (=94%) at 5 and 10 mg a.i./kg soil (equivalent to 7.5 and 15 kg a.i./ha presuming 10 cm soil depth, respectively). Samples were incubated in the dark at 28°C for 2 or 6-7 d before assessing for acetylene (C_2H_2) reduction by GC as an indication of nitrogen fixation capacity. In comparison to controls in the sandy loam, treated samples at both concentrations had significantly more acetylene remaining after 2 d incubation, but not 6 d. In the organic soil, acetylene reduction was not significantly affected despite elevated soil fungi numbers at both concentrations. Therefore treatment at up to 10 mg a.i./kg soil did not cause a lasting adverse effect in the ability of soil microorganisms to reduce acetylene.

3.7.4 Microbial enzymes

Tu (1981) conducted a similar experiment as in Tu (1978, 1979) assessing the effect of chlorfenvinphos (=94%) on the population and enzyme systems of microbes. A clay loam (1.0% OC, pH 7.2) was treated at 5 and 10 mg a.i./kg soil (equivalent to 7.5 and 15 kg a.i./ha) and incubated as before for 7 d. The high treatment significantly increased fungal, but not bacterial, populations 7 DAT relative to controls. Populations of nonsymbiotic nitrogen fixing microbes were not affected at either treatment. Dehydrogenase activity, indicative of the total range of oxidative activities, was suppressed in the low treatment only while urease activity was significantly higher than controls in the high treatment at 7 DAT. Soil organic phosphate decomposition, as measured by the phosphatase activity, was not affected at either concentration. While the effect on these microbial enzymes is measurable, their environmental significance is unknown.

3.7.5 Fungi

Bajan et al. (1977) incubated (18-25°C, duration not specified) the entomopathogenic fungi *Paecilomyces farinosus*, *P. fumoso-roseus* and *Beauveria bassiana* in potato-glucose agar amended with chlorfenvinphos at concentrations of 5-10,000 mg/L, including the field rate for Colorado potato beetles of 50 mg/L. The field rate adversely affected the growth of hyphae and final diameter of the fungal colonies but did not kill them. The LOEC was the lowest dose tested (5 mg/L). When the fungal spores from each treatment were sprayed on greater wax moth (*Galleria mellonella*) larvae at 500,000 spores/L, greater toxicity was observed with chlorfenvinphos-

exposed *P. fumoso-roseus* than control spores, although neither a statistical significance nor data were shown. The toxicity of spores of the other two fungi to moth larvae was inversely proportional to the chlorfenvinphos treatment; spores from the highest dose caused the lowest mortality of larvae.

The authors also set up pots into which soil (characteristics unspecified) and each of the three species of fungus (20 g per pot) had been added. Some of these pots were sprayed with Enolofos 50 (containing chlorfenvinphos at an unspecified content) at the field rate of 0.01% (equivalent to 100 mg a.i./kg soil or 150 kg a.i./ha) while others served as controls. After 14 d in unspecified conditions to allow dissipation, 20 Colorado potato beetle larvae were introduced into all pots prior to burrowing into the soil for pupation. After emergence of the adults that summer (duration unspecified), the mortality of pupae in treated soils was slightly lower at 63-69% compared to control soils of 75-79% although no indication of statistical significance or variability in the five replicates was given. When this experiment was repeated with beetle larvae treated in the autumn before winter hibernation and adult mortality assessed the following spring (duration unspecified), treated soils had 89-91% mortality relative to 71-88% in the controls. Thus in one case, chlorfenvinphos treatment impaired the entomopathogenic ability of the fungi while enhancing it in another.

3.7.6 Biomass

Jones et al. (1991) obtained sandy loam samples (pH 6.5 1.0% OC) in 1989 and 1990 from two field plots that had previously been treated with chlorfenvinphos (10% a.i., formulation and treatment dates not specified) in 1986 and 1989. These were again treated at 0.45, 0.82 and 1.52 kg a.i./ha in April 1990. Incubation conditions (outdoors or laboratory) were not specified before sampling at 10 and ~100 DAT for microbiological analysis. Total soil biomass and bacterial counts showed no significant differences between controls and any of the treatments. Similarly, there was no effect on total fungal biomass, vital fungal biomass and plateable propagules. However, any changes in species composition/diversity or soil processes would not be detected by these measurements of simple abundance. The authors stated that the half-life was shorter in soil previously treated with chlorfenvinphos, but failed to specify what the half-lives were or provide data to confirm. The difference in half-life was not correlated with changes in microbial biomass.

3.7.7 Fungal mycorrhiza

Ocampo and Hayman (1980) treated barley (*Hordeum vulgare*) sown in a clay loam with chlorfenvinphos (formulation unspecified) at 2 kg a.i./ha. At an unspecified later date, root and soil samples were taken and assessed for vesicular-arbuscular mycorrhizal (VAM) fungi which are beneficial for plant nutrient uptake and growth. Treated soil had 41% more spores ($\alpha = 0.05$) than controls but was similar to controls in all other measurements.

3.7.8 Soil remediation

Preliminary work in Australia has shown that chlorfenvinphos in dip sludge can be biodegraded in compost with an apparent half-life of about 8-10 d (Van Zwieten 1997). The laboratory simulation diluted the original sludge containing 1.8 g a.i./kg soil approximately 3-fold in compost before degradation. As no details in methodology were presented, this result should be treated with caution.

3.8 Mammals

3.8.1 MAFF (1994) review

3.8.1.1 Wood mouse 1

Westlake et al. (1982) fed wheat treated at 830 and 2,500 mg a.i./kg food to wild-trapped wood mice (*Apodemus sylvaticus*) and determined brain enzyme inhibition levels at different times up to 10 DAT. AChE was inhibited due to chlorfenvinphos residues at 10 DAT while nitrophenyl acetate esterase (NPAE) was inhibited at 7 DAT with the low dose and at 2 DAT with the high dose. Inhibition remained after 7 d on untreated diet. Liver NPAE was inhibited at both treatments but recovered after 7 d on untreated diet.

3.8.1.2 Wood mouse 2

Westlake et al. (1980) drilled winter wheat seeds treated with technical chlorfenvinphos at 550-600 mg a.i./kg seed into a field (application rate per hectare unknown). Small mammals trapped at the peripheral borders and outside the field were marked and released before drilling. Six wood mice were randomly selected from each trapping and subjected to blood and tissue analyses. Parent compound residues in grain left on the surface after drilling declined mostly in the first 10 d and from days 16-28 when there was heavy rain. Chlorfenvinphos residues in gut contents were highly variable with a maximum of 18 µg that could have arisen from less than one individual wheat grain. Liver NPAE was significantly lower in mice trapped in the treated field than those in the surrounding woods in the first 3 d after drilling, however considerable variability was found in the wood-trapped mice over the 35 d experiment. Significant inhibition of plasma anticholinesterase and cholinesterase occurred during the first 10 d after drilling in mice trapped in the field. The degree of inhibition was highly correlated with residues in the gut. The authors concluded that the transitory observed effects and rapid disappearance of both grain left on the surface and the residues in grain limited the potential exposure of wildlife.

3.8.1.3 Rats

The acute oral LD50 values for chlorfenvinphos dosed in peanut oil to male and female rats were 15 and 13 mg a.i./kg bodywt, respectively (Gaines 1969). When dosed dermally in a solution of xylene, these values were 31 and 30 mg a.i./kg bodywt, respectively, indicating slightly lower toxicity through dermal exposure.

3.8.1.4 Rabbits

In rabbits, the acute oral LD50 was 500-1000 mg a.i./kg bodywt (SC 8993/70) while the acute percutaneous LD50 was 1250-2500 mg a.i./kg bodywt (SC 8993/69).

3.9 Summary of Environmental Toxicology

3.9.1 Birds

The toxicity of chlorfenvinphos to several species of birds was examined in submitted studies, including those published in the scientific literature. Chlorfenvinphos was very highly toxic to starlings with an acute LD50 < 10 mg a.i./kg bodywt, highly toxic to pigeons and blackbirds (LD50 of 10-50

mg a.i./kg bodywt) and moderately toxic to mallard ducks, chickens, pheasants and quail (LD50 of 50-500 mg a.i./kg bodywt) in acute exposures. The 28-d LOEC to pigeon, pheasant and Japanese quail was 100 mg a.i./kg food for depressed brain esterase activity and/or liver and kidney esterases. Feeding by various bird species on treated wheat seeds in recently planted fields resulted in no overt symptoms until after a second sowing 12 d later when 12 pigeon and dove carcasses were found. The 8-h NOEC and LOEC for adult starlings was 3 and 6 mg a.i./kg bodywt, respectively, based on adverse brain AChE levels.

