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1 introduction

Monocrotophos was selected for review in the chemical review program. It is an organophorphorus insecticide with systemic activity and is used for the control of a wide range of chewing, sucking and boring pests (aphids, caterpillars, helicoverpa spp, mites, jassids, budworm, scale and stem borer) as well as locusts. Use is for cotton, beans (French), sunflowers, maize, millet, sorghum, soybeans, sweet corn, wheat, tobacco and for trees by injection.

1.1 Chemical Identity

Refer to Section 3 Chemistry Assessment for details

1.2 Physico-Chemical Properties

Refer to Section 3 Chemistry Assessment for details

1.3 Summary of Physico-Chemical data

From the physico-chemical properties monocrotophos is very soluble in water. It has a low partition coefficient and limited binding to sediment/soil is expected. It is volatile but low volatility from water is expected due to the low Henry's law constant, = 6.4 X 10^{-7} $atm.m^3.mol^{-1}$.

2. ENVIRONMENTAL EXPOSURE

2.1 Volume

There are five currently registered products in Australia and four registrants. All products are EC formulations and are formulated at 400 g ai/L. There were approximately 47 tonnes of active used in 1996-97. This includes 13.6 tonnes of active used under permit for control of an outbreak of spur throated locust in Queensland at a rate of 240 g ai/ha.

2.2 Application and Use Pattern.

Monocrotophos was registered for use on cotton, beans (French), granny smith apples and some varieties of pears (some labels do not have any pome fruits), bananas, sunflowers, maize, millet, sorghum, soybeans, sweet corn, wheat, triticale, panicum, potatoes, tobacco, tomatoes and for non-fruit bearing trees by injection, with the major use in sorghum and sunflowers. It was used in Australia to control a wide range of chewing, sucking and boring pests (aphids, caterpillars, helicoverpa spp, mites, moths, jassids, budworm, scale and stem borer) as well as locusts. It seemed to be used in Australia mainly as a back-up spray when insect pressure and resistance levels were high, eg tomatoes 1997-98 or for control of locusts by landholders. It was not used by the Australian Plague Locusts Commission (APLC) for locusts control as it was considered too toxic for use by the APLC.

The maximum use rate stated on previously registered labels was 4.0 L/ha, corresponding to 1.6 kg ai/ha for *helicoverpa* in cotton, with lower rates for other pests. For orchards the maximum use rate is 2 L/ha for bananas and for Granny Smith apples and pears a spray rate of 100 mL/100 L of spray. For vegetable crops the maximum rate is 250 mL/100 L or 2 L/ha, corresponding to 800 g ai/ha. There are other uses on the label at different rates, grains at 700 mL/ha (280 g ai/ha) for locusts, tobacco at 300 mL/100 L for budworm, sunflowers at 1.8 L/ha (720 g ai/ha) and tomatoes at 2 L/ha, both for *Helicoverpa spp.*

The major usage was for sorghum and sunflowers, with tomatoes and cotton the other significant uses, given in Table 1 together with the maximum rates for that crop and corresponding pest. On the label there were unlimited number of repeats allowed for most applications, apart from tomatoes in Victoria with a maximum of four applications per season. It should be noted that in the season 1997-98, monocrotophos was applied to approximately 20% of the tomatoes processing crop in Australia at least once or twice (Jean Bentley of Institute for Horticultural Development, Agriculture Victoria, personal communication) and represented a significant increase in use over the 1996-97 season.

Crop	% Monocrotophos used in 1996-97	Some rates on label		Pest
Sorghum* and Sunflowers	45.7 (sorghum + sunflowers)	900 mL/ha	360 g ai/ha	spider mites
		1.8 L/ha	720 g ai/ha	helicoverpa, bugs
		350 or 700 mL/ha	140 or 280 g ai/ha	Spur throated, Plague and Migratory locusts
Tomatoes	21.7	250 mL/100 L or 2 L/ha	1000 g ai/ha 800 g ai/ha	Tomato grub, helicoverpa
		350 or 700 mL/ha	140 or 280 g ai/ha	Spur throated locusts
Cotton*	10.6	4 L/ha	1600 g ai/ha	helicoverpa
		350 or 700 mL/ha	140 or 280 g ai/ha	Spur throated, Plague and Migratory locusts
Potatoes*	6.9	1 L/ha	400 g ai/ha	Potato moth and potato aphid
		350 or 700 mL/ha	140 or 280 g ai/ha	Spur throated locusts
Pastures/ Lucerne*	5.9	350 or 700 mL/ha	140 or 280 g ai/ha	Spur throated, Plague and Migratory locusts
Soybean	5.7	900 mL/ha	360 g ai/ha	spider mites
		350 or 700 mL/ha	140 or 280 g ai/ha	Spur throated, Plague and Migratory locusts
Tobacco*	3.5	160 mL/100 L	640 g ai/ha	helicoverpa
		350 or 700 mL/ha	140 or 280 g ai/ha	Spur throated locusts
Non-crop areas	unknown	350, 700 or 1400 mL/ha	140, 280 or 560 g ai/ha	Spur throated locusts

Table 1. Approximate estimates of usage by crops and corresponding pest with maximum rate for that crop. These estimates may vary from year to year depending on seasonal factors and crop areas planted. * Indicates those regarded as essential for that crop.

A number of the rates in Table 1 are as dilutions and these do not readily convert to rates per hectare, eg L per hectare, but best estimates are given. It was normal practice to spray to runoff, in field crops (tomatoes, sorghum etc) this normally required 200 to 1000 L/ha of spray solution, depending on the size of the plants. In extreme situations, eg. dry conditions, this could be higher, ie 1500 L/ha to achieve complete wetting of the crop. Using the figure of 1000 L of spray per hectare, the rate for tomatoes and tobacco is 2.5 L/ha (1 kg ai/ha) and 1.6 L/ha (640 g ai/ha) respectively.

The use pattern, as stated on the labels, is as indicated by crop monitoring for cotton or 4 days for cotton with heavy infestations (Ciba Geigy) or 10 days between sprays (other labels), on a weekly program basis for beans; every 7-10 days for potatoes and tobacco crops, 2 to 3 times per week during silking for sweet corn and for other crops as indicated by pest activity. It should be noted that tomatoes could have three crops per year in the tropics.

Monocrotophos is applied to crops by aircraft and tractor powered sprayers, either as a mist or a spray. Application by fogging machines and back mounted knapsacks is forbidden on two labels but not on others. The labels bans aerial spraying in Tasmania (without specific approval of the Registrar of Pesticides).

There is detailed information concerning use on the Cyanimid and United Phosphorus labels, including droplet sizes for low volume application equipment and ULV application by aerially spraying (vdm between 100-150 micron for LV and 90-120 micron for ULV) and for calculation application rates in a range of crops but this information is not consistent across all labels. Information on the size of spray droplets for ground rig application for some crops is also given. The rate of application on various crops is also not consistent across all labels.

Use of monocrotophos was identified as essential by the State Departments of Agriculture for tobacco (Qld, Vic), potatoes (Qld, WA), cotton (WA, Qld) and ornamentals (Qld, under State permit). Monocrotophos is one of the few OPs considered to be effective against *Helicoverpa armigera* in the Ord River Irrigation Area and is used for resistance management. It is also strongly supported by the Grains Council for use as an alternative to the more frequently used synthetic pyrethroids against locusts and midge in sorghum. For complete details, see Agricultural Assessment.

Monocrotophos has been used as a rodenticide in the Darling Downs, Queensland, as recently as 1989 (Eldershaw, 1996). It was used under a temporary permit due to a mouse plague that year but control was not successful.

2.3 Formulation, handling and disposal

Monocrotophos is currently formulated as an emulsifiable concentrate and sold at 400 g ai/L containing hydrocarbon solvents (550 g/L), surfactants and other additives. The EC formulation is sold in 5 and 20 litre containers and 200 litre drums and is for commercial use only. There are five currently registered products in Australia, all EC formulations, and four registrants.

Formulating the EC from the imported TGAC is a straightforward process of mixing the chemical with the hydrocarbon solvent and other additives to make the emulsifiable concentrate. The EC formulation is then transferred into the relevant containers. During these processes the chances of a significant spill are minimal and any spills are expected to be treated according to the MSDS, and involve sweeping up spills by use of absorbent materials such as hydrated limes, saw dust, clay or fuller's earth etc (based on European MSDS). Likewise spills that occur during transport are also expected to be treated according to the MSDS.

Some of the labels from different companies for the EC do not appear to comply with current labelling practices with respect to rinsing and disposal of used containers. All currently registered labels and currently sold products should comply with the current labelling requirements with respect to rinsing and disposal of containers, ie

> Triple rinse or pressure rinse empty containers before disposal. Add rinsings to the spray tank. Do not dispose of undiluted chemical on site. Break, crush or puncture and bury empty containers in a local authority landfill. If not available, bury the containers below 500 mm in a disposal pit specifically marked and set up for this purpose, clear of waterways, vegetation and roots. Empty containers and product should not be burnt.