Studies reviewed in MAFF (1994) confirmed the very high toxicity of chlorfenvinphos to starlings and high toxicity to red-wing blackbirds, house sparrows, common pigeons, brown-headed cowbirds, common grackles, house finches and quail and moderate toxicity to golden-crowned sparrows and pheasants. The 21-d NOEC and LOEC to Japanese quail were 0 and 74 mg a.i./kg bodywt, respectively, based on plasma and brain AChE inhibition.

3.9.2 Fish

Toxicity studies from the company and scientific literature on a range of fish species were assessed. Chlorfenvinphos, in various formulations, was found to be very highly toxic to *Tilapia nilotica* and common carp (LC50 < 0.1 mg/L) and highly toxic to rainbow trout (LC50 of 0.1-1 mg/L) in acute exposures. It was moderately (LC50 of 1-10 mg/L) to highly toxic to the guppy in two experiments but highly to very highly toxic to the guppy and Harlequin fish in another. Juvenile carp placed in cages in a rice paddy showed 97% mortality within 7 d after treatment with 1.2 kg a.i./ha of a granular formulation. Many dead perch and roach were reported anecdotally when a pond was treated at 74 kg a.i./ha. Unfortunately, details on methodology were lacking in several of these studies and the results should be treated with caution.

The review by MAFF (1994) found some differences in the acute toxicity of chlorfenvinphos to fish. It was listed as only highly toxic to carp, goldfish, *Orizias latipes* and guppy, and moderately toxicity to rainbow trout. The very high toxicity of chlorfenvinphos to *Tilapia nilotica* and carp was confirmed in one study, but another found only moderate toxicity to carp. The chronic 7-d NOEC and LOEC to rainbow trout were 10 and 100 µg a.i./L, respectively, based on brain acetylcholinesterase inhibition. For reproductive physiology endpoints in the striped catfish, the 84-d NOEC and LOEC were 0 and 3.02 µg a.i./L respectively. Chlorfenvinphos applied at 0.9 kg a.i./ha to a pond still caused 30% mortality to mosquito fish when introduced 15 DAT. It is apparent that there is a range of toxicity among and within a species possibly dependent upon differences in methodology.

3.9.3 Aquatic invertebrates

A number of submitted studies and those summarised from MAFF (1994) on the freshwater invertebrate *Daphnia magna* showed conflicting results ranging from moderate (LC50 of 1-10 mg/L) to very high (LC50 <0.1 mg/L) acute toxicity. Chlorfenvinphos was highly toxic to another species of water flea (*Ceriodaphnia dubia*) and the eastern oyster but moderately toxic to the scud. Only slight toxicity was found to protozoa. As experimental details were lacking in several of these studies, these results should be treated with caution. The 21-d LOEC to *D. magna* was the lowest dose tested of 0.3 µg a.i./L based on statistically significant reduced numbers of live young and young per adult.

3.9.4 Aquatic plants

One toxicity study was submitted on a freshwater alga while other studies on algae and macrophytes were summarised from MAFF (1994). Chlorfenvinphos was moderately toxic (IC50 of 1-10 mg/L) to *Selenastrum capricornutum*, *Scenedesmus subspicatus*, and moderately to slightly (LC50 of 10-100 mg/L) toxic to *S. quadricauda*. Concentrations as low as 600 µg a.i./L reduced the biomass and chlorophyll content of *Lemna minor* at an unspecified exposure duration. The bacteria *Sphaerotilus natans* showed decreased growth at 1.0-100 mg/L but increased growth at 10,000 mg/L.

3.9.5 Terrestrial invertebrates

Several studies were submitted which showed chlorfenvinphos was generally nontoxic to most terrestrial invertebrates at the maximum rate registered in Australia of 500 g a.i./ha. Earthworms were generally unaffected by chlorfenvinphos with 14-d LC50, NOEC and LOEC values of 204, 123 and 234 mg a.i./kg soil, respectively, in a laboratory experiment, and no mortality claimed in a 21-week field study (although up to half the worms were not recovered). Various studies reported a wide range of responses with chlorfenvinphos relatively nontoxic (oral LD50 = 14.9 µg a.i./bee) to highly toxic (topical LD50 = 0.41 µg a.i./bee) to bees although a midvalue of 4.1 µg a.i./bee (moderately toxic) for contact toxicity seems fairly reliable. Mortality of larval and adult ladybird beetles appears high at 76 and 88% 72 h after being sprayed with 500 mg/L, however, no EC50 could be calculated from the data provided. Rove beetles showed contrasting results with initially reduced parasitisation efficiency to eventual greater efficiency compared to controls when treated with =4 kg a.i./ha but only adverse effects at 16 kg a.i./ha. More carabid beetles were caught in traps in spring wheat plots treated at 9-22 kg a.i./ha than in controls possibly due to increased activity. In this report, the 48-h LC50 was reported as 2.3 mg/L in topical exposures while another reported 24-h LD50 values of 600-2000 mg a.i./kg soil for three different species of carabids.

Summaries reported high doses of 100 kg a.i./ha significantly decreased nematode numbers; 4.5 and 9.0 kg a.i./ha greatly decreased predatory mites and temporarily increased oribatid mites, respectively; and slugs and beetles concentrated chlorfenvinphos to 280 and 1.33 mg a.i./kg bodywt, respectively. Spiders and natural predators of rice pests were not affected by 0.75 kg a.i./ha applied three times at 10-15 d intervals. Mortality was higher to springtails at 24°C than at 13°C when other factors were constant with a 24-h LC50 of 0.5-1.0 mg a.i./kg soil. Predatory beetles and earthworms were reduced by up to 32 and 50%, respectively, at 1.8-2.2 kg a.i./ha.

The numbers of carabids caught in the field was slightly higher than controls when treated at the equivalent of up to 15 kg a.i./ha, although the statistical significance is unknown. In the laboratory, beetles were relatively resistant to treatments of 40 mg a.i./kg soil after 7 d. Complex interactions were found in another field study with springtails greatly diminished initially but recovering within 4-7 months of treatment with up to 9.0 kg a.i./ha. However, one family of springtails and oribatid mites were increased even at 6 MAT possibly due to reduced predators. Wireworms experienced up to 70% reductions although the authors regarded this as not very lethal. Fly larvae decreased by 50-80% initially but recovered as chlorfenvinphos dissipated while microarthropods (eg predatory mites) were decreased even after residues had almost disappeared.

The MAFF (1994) review reported 100% mortality to honey bees when treated at 0.56 kg a.i./ha when caged in clover and lucerne fields. When exposed to foliar residues, 41% were killed when leaves had been sprayed 3 h previously, but only 1% when residues were 24 h old. The maximum

LD50 risk zone was estimated as within 1 m of a spray nozzle based on an LD50 of 4.1 µg a.i./bee and a surface area of 1 cm^2. Chlorfenvinphos was not harmful to a carabid beetle at up to 40 mg a.i./kg soil.

This wide variety of studies shows most terrestrial invertebrates were unaffected at the maximum single application rate of chlorfenvinphos of 500 g a.i./ha.

3.9.6 Terrestrial plants

No studies were submitted on the toxicity of chlorfenvinphos to terrestrial plants.

3.9.7 Soil microorganisms

Studies generally showed chlorfenvinphos to be nontoxic to soil microbial processes at the maximum application rate in Australia of 500 g a.i./ha. However, the processes of respiration, ammonification and denitrification are not good indicators of toxicity to individual species. These processes can be maintained in the face of significant toxic impacts as resistant microbes increase their populations at the expense of sensitive species.

Nitrogen fixation (as measured by nitrogenase activity of the rhizosphere soil around rice plant roots) was somewhat slowed by application of 0.5 kg a.i./ha but this effect was inconsistent throughout the sampling period. When this process was measured by acetylene reduction, treatments of up to 10 mg a.i./kg soil (equivalent to 15 kg a.i./ha presuming 10 cm soil depth) decreased reduction after 2 d but not 6 d. The activity of some microbial enzymes was different from controls when treated at 10 mg a.i./kg soil, however the environmental significance is unknown. Entomopathogenic fungi were affected with a LOEC of 5 mg/L but showed inconclusive results at the field rate of 100 mg a.i./kg soil when soil amended with chlorfenvinphos-exposed fungi caused somewhat increased toxicity of Colorado potato beetle pupae in the winter but not summer. Total soil biomass, consisting of bacterial and fungal counts, were not affected by treatments up to 1.52 kg a.i./ha. Chlorfenvinphos treatment at 2 kg a.i./ha increased the number of spores (by 41%) of a beneficial fungi. Preliminary work has shown that composting under favourable conditions can biodegrade chlorfenvinphos in dip sludges.

3.9.8 Mammals

The UK review reported inhibition of brain acetylcholinesterase in the wood mouse up to 10 d after treatment with 2,500 mg a.i./kg food. In a field drilled with treated wheat seed, trapped wood mice had variable residue concentrations in their gut correlated with significant inhibition of plasma cholinesterases in the first 10 d after treatment. However, the rapid disappearance of surface grain and residues in grain limited the transitory exposure to wildlife.

3.9.9 Conclusions

Chlorfenvinphos was very highly toxic to starlings with an acute LD50 < 10 mg a.i./kg bodywt, highly toxic to pigeons and blackbirds and moderately toxic to mallard ducks, chickens, pheasants and quail in acute exposures. The 28-d LOEC to pigeon, pheasant and Japanese quail was 100 mg a.i./kg food while the 8-h NOEC and LOEC for adult starlings was 3 and 6 mg a.i./kg bodywt, respectively. Chlorfenvinphos was very highly toxic to *Tilapia nilotica* and common carp and highly toxic to rainbow trout in acute exposures. It was moderately to highly toxic to the guppy in two

experiments but highly to very highly toxic to the guppy and Harlequin fish in another. However, the UK review found it was only highly toxic to carp, goldfish, *Orizias latipes* and guppy, and moderately toxicity to rainbow trout. Several studies reported variable acute toxicity to water fleas ranging from moderate to very high but the chronic 21-d LOEC was the lowest dose tested in the study of 0.3 µg a.i./L. Chlorfenvinphos was highly toxic to the eastern oyster but moderately and slightly toxic to the scud and protozoa, respectively. Algae were less sensitive with IC50 values in the moderate to slightly toxic range. Concentrations as low as 600 µg a.i./L adversely affected a macrophyte at an unspecified duration. Several studies showed terrestrial invertebrates and soil microorganisms were generally unaffected unless concentrations were higher than the maximum application rate in Australia of 500 g a.i./ha or its equivalent concentration in the top 10 cm of soil. Chlorfenvinphos was moderately toxic to the honey bee with a contact LD50 of 0.41 µg a.i./bee. Wood mice experienced enzyme inhibition after ingesting treated food at high rates but exposure was transitory in a field experiment.

4. ENVIRONMENTAL HAZARD

The environmental exposure of chlorfenvinphos is expected to be highest to organisms living in the vicinity where it will be applied. For Birlane 500 Insecticide (as the only EUP registered for broadacre application), residues would be expected on and around farm buildings, pasture plants, lucerne, potatoes and soil. Surface water, uncultivated land and nearby non-target plants (e.g. trees and grasses) may be contaminated through overspray, spray drift and/or run-off. The other EUPs for sheep, cattle and other animals are applied as spot treatments, races or dips and may have environmental exposure from treatment solution dripping from freshly treated animals. The exposure may also be high to organisms exposed to wool scouring effluents which may contain residues washed from treated fleece.

4.1 Estimated Environmental Concentrations

As there are nine registered EUPs with several different use patterns, it is appropriate to establish the estimated environmental concentration (EEC), if possible, for individual use patterns for use in subsequent hazard calculations. These hazard calculations were not carried out for those use patterns for which appreciable EECs could not be estimated.

4.1.1 Pasture, lucerne and potato

In the worst case scenario of a direct overspray of a 15 cm deep body of water with the maximum single application rate of 500 g a.i./ha of Birlane 500 Insecticide, the EEC would be 0.33 mg/L. This maximum application rate is registered in pasture and lucerne in Tasmania only with a lower rate of 385 g a.i./ha in Victoria and South Australia and 275 g a.i./ha in Queensland. Although no maximum number of repeated applications (at 275 g a.i./ha) is specified on the label for use in potatoes, it is only expected to be used in exceptional circumstances. Therefore, the worst case EEC of 0.33 mg/L will encompass these uses.

Based on mobility and dissipation studies, chlorfenvinphos is not expected to leach significantly deeper than 10 cm below the surface of soil. Therefore, the EEC in bare soil resulting from an application of 500 g a.i./ha would be 0.38 mg a.i./kg soil presuming a worst case low soil density of 1.3 g/mL.

4.1.2 Sheep jetting/dressing and lamb marking

The labels of Coopers Suprex 100 Jetting Fluid and WSD Jetting Fluid 100 direct users to apply up to 3 L of diluted (0.5 g a.i./L) solution for jetting each sheep of the flock depending on the length of wool. This equates to a maximum application rate of 2.5 g a.i./sheep. In Environment Australia's experience, up to two thirds the applied amount will run-off from the sheep. However, due to the stripping nature of chlorfenvinphos, proportionally more is expected to be retained in the fleece. Assuming that approximately half the applied active ingredient runs off, 1.25 g a.i./sheep will contaminate the soil of the fenced yard where jetting is usually done (although some yards are concreted and channel run-off away from soil). At a temporary holding density of about 3 sheep/m^2 while treatment solution drips, this would equate to an EEC of 29 mg a.i./kg soil in the top 10 cm of soil with a density of 1.3 g/mL.

For the dressing of flystruck sheep, a more concentrated dilution of 0.83 g a.i./L is recommended. Two other products, WSD Aerosol Sheep Dressing and David Grays Aerosol Sheep Dressing, are also registered for sheep dressing. These products, containing 0.64 g a.i./kg, are sprayed directly onto the struck area and surrounding skin. However, as the area to be dressed is generally less than the whole sheep, there is unlikely to be significant run-off and the number of sheep requiring dressing is usually minor in comparison to the whole flock, the environmental exposure from this use pattern is expected to be much lower compared to jetting.

For marking male lambs, a 0.5 g a.i./L solution is used on a small area of the animal. This is generally done in a fenced yard but can be done in a paddock. As with dressing, this use pattern is not expected to result in a significant environmental exposure in comparison to jetting.

Although chlorfenvinphos is registered for use on sheep in Australia, it is rarely used for this purpose (I. Russell, pers com).

4.1.3 Dipping and spraying of cattle, sheep, horses, deer, goats and dogs

Plunge dips and spray races are to be charged at 0.552 g a.i./L with the EUPs Coopers Blockade S Cattle Dip and Spray or Barricade S Cattle Dip and Spray (which also contain cypermethrin). After treatment, animals are to be turned out into shady paddocks as soon as possible where any drippings will contaminate the soil. The amount of solution lost from a sheep's fleece is expected to be the worst case scenario for any of the animals registered for treatment (the hair on other animals is shorter and not expected to hold as much solution). Short wool treatments may require about 2.5 L of solution per sheep and long wool up to 5 L per sheep (equivalent to 1.38-2.76 g a.i./sheep). Therefore as in the case of jetting, if half of the applied amount is lost to soil, then a worst case of 1.38 g a.i./sheep would be expected. Given a holding density of about 3 sheep/m^2, a worst case EEC of 32 mg a.i./kg soil in the top 10 cm (with a soil density of 1.3 g/mL) is expected. As with sheep jetting/dressing, chlorfenvinphos is rarely used on sheep (I. Russell, pers com).

For cattle, no studies were submitted on the concentration of administered chlorfenvinphos in faeces in order to determine safety to beneficial arthropods that breed in the excreta, eg dung beetles. However, ATSDR (1997) report about 16% of the dietary dose given to adult female Wistar rats was excreted in the faeces (presumably as unchanged parent compound) and 70-90% in the urine (presumably as metabolites). Although cattle are treated dermally, there is potential for absorption as well as ingestion (and therefore excretion in the faeces) of chlorfenvinphos as cows are noted to lick themselves periodically. At present, an EEC in faeces cannot be calculated and the

manufacturers should comment on this possible exposure and provide relevant data.

4.1.4 Backrubbers and overspray for buffalo fly on cattle

The application of Supona Buffalo Fly Insecticide by backrubbers is not expected to result in significant environmental exposure unless spilled. The environmental exposure due to drift from application by coarse spray is likely to be low, especially when applied by hand and in cattle holding yards. Therefore an EEC from this use pattern is expected to be much lower than from others above, though exposure of dung breeding insects by contaminated faeces is a possibility.