For refillable containers the following should be added:

> For closed/mixing systems, empty contents fully into application equipment. Close all valves and return to point of supply for refill or storage.

2.4 Overseas Regulatory Actions

Monocrotophos has been voluntarily withdrawn from sale in the US in 1989 following concern on its toxicity to non-target species, especially birds (Anonymous, 1997 A). It is also banned in Indonesia, Sri Lanka and Philippines, severely restricted in Kuwait (for use on plants to flowering stage only), Malaysia (for use on coconut and oil palm by truck injection) and Germany (not to be handled by adolescents and pregnant and nursing women). The article also states that it is not used in the UK.

Recently, in 1996, the companies selling monocrotophos in Argentina have voluntarily agreed to withdraw the product from the market and bought back all existing supplies following concerns over bird deaths from its use in grasshopper control (Pesticide Action Network North America Updates Services, 4 November 1996—for further details see p 36).

Monocrotophos is a PIC (Prior Informed Consent) chemical due to its high toxicity.

3. ENVIRONMENTAL FATE

All of the following reports for chemical fate and degradation were submitted by Novartis in response to the ECRP data call-in or are from existing TGAC holdings and the scientific literature. The studies presented here were not performed according to Good Laboratory Practices or internationally acceptable guidelines, unless stated otherwise.

One extensive review on environmental fate and toxicity was found in the literature (Guth, 1994). All data from this review are in included in this report.

3.1 Hydrolysis

3.1.1 Hydrolysis as a function of pH

Hydrolysis studies were conducted on radiolabelled (^{14}C at the 1,3 crotonamide position) for 30 days under dark conditions at various pHs as indicated below (Lee, 1980). Two dosing levels were used, 25 and 250 ppm and there was only minor variation between the two dosing levels. Quantification was done by scraping radioactive areas on the TLC plates followed by radioassay. Monodesmethyl monocrotophos (SD 11191, see Appendix 1 for structure) was recovered in the aqueous phase and was derivatised before analysis by GC. Material balance was good for all studies.

Half-lives @ 25 C and 25 ppm were determined as 131 days (pH 3), 134 days (pH 6), 26 days (pH 9), 139 days distilled water (pH 6.6) and 147 days in nonsterilized natural water (pH 7.6). The natural water was taken from an irrigation cannel. At 35 C the half lives were 47, 33, 4.6, 25 and 29 days for pH 3, 6, 9, distilled water and natural water respectively.

The predominant species from hydrolysis under acidic and neutral conditions was monodesmethyl monocrotophos (SD 11191), with minor amounts of N-methyl acetoacetamide (SD 9112, see Appendix 1). Hydrolysis under basic conditions yielded predominantly SD 9112 with the demethylated product (SD 11191), approximately in the ratio 3:1. It was considered that the results show two different mechanisms of hydrolysis, one hydrolysis by water to give SD 11191 and the other base catalysed giving SD 9112.

3.1.2 Rate of Hydrolysis

The hydrolysis of monocrotophos was studied at pH 5, 7 and 9 and at various temperatures (30, 50 and 70 C) (Burkhard, 1975). Aliquots of the hydrolysis solutions were analysis by CG after extraction.

From the data, first order kinetics were revealed and the rate constants determined together with the Arrhenius parameters. From the Arrhenius equation, the half lives at temperature of 20 C were calculated as 96, 66 and 17 days at pH 5, 7 and 9 respectively.

3.1.3 Hydrolysis in Seawater

The hydrolysis of radiolabelled monocrotophos (^{14}C N-methyl) was examined in both seawater (pH 8.0) and tap-water adjusted to pH 8.0 (Roberts and Stoydin, 1972). The treated waters were then stored at 20-22 C in sealed clear glass in the open laboratory. Analysis was by TLC and radioassay following extraction (chloroform), which showed that all extracts had only one radioactive component, monocrotophos, as indicated by TLC. The radioactive in the aqueous phase was not identified.

The half life of monocrotophos was determined to be approximately 100 and 150 days for seawater and tap-water respectively.

3.1.4 Conclusion

From three experiments it is concluded that in acidic conditions, pH between 3 and 8, hydrolysis is slow, with half lives between 66-150 days and is classified as slightly hydrolysing (Netherlands classification, see Mensink, Montforts, Wijkhuizen-Maślankiewicz, Tibosch and Linders, 1995). At higher pH hydrolysis is quicker, the half life was 17 and 26 days at pH 9.0 in two studies, and is classified as moderately hydrolysing. Hydrolysis is unlikely to be a significant contributor to the overall degradation of monocrotophos at the normal environmental pH range (5-9).

3.2 PHOTODEGRADATION

3.2.1 Aqueous Photolysis

Aqueous photolysis for a sample of ^{14}C monocrotophos (labelled in the 1,3-crotonamide) was examined in both distilled and natural water (Lee, 1980 A).

The study was conducted at pH 6.6 and 7.6 for the distilled and natural water respectively, at a nominal concentration of 25 µg/mL of monocrotophos for a period of 30 days outside in natural sunlight (Modesto, California). The control sample was wrapped in aluminium foil. Maximum temperatures ranged from highs of 37 to 25 C and minimums of between 20 to 10 C.

Analysis of products was achieved using two dimensional TLC and quantified by radioassay of the scraped radioactive areas. The total mass balance was good for all experiments.

Results showed that the rate of aqueous degradation was not increased by exposure to sunlight. The half lives of all samples tested was approximately 26 days, regardless of the type of water. There was no qualitative and quantitative difference in the products formed in any sample.

It was concluded the monocrotophos degraded in aqueous solution and that direct sunlight did not show any observable effect.

3.2.2 Photodecomposition in aqueous and methanolic solutions.

The photodecomposition of monocrotophos was briefly examined in aqueous and methanolic solutions using a photochemical reactor with a minimum wavelength of 290 nm (Guth and Voss, 1970). The relationship of the photochemical reactor to natural sunlight is not clear from the report.

Samples of monocrotophos were irradiated for 6 hours and the effect on cholinesterase inhibition examined. There was no change in the inhibition of cholinesterase and it was therefore concluded that monocrotophos was photolytically stable.

3.2.3 Photolysis Rate on Soil

The photolysis of ^{14}C-monocrotophos on soil from exposure to natural sunlight was examined (Lee, 1980 B).

The study was conducted using a sterilised sandy loam soil (81.6% sand; 11.2% silt and 7.2% clay, pH 7.3), which was dosed with 5 ppm ^{14}C-monocrotophos and transferred to Petri dishes as a thin layer. Control samples were covered with aluminium foil. These were then placed outside in the sunlight for 30 days. Samples of soil were taken after approximately 0, 7, 14, 21, and 30 days. The soil samples were extracted, then analysed by two dimensional TLC and radioassay as before.

There was a steady decrease in total radioactivity for all samples, with no significant difference between controls and test samples. There was a significant difference between the control and treated soil in the extractable and bound residues. At the end of the 30 day period, 48% and 5% of the applied radioactivity was recovered from the extracts in the control and exposed soils respectively, with approximately 17 and 63% as bound residues (see Table 2).

	Total recovered	Extract	Bound	Parent	Compound 2	Compound 3
Exposed	67.8	5.2	62.6	2.5	1.4	0.5
Control	64.5	47.6	16.9	45.4	1.3	0.4

Table 2. Radioactive in various fraction as a percentage of total applied.

Analysis of the reaction products showed that these were identical to those in the case of hydrolysis, ie SD 9112 and 11191, and were <2.2% of the applied radioactivity in all samples.

The half lives for dissipation were 30 and 3 days for control and exposed respectively. There was no evidence presented in the report that sterile conditions were maintained during the test. As there was no degradation in the solution photolysis studies, ie no direct photolysis, the photodegradation observed in this study is likely to be due to sensitised photo-reactions.

3.2.4 Photochemical Degradability of Monocrotophos in Gaseous Phase

No studies were presented.

3.2.5 Other studies

The effect of sunlight on thin films of monocrotophos has been examined (Tantawy, Elewa, Marei and Mansour, 1974). Thin films of Azodrin and Nuvacron, prepared by evaporation of acetone solution in glass beakers were exposed to sunlight (Alexandria, Egypt) for 6 hours (8 am to 2 pm) per day and the reduction in mortality for cotton leaf hopper (*Spodoptera littoralis*) determined. There was a slow decrease in mortality for successive exposures and a significant drop in mortalities after 6 days of exposure.

As there was no analysis of the thin films and no evidence that conditions were sterile, it is unclear as to where the reduced mortalities were due to photolysis or some other mechanism.

3.2.6 Summary and conclusion of photodegradation

Aquatic
Based on the single study presented there is no evidence that monocrotophos photolyses in water.
Soil
In the study presented, there was evidence that sensitised photolysis had occurred, with a significant increase in the rate of degradation between the sample exposed to sunlight and the dark control, with a half life of 3 days compared to 30 days.

It is concluded that there is no evidence in the studies presented by the registrants that direct photolysis will be a degradation pathway in the environment but indirect photolysis could contribute to degradation in the environment.