4.1.5 Wound dressing in sheep, cattle and horses

The product Defiance S Insecticidal Flystrike, Mules and Wound Dressing is to be applied directly to superficial wounds, presumably by brush or coarse spray (not specified on label). For sheep specifically, a maximum application rate of 8 mL/kg bodywt (equivalent to 20 mg a.i./kg bodywt) for mules and marking wounds is to be applied with a stencil brush or pressurised sprayer as a coarse to medium spray. As the environmental exposure from these uses is not expected to be high, an EEC calculation is not applicable. As well, chlorfenvinphos is rarely used on sheep (I. Russell, pers com).

4.1.6 Flies in farm buildings and mushroom casings

Birlane 500 Insecticide is to be applied as a directed spray of 25 g a.i./L to fly resting places such as walls, partitions and rafters in and around milking sheds, stables and other farm buildings. No indication of droplet size is given, however, it is unlikely to be fine or susceptible to drift, especially when applied to the interior of farm buildings. Therefore the environmental exposure is not expected to be high and no EEC is applicable.

When used on mushroom casings, Birlane 500 Insecticide is mixed with peatmoss, limestone and water in an indoor setting with no run-off. The casings are used for three cropping cycles of mushroom, after which there are no detectable residues of chlorfenvinphos due to biodegradation. There is no EEC applicable for this use pattern.

4.1.7 Wool scouring

4.1.7.1 Australia

Monitoring data in Australian wool clips in 1997/98 found a mean concentration of 0.22 mg a.i./kg wool which is equivalent to about 1.7 mg a.i./kg in the wool wax (see 1.2 Environmental Monitoring). Residues were only found in 10% of the wool clips tested and only 1% contained residues higher than 2 mg a.i./kg. These results were similar to a previous survey in 1992-1994 reporting mean residue concentrations of 0.6-0.7 mg a.i./kg wool. In clips where individual struck sheep were treated, the mean was 0.7 mg a.i./kg wool with a maximum concentration of 4.1 mg a.i./kg wool.

As a worst case scenario, the sewage treatment plant at Black Rock in Geelong was modelled by Savage (1998) for its discharge containing pesticide residues. Adapting the assumptions in this review, the calculations for EEC are as follows:

- Assume 50 tonnes of wool scoured with a mean concentration of 0.22 mg a.i./kg wool would contain 50,000 kg wool X 0.22 mg a.i./kg wool = 11 g a.i.

- 96% of the residue is removed from the wool by the scouring process and 70% of that residue is discharged in the effluent (after 30% recovery of the raw wool grease). Therefore the amount of chlorfenvinphos discharged in the effluent is 11 g a.i. X 0.96 X 0.7 = 7.4 g a.i.

- Assuming 50% of organophosphorus insecticide residues (including chlorfenvinphos) are removed by the sewage treatment plant, only 7.4 g a.i. X 0.5 = 3.7 g a.i. is discharged to the ocean outfall.

- As the volume of sewerage discharged to the outfall is 50 ML/day, the estimated environmental concentration in the discharge is 3.7 g a.i. ÷ 50 ML/d = 74 ng a.i./L/d.

Effluent from inland scouring operations is used to irrigate land and Savage (1998) estimated in a worst case scenario an annual application rate of 350 g a.i./ha for organophosphate insecticides given an initial concentration of 4.5 mg a.i./kg wool. As the mean concentration of chlorfenvinphos in the Australian wool clip in 1997/98 was 0.22 mg a.i./kg wool, this would equate to an annual application rate of 17 g a.i./ha. This in turn would result in an EEC of 0.013 mg a.i./kg soil in the top 10 cm of soil with a density of 1.3 g/mL.

4.1.7.2 United Kingdom

As a significant proportion of the Australian wool clip is sent overseas to the UK for scouring, chlorfenvinphos residues pose a potential trade barrier. The following EEC calculations for the Spenborough scour in the UK (discharging to the Spen Beck River) followed the guidelines of Savage (1998) for the annual average UK/EU Environmental Quality Standard:

- Assuming 27.6 tonnes of wool scoured per day with a mean concentration of 0.22 mg a.i./kg wool would contain 27,600 kg wool X 0.22 mg a.i./kg wool = 6.1 g a.i.

- 96% of the residue is removed from the wool by the scouring process and 20% of that residue is discharged in the effluent (after 80% recovery of residues in the wool grease). Therefore the amount of chlorfenvinphos discharged in the effluent is 6.1 g a.i. X 0.96 X 0.2 = 1.2 g a.i.

- Assuming 50% of organophosphorus insecticide residues (including chlorfenvinphos) are removed by the sewage treatment plant, only 1.2 g a.i. X 0.5 = 0.6 g a.i. is discharged to the Spen Beck river outfall per day.

- As the mean daily river flow is 149 ML/day, the estimated environmental concentration in the discharge is 0.6 g a.i. ÷ 149 ML = 4.0 ng a.i./L.

A similar calculation to meet the Maximum Allowable Concentration (MAC) in the UK gives an EEC of 8.5 ng a.i./L. The MAC is allowed for short periods of time only and is based on acute toxicity under conditions of a low daily river flow of 71 ML (Savage 1998).

4.2 Hazard to Terrestrial Organisms

Chlorfenvinphos is likely to have the greatest environmental exposure to terrestrial organisms through the spraying of Birlane 500 Insecticide on pasture, lucerne and potato as a broadacre application, including through the potential for spray drift to nontarget areas. The dipping and/or spraying of sheep, cattle and other animals may also result in exposure, however, the potential for off-site

movement during these uses is expected to be lower. Scouring of treated wool in inland centres may result in effluents (containing chlorfenvinphos residues), which are then used to irrigate land. The uses on cattle by backrubbers and coarse overspray, localised treatment of animal wounds, farm buildings and mushroom casings are not expected to result in any significant exposure and therefore the associated environmental hazard is generally expected to be low.

Acute hazard is generally measured by the Q value calculated as EEC ÷ LD50 (or LC50) (Urban and Cook 1986). If $Q < 0.1$, no hazard is expected whereas $0.1 = Q = 0.5$ indicates hazard that may be mitigated by restricted use. If $Q = 0.5$, then the hazard is unacceptable and the use pattern must be avoided. Chronic hazard is evaluated by simply comparing the EEC with the NOEC; if EEC < NOEC, then there is no hazard (Urban and Cook 1986). If EEC > NOEC, then the hazard is unacceptable.

4.2.1 Birds

Starlings were the most sensitive bird species and had an LD50 (duration unspecified) of 3.2 mg a.i./kg bodywt (Schafer 1972, 1983). Although this species is not native to Australia, it can be used as a surrogate for estimating the hazard to sensitive native species. Assuming a body weight of 100 g and a food consumption of 20 g, the dietary LC50 for the starling was estimated from the LD50 as 16 mg a.i./kg food (Urban and Cook 1986). The EEC in potential food items can be estimated from the maximum application rate of Birlane 500 Insecticide of 500 g a.i./ha (for spraying of pasture, lucerne and potato in Tasmania only) and the updated Kenaga nomogram (Urban and Cook 1986, US EPA 1993, Fletcher et al. 1994, Pfleeger et al. 1996). A dietary makeup of 50% grains and 50% small insects for a flock of starlings is estimated. The dietary EEC is then calculated as follows:

Starling diet = 50% grains + 50% small insects

EEC of chlorfenvinphos in grains	= 49 mg a.i./kg food
EEC of chlorfenvinphos in small insects	= 60 mg a.i./kg food
Dietary EEC of chlorfenvinphos	= 0.5 X 49 + 0.5 X 60 mg a.i./kg food
	= 55 mg a.i./kg food

A similar calculation for the lower application rate of 275 g a.i./ha in Queensland for the same use results in a dietary EEC of 30 mg a.i./kg food. From these calculations, as both dietary EEC values are higher than the estimated LC50 of 16 mg a.i./kg food, the Q value is >0.5 and the hazard to sensitive birds is potentially unacceptable for the use pattern on pasture, lucerne and potatoes.

In pastures, the pests (underground grass grubs, pasture webworms and corbies) could rise to the surface after application and may be easy prey for insectivorous birds which may gather to feed on them. Pastures may also contain a wider range of nontarget invertebrates which may be oversprayed. However, application to potatoes and lucerne is not expected to result in high exposure to birds as the pests (potato moth and redlegged earth mite) are not easily preyed upon when intoxicated and it is unlikely that many birds would be exposed in this manner or only consume contaminated food. In these crops, it is more likely for exposure to occur through spray drift to nontarget areas, in which a worst case estimate of approximately 10% drift of the amount sprayed would apply (Urban and Cook 1986). The dietary EEC would then be reduced to 5.5 mg a.i./kg food, with a resultant Q value of 0.19 and 0.34 (for application rates of 275 and 500 g a.i./ha, respectively) indicating hazard that may be mitigated by restricted use. As birds are mobile and expected to leave treated areas if the food becomes unpalatable, the exposure and hazard will be

greatly reduced. Similarly, the relatively rapid dissipation of chlorfenvinphos will also serve to limit the hazard.