4 METABOLISM

4.1 Aerobic Soil Metabolism

Aerobic Metabolism in Three Soils

The aerobic soil metabolism of ^{14}C monocrotophos (labelled in the 1,3-crotonamide) was studied using three different soils, Hanford sandy loam, Catlin silty loam and Piedmont sandy clay loam (Lee, 1980 C). Characteristics of these soils is given in Table 3. The soils were treated with monocrotophos at a nominal dose of 5 µg per gram of soil, then thoroughly mixed for two hours. The soil moisture was adjusted to 75% of field capacity by adding tap water, then the soil sealed. Volatiles were trapped and the total radioactivity quantified throughout the study period. There was no measurement of the actual concentration of monocrotophos in the soil; however the time 0 measurements indicate that the soil contained between 98 to 102% of the expected radioactivity.

	Hanford	Catlin	Piedmont
pH	7.3	5.3	6.4
Organic Matter %	1.06	2.00	1.50
Sand %	81.6	19.6	52.0
Silt %	11.2	62.8	15.6
Clay %	7.2	27.6	32.4
Texture	Sandy loam	Silty clay	Sandy clay

Table 3. Characteristics of the soil used in the aerobic soil metabolism studies

Samples were taken throughout the study at 0, 5, 10 and 15 days then 1, 2 and 3 months after treatment. The system was purged with moist air and volatiles trapped. At each sampling point the soil was extracted and the distribution of all radioactivity amongst volatiles, CO_2, soil extract and the extracted soil was determined. The soil extracts were further analysed by two dimensional TLC to determine the extent and the decline of monocrotophos and its soil metabolites. The results are summarised in Table 4, 5 and 6 for each of the soils.

The overall accountability for the applied radioactivity was good and ranged from 90 to 105%.

The degradation of monocrotophos was first order, with half-lives of between 2.5 and 5 days for the soils tested. After 30 days less than 1% of the applied dose was recovered as parent compound.

The degradation of monocrotophos in aerobic soil produces mainly CO_2 and non-extractable residues, together with minor metabolites, most of which were not identified. During the study, minor amounts of the metabolites SD 9112 and SD 12657 (N-hydroxymethyl derivative, see Appendix 1) were formed in the soils, with the most abundant being SD 12657 (3.5% of applied dose 5 DAT) in the Catlin soil. The identity of these minor metabolites from the Catlin soil were confirmed by GC-MS.

	Time After Treatment						
	0	5 d	10 d	15 d	30 d	60 d	90 d
CO_2	0.0	2.6	26.5	43.3	56.0	57.9	59.0
Unextractable	3.1	59.2	59.5	50.8	38.3	40.1	42.3
monocrotophos	93.2	21.6	6.2	0.6	0.4		
SD 9112		2.1	0.8				
SD 12657		3.5	1.6				
Others	2.2	1.1	0.7	0.7	1.1	1.2	0.2

Table 4. ^{14}C residues of monocrotophos during the aerobic soil metabolism study from Catlin silty loam. Results as percentage of initial applied dose. Others include that remaining in aqueous phase after extraction, radioactivity at the origin of TLC plate and minor metabolites

	Time After Treatment						
	0	5 d	10 d	15 d	30 d	60 d	90 d
CO_2	0.0	0.1	10.2	37.3	37.4	51.4	51.8
Unextractable	3.1	18.2	26.3	46.5	53.8	52.4	49.8
monocrotophos	96.4	74.5	58.2	9.5			
Others	2.8	3.4	4.2	3.7	1.9	1.5	0.9

Table 5. ^{14}C residues of monocrotophos during the aerobic soil metabolism study from Hanford sandy loam. Results as percentage of initial applied dose. Others include that remaining in aqueous phase after extraction, radioactivity at the origin of TLC plate and minor metabolites

	Time After Treatment						
	0	5 d	10 d	15 d	30 d	60 d	90 d
CO_2	0.0	1.4	18.5	45.9	55.0	60.2	61.5
Unextractable	2.3	43.9	52.9	41.9	37.3	35.7	35.8
monocrotophos	92.4	41.0	12.7	4.7	0.6	0.4	0.4
Others		4.9	5.9	2.9	1.0	1.4	0.8

Table 6. ^{14}C residues of monocrotophos during the aerobic soil metabolism study from Piedmont sandy clay. Results as percentage of initial applied dose. Others include that remaining in aqueous phase after extraction, radioactivity at the origin of TLC plate and minor metabolites

The non-extracted material in the soil for the 90 day samples was examined further. After the initial extractions the soil was further extracted by aqueous extraction, which released 4 and 7% of the applied radioactivity from the Hanford and Catlin soils respectively. This material was not analysed further.

Comparative Aerobic Metabolism in Sterilised and Nonsterilised Soil
Monocrotophos was incubated under aerobic conditions as above for 30 days using sterilised and non-sterilised Hanford sandy loam soil (Lee, 1980 D). The soil was sterilised by autoclaving and the sterility was tested by incubation in growth medium. There was no evidence of microbial growth. Samples were analysed at time 0, 15 and 30 days. Results are given in Table 7.

	Sterile			Non-sterile		
	0	15 d	30 d	0	15 d	30 d
CO_2		ND	ND		37.3	37.4
Unextractable	6.0	34.7	41.2	3.1	46.5	53.8
monocrotophos	92.1	62.4	56.5	96.4	9.5	ND
Others	2.3	2.4	2.0	2.8	3.7	1.9

Table 7. ^{14}C residues of monocrotophos during the aerobic soil metabolism study from Piedmont sandy clay. Results as percentage of initial applied dose. Others include that remaining in aqueous phase after extraction, radioactivity at the origin of TLC plate and minor metabolites. ND = Not Detectable

The unextractable material from the 30 day samples were further examined by extraction with various solvents and water. The aqueous extract of the sterile soil contained >95% of the radioactivity from initially unextractable material, which was identified by TLC to be parent compound. Further extraction of the non-sterile soil failed to recover any significant amount of the bound radioactivity.

The results from this experiment clearly indicate that the rapid degradation of monocrotophos in soil is due to microbial action.

Degradation of Monocrotophos in Two German Soils
Two German soils (characteristics in Table 8) were treated with monocrotophos and the soil moisture adjusted to 40% of the soil water capacity (Keller, 1980). The soils were then incubated in the dark at a temperature 22 C but not sealed. Water losses were compensated by adding additional water when required.

At various times samples were taken, extracted and analysed by GC for monocrotophos. There was a 62% and 90% reduction in monocrotophos concentration in soil 1 after 1 and 2 days respectively and for soil 2 there was 53%, 58% and 74% reduction in the concentration of monocrotophos for days 8, 16 and 30 respectively. The half lives were estimated to be <1 day and 7 days for soil 1 and 2 respectively.

	pH	Organic carbon	Clay	Silt	Sand
Soil 1	6.5	2.2%	8.9%	7.3%	83.8%
Soil 2	4.8	1.1%	10.5%	12.4%	77.1%

Table 8. Characteristics of two Germany soil, 1 and 2.

The degradation of Azodrin in Soil
The degradation of Azodrin (monocrotophos) was examined in a sandy loam soil from Trinidad (see Table 9 for details of the soils) (Roberts, 1974).

	pH	Organic carbon	Clay	Silt	Sand
Trinidad	5.8	6.0%	23%	17%	54%

Table 9. Characteristics of sandy loam soil from Trinidad.

The soil samples were treated with ^{14}C monocrotophos, radiolabelled in either the N-methyl or O-methyl positions, then stored in the dark at 20-22 C, open to the air (aerobic) before being analysed. The soil was extracted and the extracts analysed by TLC. The soil bound residues were quantified by combustion analysis. Results are summarised in Table 10.

	Time After Treatment						
	N-(^{14}C-methyl)			O-(^{14}C-methyl)			
	1 week	6 weeks	32 weeks	1 week	3 weeks	10 weeks	24 weeks
monocrotophos	78	0	4	92	87	2.5	12.5
SD 9112	0.5	1.7	26	ND	ND	ND	ND
SD 11191	0	0	1	0	2.1	0.4	0
Unextractable	16.5	4.5	30	1.3	2.5	2.2	12.5
Others	4	25.8	34	1	0	17.3	22.0

Table 10. ^{14}C residues of monocrotophos during the aerobic soil metabolism study from sandy loam from Trinidad. Results as percentage of initial applied dose. Others include polar products in the aqueous phase after extraction and unidentified minor metabolites. ND = not detected, radiolabel would not allow detection of this metabolite

There is considerable variation in the results in Table 10, particularly for the metabolite SD 9112. Some of this variability was explained in the report as being due to the fact that treatments occurred at different time and that the biological activity of the Trinidad soil may have deteriorated. Also, it is noted that the metabolite identified in this study as SD 11191 (monodesmethyl) was not observed in the other soil metabolism studies but was noted in the hydrolysis study. A half life could not be determined.

The study does not meet current standards and given the variability in the results, is considered unreliable.

4.2 Aerobic Aquatic Metabolism

No studies were presented.