Incidents of bird poisonings overseas only seemed to occur when treated seeds were ingested. As seed treatments involve the application of relatively high application rates targeted specifically to the seeds, the general broadcast spraying of Birlane 500 Insecticide will result in broader but lower exposure. It is impossible to accurately estimate the potential for bird poisonings to occur under Australian conditions, but the conservative risk quotient method used here indicates that toxic levels can be reached and incident reports are an unreliable basis for making quantitative determinations of risk, even on a comparative basis against other chemicals. Given the restricted use and limited number of incident reports, it is expected that impacts from use on lucerne and potatoes will be isolated rather than commonplace, and avian populations should generally remain unaffected. However, the hazard to birds from applications to pasture is potentially much higher and needs further clarification.

Cyanamid/Fort Dodge has responded (Robinson 1999) that the preceeding hazard assessment for pastures is overly conservative and does not accurately reflect events in the field. They claim that estimating the 95th percentile LD50 of all toxicity data as 7.3 mg a.i./kg bodywt reduces the hazard. However, they cite an unpublished and as yet not widely accepted methodology which has not been assessed. They also argue that the dietary LC50 estimation from a single dose LD50 study is conservative but do not provide an alternative estimate for the well known Urban and Cook (1986) method used. The use of worst-case maximum residues in food items and assuming that 100% of the diet has been treated is appropriate to model the acute toxic effect of chlorfenvinphos on birds. Additionally, the company's claim that the literature indicates residues in insects of "5 ppm or less per lb a.i. applied/A" is incorrect; Environment Australia has calculated concentrations of 8.3-33 mg/kg in grasshoppers (which are considered large insects) based on Forsyth and Westcott (1994) and Forsyth et al. (1994) as cited by the company. Therefore, the hazard assessment is considered a realistic worst case scenario.

For the treatment of cattle, sheep and other animals, contamination of the soil in areas where treatment will occur is unlikely to result in significant exposure to birds. It is possible that some birds which have been observed to associate with cattle could be adversely affected; Haley et al. (1993) reported in the US that another organophosphate insecticide famphur pour-on treatment (application rate unspecified) killed magpies consuming cattle hair and hawks preying upon the magpies for up to 82 DAT. Although treated animals are not expected to harbour populations of ectoparasites, eg ticks, in sufficient numbers to impart an appreciable dose to feeding birds, this hazard cannot be assessed without further data.

Cyanamid/Fort Dodge responded that similar poisonings are unlikely to occur in Australia as famphur is more toxic to birds than chlorfenvinphos, although this claim cannot be confirmed. However, we agree the different application method of famphur (concentrated direct pour-on treatment to backs of cattle) may overestimate the hazard of chlorfenvinphos (diluted dip or spray race). While the company is correct in that magpies in the US behave differently than in Australia (indeed they are different species), the native species Willie wagtail (*Rhipidura leucophrys*) live in close association with cattle (eg. perching on their backs, Macdonald 1973). The Cattle egret (*Ardea ibis*) also use cattle as a vantage point and may feed on their ectoparasites (Marchant and Higgins 1990). Therefore, these birds may be exposed to chlorfenvinphos. As the Willie wagtail is a small bird with a relatively high metabolism and food consumption rate, the hazard is also expected to be higher with a given dose. The establishment of a watching brief would be appropriate in this

case (covering the range of OPs used on cattle).

Wool scouring effluent containing chlorfenvinphos residues and discharged to ocean outfalls is not expected to be a hazard to birds. In inland scouring operations whose effluent is used to irrigate land, Savage (1998) estimated (worst case scenario) an annual application rate of 350 g a.i./ha for organophosphate insecticides given an initial concentration of 4.5 mg a.i./kg wool. The mean concentration of chlorfenvinphos in the Australian wool clip in 1997/98 of 0.22 mg a.i./kg wool would equate to an equivalent annual application rate of 17 g a.i./ha. This in turn equates to a concentration of 2 mg a.i./kg food in the starling diet based on the Kenaga nomogram. Given that this figure is also annualised, the hazard to birds from residues in wool scouring effluent would seem insignificant.

4.2.2 Earthworms

The EEC of 0.38 mg a.i./kg soil in the top 10 cm of soil after application of the maximum rate of Birlane 500 Insecticide is significantly less than the 14-d NOEC for *Eisenia foetida* of 123 mg a.i./kg soil (Weyman 1997, page 314). This indicates no chronic hazard to earthworms is expected from this use pattern.

For the use of chlorfenvinphos in sheep jetting, the EEC of 29 mg a.i./kg soil in fenced holding yards is also less than the NOEC and indicative of low hazard. As the environmental exposure from dressing and lamb marking is expected to be lower than that for jetting, the hazard will also be lower. In the dipping and spraying of livestock, the soil contamination from sheep is likely to be the worst case. As the EEC of 32 mg a.i./kg soil is also less than the NOEC, there is unlikely to be any chronic hazard to earthworms. For application of chlorfenvinphos by backrubbers, coarse overspray and wound dressing and to farm buildings and mushroom casings, the exposure and hazard to earthworms is expected to be lower. Similarly, the EEC from irrigation using inland wool scouring effluent of 0.013 mg a.i./kg soil is much lower than the NOEC and would also not pose a hazard.

4.2.3 Beneficial arthropods

The maximum application rate of Birlane 500 Insecticide of 500 g a.i./ha is equal to 5 µg/cm^2. The hazard to honey bees may be estimated on the assumption that a bee in a spray cloud has a target area of 1 cm^2 (Davis and Williams 1990). The topical LD50 for bees was 0.4-9.8 µg a.i./bee (Stevenson 1978, Beran 1970, Batista et al. 1975, page 315), and exposure of approximately 5 µg/bee may be expected if Birlane 500 Insecticide is sprayed at the maximum rate while they are actively foraging. Thus bees would be expected to be adversely affected by this application. This hazard is supported by Johansen and Hutt (1963, page 315) and SC 8993/30 (page 318) which found 100% mortality when bees were sprayed at 560 g a.i./ha. They further showed that mortality was sharply reduced to 14 and 1% when foliage was treated 3 and 24 h prior to exposure, respectively. It is noted that the label of Birlane 500 Insecticide states “Dangerous to bees. Do NOT spray any plants in flower.” which is considered adequate to reduce the hazard to bees to an acceptable level. The use patterns on sheep/lambs, cattle, horses, deer, goats, dogs, farm buildings or mushroom casings are not expected to result in exposure to bees either during application or in the disposal of residues such as in wool scouring effluent.

For other beneficial arthropods, the most sensitive organism (for which a dose could be determined) was the springtail with an LC50 of 0.5-1.0 mg a.i./kg soil (Thompson and Gore 1972, Tomlin 1975,

page 317). In these studies, soil concentrations of 0.5 mg a.i./kg soil caused 0 and 9% mortality after 24 h. As the EEC from Birlane 500 Insecticide application is lower at 0.38 mg a.i./kg soil, this use is not expected to pose a significant hazard.

For the use in sheep jetting, and the dipping and spraying of livestock, the EEC of 29-32 mg a.i./kg soil in fenced holding yards is higher than the NOEC and indicates a potential hazard. However, as these uses are restricted to areas where beneficial arthropods are unlikely to occur, chlorfenvinphos biodegrades in soils with DT50s of 11-98 d (faster in warm moist conditions) and arthropod populations tend to recover relatively quickly, the hazard to the majority of arthropods from these uses is not considered significant. As the environmental exposure from dressing and lamb marking is expected to be lower than that for jetting, the hazard will also be lower. For application by backrubbers, coarse overspray and wound dressing and to farm buildings and mushroom casings, the exposure and hazard to arthropods is expected to be low. The Q-value of 0.03 (EEC of 0.013 mg a.i./kg soil ÷ LC50 of 0.5 mg a.i./kg soil) for irrigation using scouring effluent indicates no expected hazard for springtails.