There was, however, a report on the effect of different formulations on the distribution and uptake of monocrotophos when applied to rice (Osgerby and Page, 1969). As part of these studies, the degradation of monocrotophos in water was examined. The water samples were analysed directly by cholinesterase inhibition.

Only graphic results were present but there is clearly a rapid degradation of monocrotophos from the initial dose estimated at 13 ppm (25 mg ai in 2 L of water plus 5 kg of soil, assuming no adsorption to soil) to <0.2 ppm in approximately 10 days. A half life was not determined. Environment Australia has calculated that for a first order degradation this corresponds to a half life of approximately 2 days.

In a study on the persistence of pesticides in river water, monocrotophos was found not to degrade at all (100% recovery as parent) after 8 weeks (Eichelberger and Lichtenberg, 1971). Monocrotophos was the most stable OP studied. The water was taken from a small stream that received domestic and industrial waste together with farm runoff. The pH was 7.3 and increased to 8.0 after 8 weeks. The dosed water was kept at laboratory temperature in both natural and artificial (room) lighting. Analysis was by extraction and GC.

However, a field study (see p 20) in a rice paddy showed rapid degradation in the aqueous phase.

4.3 Anaerobic Aquatic Metabolism

The study was performed as part of the aerobic study above using ^{14}C-monocrotophos (Lee, 1980 C). The study was performed in the dark using the same soils as for the aerobic study.

The soils were incubated aerobically for 30 days prior to flooding the soil with water (2-3 cm depth) and purging continuously with nitrogen. Samples were taken after 30 and 60 days post anaerobic. Due to the rapid degradation of monocrotophos during the aerobic period, there was no monocrotophos in any samples taken during the anaerobic period. No further examination was made of these samples.

4.4 Conclusions-Soil and Aquatic Metabolism

Aerobic Soil Metabolism
The degradation of monocrotophos under aerobic conditions in soil is fast, with a half life of between <1 and 7 days, based on 5 different soils. The major product is carbon dioxide and non-extractable

residues. Some minor metabolites were identified in some soils, with the N-hydroxymethyl derivative being the highest at 3.5% of the applied dose. The major degradation pathway appears to be direct metabolism to carbon dioxide or incorporation into the organic fraction of the soil followed by mineralisation.

Aerobic Aquatic Metabolism
No studies were presented that determined a half life. However, monocrotophos was shown to degrade rapidly under aquatic aerobic conditions but by contrast there was no degradation in natural river water at room temperature, consistent with the hydrolysis experiments. It is concluded that the limited studies show that in aquatic systems with high microbial activity, ie with soil/sediment, degradation could be rapid.

Anaerobic Aquatic Metabolism
No studies were presented that determined a half life or examined whether monocrotophos degrades under anaerobic conditions.

5. MOBILITY

5.1 Soil Adsorption/Desorption

A soil adsorption/desorption study was performed using four soils, Hanford sandy loam, Catlin silty clay loam, Piedmont sandy clay loam and Tujunga agricultural sand (Lee, 1980 E). The characteristics of three of these soils has been presented in Table 3, with Tujunga sand having the following characteristics: pH = 4.8 (salt buffer), om 0.35%, sand 84.6%, silt 8.4% and clay 7.0%.

^{14}C-monocrotophos (labelled in the 1,3-crotonamide) at three different concentrations (0.1, 1.0 and 10 ppm) was added to each of the soils in aqueous calcium sulfate (0.01 M), mixed for 24 hours and the amount absorbed determined by radioassay. The Freundlich constants were determined for each soil and the Koc then calculated. Desorption was examined by replacing half of the $CaSO_4$ solution (0.01 M), mixing for 2 hours and after centrifugation replacing half of the solution again. This was repeated three times, in duplicate and the result are presented as percentage desorbed rather than the more 'normal' K_d.

There was a significant deviation from current US EPA requirements in that the soils used were not sterilised and the decrease in radioactivity in the adsorption solutions could be due to degradation. The results are summarised in Table 11.

Soil	organic matter	K	Koc	% Desorption
Tujunga sand	0.35%	0.077	22.0	91.4
Hanford sandy loam	1.06%	0.158	14.9	21.5
Piedmont sandy clay loam	1.50%	0.119	7.9	66.6
Catlin silty clay loam	2.00%	0.615	30.8	51.7

Table 11. The adsorption and desorption coefficients. Koc = K/% om X 100

The results of the adsorption/desorption experiment for monocrotophos show that it is weakly absorbed to the four soils tested. Monocrotophos can be rated as having high mobility in soil for the soils tested.