Adverse effects on dung beetles are well known for the macrocyclic lactone pesticides and more recently have been reported with synthetic pyrethroids. To date, there have been no reports of adverse effects on dung beetles from organophosphate insecticides such as chlorfenvinphos, and Environment Australia notes other beetles seem to be relatively insensitive (see 3.9.5 Terrestrial invertebrates). However, as the two EUPs Coopers Blockade S Cattle Dip and Spray and Barricade S Cattle Dip and Spray contain both chlorfenvinphos and cypermethrin (a pyrethroid), and Supona Buffalo Fly Insecticide is used as a coarse spray on cattle, the potential for adverse effects exists.

Cyanamid/Fort Dodge calculated an EEC of 5.4 mg a.i./kg faeces, based on a treatment volume of 10 L of a 0.552 g a.i./L solution and cattle weighing 250 kg producing 5% body weight per day in faeces (Robinson 1999). Dermal absorption in cattle was estimated at 30% while 4.5% of the total dose was excreted in faeces when administered to dogs, based on unsubmitted but published studies. This EEC was recalculated to be 6.0 mg a.i./kg faeces following the same methodology and parameters. Robinson (1999) argued that since the LC50 values to carabid and staphylinid beetles (600-2,000 mg a.i./kg soil) were higher than the EEC in faeces, then there is no hazard to dung beetles. It is noted that while the sensitivity of dung beetles (Scarabaeidae) to chlorfenvinphos is unknown, carabid and staphylinid beetles are expected to be adequate surrogates. Therefore, the hazard to dung beetles is expected to be low.

4.2.4 Soil microorganisms

The most sensitive study showed a transient adverse effect (disappeared after 6 d) on nitrogen fixation (as measured by acetylene reduction) when soil was treated at 10 mg a.i./kg soil (Tu 1978, 1979, page 320). The EEC from Birlane 500 Insecticide application of 0.38 mg a.i./kg soil is lower than this value indicating there is no significant hazard to soil microbial function.

The EEC of 29 mg a.i./kg soil in sheep jetting may adversely affect microorganisms, but this will be mostly limited to fenced holding yards and be of a transitory nature. The worst case EEC of 32 mg a.i./kg soil for the dipping and spraying of sheep is expected to pose a similar hazard. As chlorfenvinphos is biodegraded, the soil concentration will fall and susceptible microorganisms are expected to recover quickly. For application of chlorfenvinphos by backrubbers, coarse overspray and wound dressing and to farm buildings and mushroom casings, the exposure and hazard is

expected to be lower. Similarly, the EEC from irrigation using wool scouring effluent of 0.013 mg a.i./kg soil is lower than the adverse effect concentration and would also not be a hazard. Thus the hazard from chlorfenvinphos is acceptable.

4.3 Hazard to Aquatic Organisms

Water bodies adjacent to pasture, lucerne and potato plots may be contaminated by chlorfenvinphos through direct overspray of Birlane 500 Insecticide. Contamination outside the target area is likely to result from spray drift, particularly when small (vmd < 100 µm) droplets are used, and from run-off of material sorbed to soil and organic matter particles. The other use patterns are not likely to result in direct contamination of water except when the effluent of wool scouring operations is released to ocean outfalls or land for irrigation with subsequent run-off.

4.3.1 Direct overspray

The worst case scenario of a direct overspray of a 15 cm deep body of water resulted in an EEC of 330 µg a.i./L. The most sensitive adverse effect on fish was the 96-h LC50 for *Tilapia nilotica* of <30 µg a.i./L (Stephenson et al. 1984, page 305). The Q-value for fish (Table 16), calculated by dividing the EEC by the adverse effects concentration, is >11 which falls into the category of "unacceptable risk" (Urban and Cook 1986). The most sensitive aquatic invertebrate was the water flea with a 48-h LC50 of 0.1 (0.09, 0.11) µg a.i./L (Bogacka and Groba 1980, page 311), giving a Q-value of 3300 indicating an unacceptable risk. The most sensitive plant was duckweed with a LOEC of 600 µg a.i./L (duration unspecified, Bogacka and Groba 1980). The resulting Q-value of 0.55 represents a marginally unacceptable hazard.

Table 16. Chlorfenvinphos Q-values for the most sensitive aquatic species exposed through direct overspray at 500 g a.i./ha, 10% spray drift and 0.6% run-off. Shading represents an unacceptable risk (Q = 0.5) and no shading indicates no risk (Q < 0.1, Urban and Cook 1986).

Most Sensitive es	**Toxicity (µg a.i./L)**	**Q-Values**		
		Direct Overspray	**10% Spray Drift**	**0.6% Run-off**
Tilapia nilotica	96-h LC50 < 30	>11	>1.1	>0.067
Water flea	48-h LC50 = 0.1 (0.09, 0.11)	3300	330	20
Duckweed	LOEC = 600 (duration unspecified)	0.55	0.055	NA

NA = not applicable

At the lower application rate of 275 g a.i./ha in Queensland, the worst case EEC direct overspray of 183 µg a.i./L would still give Q-values of 6.1 and 1830 for fish and invertebrates, respectively, indicating an unacceptable hazard. For plants, the Q-value is 0.31 which indicates a hazard which can be mitigated by restricted use.

As these risks are unacceptably high, the likelihood of direct overspray of a water body during application should be reduced to a low level by, for example, allowing aerial application of Birlane 500 Insecticide only with special approval as is the case in Tasmania (where the maximum application rate of 500 g a.i./ha applies). Birlane 500 Insecticide would normally be applied by ground spraying. In this case, it would be more likely that surface water bodies will be contaminated by spray drift or run-off rather than direct overspray.

4.3.2 Spray drift or run-off

Application of Birlane 500 Insecticide may contaminate water by spray drift or run-off, where the resulting EEC of chlorfenvinphos is expected to be considerably lower than that from direct overspray. The risk and extent of spray drift can be minimised if applications are made under suitable meteorological conditions and with appropriate equipment. However, it must be assumed that some spray drift will occur and hence contamination of soil and water outside the target areas.

Assuming 10% of the amount sprayed will reach the aquatic environment via spray drift as a worst case (Urban and Cook 1986), an EEC of 33 µg a.i./L would result. The Q-values are accordingly lower (Table 16) but still indicate an unacceptable hazard for fish and water fleas. For duckweed, the hazard is now expected to be low.

The AgDRIFT model of the Spray Drift Task Force (1997) was also used to predict the EEC from spray drift based on a comprehensive dataset using worst case Tier 1 parameters (eg. nozzles producing a fine spray with vmd (volume mean diameter) = 100 µm). In applying 500 g a.i./ha using a low boom spray, a distance of 300 m from a stream (4 m deep and 2 m wide) would be required to achieve an EEC of 0.01 µg a.i./L (equivalent to 0.08% drift) to be protective of water fleas (the most sensitive species, Q-value = 0.1). For Queensland where the maximum application rate is 275 g a.i./ha, the distance would still need to be 165 m to achieve the Q-value of 0.1. To achieve an EEC of 3 µg a.i./L to be protective for fish, the equivalent conditions would be 15 m distance (from a stream 15 cm deep and 2 m wide) for the high application rate in Tasmania and 6 m distance for that in Queensland.

However, as Birlane 500 Insecticide is not expected to be applied in a fine spray for pastures, lucerne and potatoes, the AgDRIFT worst case model may not be appropriate. In contrast to these predictions, Marrs et al. (1989) found that 0.5-6% of the application rate could drift 5 m in a range of studies, but it is recognised that 1% drift at 5 m to be a reasonable mean based on the data presented. If the reduction in drift were proportional to the distance travelled, a 62 m buffer would be sufficient to reduce the drift to 0.08% to protect daphnids. As it is not expected that these restrictive conditions are likely to be met in many of the pasture, lucerne and potato growing areas where Birlane 500 Insecticide is used, this clearly indicates the potentially unacceptable hazard to aquatic invertebrates that may be associated with spray drift from ground based equipment.

For the aerial spraying of Birlane 500 Insecticide with coarse droplets in Victoria and South Australia at 385 g a.i./ha (aerial application is prohibited in Tasmania), the AgDRIFT model predicts that a buffer zone of 281 m is required to produce an EEC of 0.01 µg a.i./L to be protective of daphnids in a water body 17 m deep. To protect fish, the EEC of 3 µg a.i./L would require a 106 m buffer in 15 cm deep water. Even at the lower application rate of 275 g a.i./ha in Queensland, a buffer of 285 m is required for daphnids in a 12 m deep water body, and 82 m buffer for fish in 15 cm deep water. These conditions are clearly unlikely to be met in the aerial spraying of pasture, lucerne and potato which indicates the unacceptable hazard to aquatic invertebrates and fish. Therefore it is recommended that aerial application should be prohibited in all States unless data are generated to indicate an acceptable hazard.

The US review (ATSDR 1997) summarised a field study by Racke (1992) which reported 0.3-0.6% of the applied chlorfenvinphos was found in run-off water after a rain event of unspecified intensity or time after application. If 0.6% of the maximum application rate of 500 g a.i./ha reached water as run-off, the EEC would then be 2 µg a.i./L with only the Q-value for water fleas indicating

an unacceptable hazard (Table 16). Calculations show these conclusions for hazard (Q > 0.5) are the same for an application rate of 275 g a.i./ha.

In the case that run-off resulted in an EEC of 2 µg a.i./L, biodegradation would occur at a rate dependent on temperature and other factors. Environmental fate studies using natural pond water and sediment found half-lives of 7 and 70 d in the water (27 and 91 d in the whole system) at 25 and 10°C, respectively (Edwards and Gibb 1981, page 280). In natural stream water and sediment systems, the half-life was 38-40 d at 20°C (Wahle 1993, page 280). In order for the Q-value to drop below 0.1 and indicate an acceptable hazard to water fleas, the concentration in water must be <0.01 µg a.i./L. With best and worst case half-lives of 7 and 70 d, respectively, a starting concentration of 2 µg a.i./L would decrease to 0.01 µg a.i./L after 53 and 532 d (approximately 7.6 half-lives required). This indicates the unacceptable hazard from 0.6% run-off would persist for 53-532 d not accounting for dilution effects. Furthermore, the hazard to benthic organisms from chlorfenvinphos partitioning to sediment is unknown as no toxicity studies were submitted on this subject. In order to reduce the potential hazard from the persistence of chlorfenvinphos in natural waters, it is recommended that application should be limited to only once per year as only one spray is normally required to control corbies in pasture. This constraint is not expected to be overly restrictive.

4.3.3 Effluent from wool scouring

The EEC of the daily discharge at an Australian sewage ocean outfall is 74 ng a.i./L (see 4.1.7 Wool scouring). Using the most sensitive freshwater species as surrogates for marine species, the Q-values indicate no risk for fish and plants, but an unacceptable risk for invertebrates (Table 17). However, this does not account for any dilution in ocean water, which is expected to be large. Shoreline sewage treatment plant outfalls experience a 20:1 dilution within 50 m while dilutions of 150:1 are measured for deepwater outfalls (Sydney Water 1996). At the lower dilution rate, the EEC would be 3.5 ng a.i./L with a Q-value of 0.035, indicating low hazard at >50 m from the outfall.

Table 17. Chlorfenvinphos Q-values for the most sensitive aquatic species exposed through ocean outfalls and surface run-off from land irrigated with effluent.

Most Sensitive Species	**Toxicity (µg a.i./L)**	**Q-Values**			
		Ocean Outfall with no dilution	**Ocean Outfall with dilution**	**Annual run-off from irrigated land**	**Weekly run-off from irrigated land**
Tilapia nilotica	96-h LC50 < 30	0.002	NA	0.004	NA
Water flea	48-h LC50 = 0.1 (0.09, 0.11)	0.74	0.035	1.3	0.025
Duckweed	LOEC = 600 (duration unspecified)	0.0001	NA	0.0002	NA

NA = not applicable

An aquatic hazard assessment for the chlorfenvinphos residues in effluent used to irrigate land can be done using the US EPA's standard model of 1.5% loss from a 10 ha catchment into a 1 ha pond of 2 m depth (Urban and Cook 1986). Given an equivalent single annual worst case application rate of 17 g a.i./ha (see EEC for wool scouring, page 328), this calculation yields an EEC in water of 0.13 µg/L. The resulting Q-values (Table 17) show that the hazard is the same as for an ocean outfall

with no dilution. However, since the application rate is spread out over a year, the hazard would be proportionally lower given, for example, a weekly application rate (0.33 g a.i./ha), EEC (0.0025 µg/L) and Q-value (0.025). Actual application rates will depend on the hydraulic, nutrient and salt loadings of individual sites (ARMCANZ and ANZECC 1995). The nonpersistent nature of chlorfenvinphos in aerobic soil is expected to further reduce the hazard to an acceptable level. Additionally, effluent is retained in settling ponds before irrigation which will allow some separation of grease and dirt, biodegradation, and adsorption to organic matter to reduce the EEC. Also, the equivalent annual application rate does not take grease recovery into account which will further reduce chlorfenvinphos residues (Savage 1998).

For the UK scouring plants, the UK Environmental Agency has set an annual average Environmental Quality Standard for organophosphate insecticides of 10 ng a.i./L (Savage 1998). The mean EEC applicable to this EQS was calculated to be 4.0 ng a.i./L which is lower than the EQS and indicative of an acceptable hazard. The EEC for the Maximum Allowable Concentration is 8.5 ng a.i./L which is lower than the MAC for organophosphates of 100 ng a.i./L (calculated using a low daily river flow rate and allowed for only a short time period), and also indicates no hazard is expected. The low acceptable hazard in both these cases results from the very low market share of chlorfenvinphos as a sheep ectoparasiticide. However, the hazard could rise significantly if the market share increased since residues from long wool jetting can peak at up to 934 mg a.i./kg wool and still be 395 mg a.i./kg wool after 84 d (see 2.14 Fate of Residues in Wool). Therefore, it is recommended that the environmental impact be re-examined should the market share for chlorfenvinphos increase.

4.4 Hazard to Terrestrial Plants

As no studies were submitted on the toxicity of chlorfenvinphos to terrestrial plants, the hazard can not be assessed. However, as i) Birlane 500 Insecticide is applied to plants to protect them from insect attack, ii) chlorfenvinphos is a neurotoxin and iii) there is an acceptable hazard to the most sensitive aquatic plant (duckweed), it is expected that the hazard to terrestrial plants from the registered products is insignificant.

4.5 Summary of Environmental Hazard

Of all the various use patterns, chlorfenvinphos is likely to have the greatest environmental exposure through the spraying of Birlane 500 Insecticide on pasture, lucerne and potato. The treatment of sheep, cattle and other animals may also result in exposure. However, the potential for off-site movement during these uses is expected to be lower. The disposal of wool scouring effluent containing residues may also result in some exposure while the uses on cattle by backrubbers and coarse overspray, localised treatment of animal wounds, farm buildings and mushroom casings are not expected to result in any significant exposure.

A preliminary worst case assessment shows that the application of Birlane 500 Insecticide at the maximum rate of 500 g a.i./ha in Tasmania is a potential hazard to birds through dietary exposure. However, a more detailed assessment indicates any adverse effects on birds from applications to potatoes and lucerne are likely to be isolated with populations remaining unaffected due to the more likely reduced exposure through spray drift, the mobility of birds and the broadacre application instead of the concentrated seed dressings which have resulted in poisoning reports. However, use in pastures may cause dosed pests (underground grass grubs, pasture webworms and corbies) to become easy prey for birds resulting in an unacceptable hazard; therefore, the continued registration of this use pattern cannot be supported without further information, such as results of monitoring to

determine whether birds are present during or visit shortly after application to feed. In the use pattern of the other products containing chlorfenvinphos on cattle, sheep and other animals, soil contamination is unlikely to result in significant exposure to birds. However, the hazard to birds which associate with cattle is unknown as poisonings have occurred in this manner with another organophosphate insecticide. The establishment of a watching brief would be appropriate in this case.. The irrigation of land with wool scouring effluent containing residues is not expected to be a hazard to birds.

No chronic hazard to earthworms is expected from any of the registered products containing chlorfenvinphos. Of all the products and all the beneficial arthropods, only Birlane 500 Insecticide poses an unacceptable hazard to bees; its application to any plants in flower is prohibited on the label which is expected to reduce the hazard to an acceptable level. The hazard to dung beetles is expected to be low given the EEC in cattle faeces relative to the toxicity to related beetles.. Soil microorganisms may be adversely affected by dripping solution from treated sheep but this will be mostly limited to fenced holding yards and expected to be transitory as residue concentrations decline due to biodegradation.

The direct overspray of Birlane 500 Insecticide of a 15 cm deep body of water at the maximum rate in Tasmania, and also at the lower maximum rates in other States, would result in an unacceptable hazard to fish, aquatic invertebrates and plants. As ground spraying is the more likely application method and aerial application is prohibited in Tasmania, exposure by spray drift or run-off is more likely. In the worst case of 10% drift, fish and invertebrates are still at risk. In the more realistic case of 1% drift at 5 m suggested by the literature, a 62 m buffer would be sufficient to reduce the drift and the EEC sufficiently to protect daphnids. As it is not expected that these restrictive conditions are likely to be met in many of the pasture, lucerne and potato growing areas where Birlane 500 Insecticide is used, this clearly indicates a potentially unacceptable hazard to aquatic invertebrates that may be associated with spray drift from ground based equipment.

Computer modelling of aerial spraying with coarse droplets at 385 g a.i./ha (aerial application is prohibited in Tasmania) predicts that a buffer zone of 281 m is required to be protective of daphnids in a water body 17 m deep. To protect fish would require a 106 m buffer in 15 cm deep water. Even at the lower application rate of 275 g a.i./ha, a buffer of 285 m is required for daphnids in a 12 m deep water body, and 82 m buffer for fish in 15 cm deep water. These conditions are clearly unlikely to be met which indicates the unacceptable hazard. Therefore it is recommended that aerial application should be prohibited in all States.

If 0.6% of the amount applied reached water as run-off (as reported in field studies), the hazard would be unacceptable only for invertebrates. Given half-lives of chlorfenvinphos in natural water studies of 7-70 d, the estimated initial concentration would take 53-532 d to decline to a nonhazardous level, indicating the hazard would persist. Further, the hazard to benthic organisms from chlorfenvinphos partitioned to sediment is unknown as no toxicity studies were submitted on this subject.

Given the potential hazard to aquatic invertebrates from spray drift and run-off, further information is needed before Environment Australia can support continuation of this high rate use pattern. This information should be in the form of monitoring of chlorfenvinphos residues in receiving waters, particularly shallow ponds, and/or sediments caused by drift and/or run-off to surface waters.

Effluent from wool scouring containing chlorfenvinphos residues would be further treated at sewage

treatment plants before discharge to the environment. In the worst case of the sewage outfall at Geelong, the predicted hazard to invertebrates is unacceptable and these organisms near the outfall may be adversely affected. However, after accounting for the dilution effect in the ocean of at least 20:1 within 50 m of the outfall, the hazard is expected to be acceptably low. When effluent containing residues is used for irrigation, the weekly equivalent application rate is low enough to be an insignificant hazard considering that chlorfenvinphos is nonpersistent and effluent is retained in settling ponds before irrigation allowing dissipation. The EECs for chlorfenvinphos in UK rivers are below both the average annual Environment Quality Standard and the short term Maximum Allowable Concentration, thus indicating an acceptable hazard. However, it is recommended that the environmental impact be re-examined should the market share for chlorfenvinphos increase as the hazard could rise significantly.

Although no studies were submitted on the toxicity of chlorfenvinphos to terrestrial plants, the hazard to terrestrial plants from the registered products is expected to be insignificant as they are used to protect plants from insect attack, chlorfenvinphos is a neurotoxin and there is an acceptable hazard to the most sensitive aquatic plant (duckweed).

5. CONTROLS AND LABELLING

5.1 Formulation/Packaging

The labels are satisfactory.

5.2 Transport

The labels are satisfactory.

5.3 Storage and Disposal

Label instructions for storage and disposal of empty containers, etc are adequate except for the label for WSD Jetting Fluid 100 which directs users to "Discard run-off wash with care" but does not give details on how to do so.

5.4 Use

- To alert users of the toxicity to aquatic organisms, under "Protection of Wildlife, Fish, Crustaceans and Environment" the statement

  "DO NOT USE this product in a manner which causes the product or used container to enter streams, rivers or waterways".

  should be added before the statement "Do not contaminate streams, rivers or waterways with this product or used container" on registered product labels.

- To reduce the potential for spray drift to nontarget water bodies, it is recommended the following statement be added to the 'Birlane 500 Insecticide" label.

DO NOT APPLY THIS PRODUCT BY AIRCRAFT."

- To further reduce the potential for spray drift, the following statement should be added to the label of Birlane 500 Insecticide:

  DO NOT USE this product in a manner which adversely impacts on areas adjacent to target area.

- To reduce the potential adverse effect any spray drift or run-off may have to aquatic invertebrate communities, the following statement should be added to the label of Birlane 500 Insecticide:

  "Do NOT apply this product by ground application methods more than once every 12 months".

To reduce the potential for bees to be affected following the sue of "Birlane 500 insecticide" the following statement is to be added to the label:

Dangerous to bees. Do not apply to flowering plants on which bees are present. Do not apply if spray will affect beehives.

6. CONCLUSIONS AND RECOMMENDATIONS

The greatest hazard from the use of chlorfenvinphos is to aquatic invertebrates (due to their high sensitivity) from the spraying of Birlane 500 Insecticide in pasture, lucerne (at the maximum application rates of 500 g a.i./ha in Tasmania, 385 g a.i./ha in Victoria and South Australia and 275 g a.i./ha Queensland) and potatoes (at 275 g a.i./ha). Even at the lower exposure rates from spray drift and run-off, the hazard is still unacceptable and may require from about eight weeks to 1.5 years to dissipate to an acceptable concentration in natural waters, depending on temperature. The hazard to benthic organisms is unknown as no toxicity studies were submitted on this subject. Monitoring data of chlorfenvinphos residues in receiving waters, particularly shallow ponds, and/or sediments caused by drift and/or run-off to surface waters are required before these use patterns can continue.

Aquatic invertebrates within 50 m of the ocean outfalls of sewage plants treating effluent from wool scours containing chlorfenvinphos residues may be adversely affected. However, after accounting for the dilution effect in the ocean of at least 20:1 within 50 m of the outfall, the hazard is expected to be acceptably low. The use of wool scouring effluent for irrigation is considered a low hazard given that the equivalent weekly application rate is low, chlorfenvinphos is relatively nonpersistent and effluent is retained in settling ponds before irrigation allowing dissipation. As well, the EECs in the UK riverine environment are below the annual average Environmental Quality Standard of 10 ng a.i./L and the short-term Maximum Allowable Concentration of 100 ng a.i./L for organophosphate insecticides; this indicates an acceptable hazard.

There is also a hazard to honey bees, however, the label of Birlane 500 Insecticide prohibits spraying on any plants in flower which is expected to reduce the hazard to an acceptable level.

Soil microorganisms may be adversely affected by dripping solution from treated sheep but this will be mostly limited to fenced holding yards and is expected to be transitory as residue concentrations decline due to biodegradation.

The hazard to birds from the use of Birlane 500 Insecticide in pastures is potentially unacceptable and cannot be supported without further information, such as results of monitoring of birds feeding in or visiting sprayed pastures. Similarly, the hazard to birds from chlorfenvinphos use on cattle is unknown as poisonings have occurred in this manner with another organophosphate insecticide.

The hazard to terrestrial plants from the registered products is insignificant as they are used to protect plants from insect attack, chlorfenvinphos is a neurotoxin and there is an acceptable hazard to the most sensitive aquatic plant (duckweed).

To alert users of the toxicity to aquatic organisms, reduce the potential for offsite movement of chlorfenvinphos to nontarget water bodies and reduce the potential adverse effect any spray drift or run-off may have to aquatic invertebrate communities, Environment Australia recommends the suggested label modifications under 5. Controls and Labelling.

In summary, the following conclusions and recommendations:

- The use of Birlane 500 Insecticide in pasture, lucerne and potatoes presents an unacceptable hazard to aquatic invertebrates, which may be adversely affected by direct overspray, spray drift and/or run-off, and an unknown hazard to benthic organisms for which no toxicity data were submitted. Monitoring data on chlorfenvinphos residues in receiving waters, particularly shallow ponds, and/or sediments caused by drift and/or run-off to surface waters are required before the continuation of these use patterns. Until these data indicate an acceptable hazard, aerial application should be prohibited in all States. Application by ground spray only once every 12 months is recommended.

- The hazard to birds from the use of Birlane 500 Insecticide in pastures is potentially unacceptable and the continued registration cannot be supported without further information, such as results of monitoring of birds feeding in or visiting sprayed pastures.

- Similarly, the hazard to birds from chlorfenvinphos use on cattle is unknown as poisonings have occurred in this manner with another organophosphate insecticide. The establishment of a watching brief would be appropriate in this case.

- There is a potential hazard to aquatic organisms associated with high residues in wool and it is recommended that the environmental impact of chlorfenvinphos in scouring effluent be re-examined should the market share for chlorfenvinphos use on sheep increase.

- All other registered use patterns present a low hazard to the environment and can be supported based on this initial review.

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