While this is an old study, the methodology used is close to current methods for K_{ads}, apart from the using non-sterile soils and as such is acceptable for absorption.

5.2 Leaching Study of Monocrotophos by Soil Column

Soil columns were filled with soil to a height of 27 cm, using the same 4 soils used in the adsorption/desorption study above, then 3 cm of treated soils containing 5 ppm of radiolabelled ^{14}C monocrotophos (labelled as before) was added to the top of the columns (Lee, 1980 F). The soils used were not sterilised before use. The columns were then leached with an equivalent of 20-acre inches of water (equal to 51 cm rainfall) and the leachate collected. The leachate and the soil column was analysed for radioactivity and the chemical identity of the radioactivity identified by two dimensional TLC.

In a second experiment, Hanford sandy loam was aerobically aged for 30 days before being added to the top of the soil column. The column was then eluted with equivalent of 0.5 acre inch per day (equal to 1.27 cm of rain per day) for 45 days. The leachate was collected and analysed together with the degradation products on the column.

Approximately 95, 96 and 102% of the applied radioactivity was recovered in the leachate from the Tujunga, Catlin and Hanford soils respectively. The majority of the radioactivity was in the early fractions and >95% of the total radioactivity from pooled fractions was identified as parent compound.

Approximately 64% of the applied radioactivity was recovered in the leachate from the Piedmont soil column, with 33% from the 3-12 cm soil fractions from the column. Analysis of these soil fractions showed that approximately 90% of the radioactivity was extractable and 87% was identified as parent compound with 8% of the radioactivity in the soil as unextractable material.

Combustion analysis showed that 54% of the applied radioactivity was recovered from the Hanford soil after the 30 days aerobic incubation. After the 45 days of elution of the column, <1% of the applied radioactivity was found in the leachate. The majority of the radioactivity remained in the top 3 cm of the column, which was not extractable. This is consistent with the aerobic soil metabolism study.

It was concluded that monocrotophos has high soil mobility, particularly in soil with limited clay content.

While this study is old and was not performed to current guidelines, the overall results are considered acceptable.

5.3 Literature Reports

In a major review of the environmental fate and toxicity of monocrotophos (Guth, 1994), monocrotophos was considered to be mobile in all soils tested, based on soil thin layer chromatograms. The soils used were those above, namely Hanford sandy loam, Catlin silty clay loam, Piedmont sandy clay loam and Tujunga agricultural sand.

In the same review, monocrotophos was calculated to be non-volatile from soil, based on volatilisation from water (Henry's Law), modified for the effects of adsorption to soil.

5.4 Conclusions from Mobility Studies

Soil adsorption/desorption
The soil adsorption/desorption of monocrotophos was determined in four soils by the standard batch flask method. It was concluded that monocrotophos is only weakly adsorbed to most soils and is rated as being mobile in soils. There was significant desorption which confirms that binding is weak.

Leaching
In a column leaching study, on the same four soils used in the adsorption/desorption study, most of the applied monocrotophos was found in the leachate and it was concluded that monocrotophos is mobile. However, using treated soil that was aerobically aged for 30 days, there were no monocrotophos or metabolites in the leachate, thus indicating that the rapid degradation will limit the extent of leaching that is likely to occur under field conditions.

Volatility from Soil
It has been calculated in the literature that monocrotophos is not volatile from soil, based on Henry's law constant, modified for adsorption to soil.

6 SPRAY DRIFT

No spray drift studies were presented by the respondents.

6.1 Literature Reports

6.1.2 Off target Deposition of Pesticides from Aerial Applications

A recent paper on aerial spray drift examined the results of 36 applications under "standard conditions"—side by side applications—which allowed a statistical approach to the amount of spray drift that occurs (Bird, Esterly and Perry, 1996). The field was sprayed with four parallel swaths, 13.7 m apart using a fixed-wing aircraft, with unstable air and a wind speed from 2-20 kph. The droplet size used in this study was 238 µm vmd, which is substantially large than that recommend on some of the monocrotophos labels, 100-150 µm vmd and 90-120 µm vmd for LV and ULV applications respectively. Therefore, due to the limited number of swaths sprayed and the larger droplets used, this is likely to underestimate the spray drift from typical Australian applications.

The results are summarised in Table 12 and show that even under the best conditions, with the best application techniques, considerable spray drift occurs, ie 25% of applications resulted in spray drift of >0.22% of the application rate 300 metres downwind.

Also included in the paper by Bird et al. is a summary of 45 previous studies reported in the scientific literature, with results as average cumulative probability. Most of this previous literature work (60% of studies) reviewed was done when there were stable to very stable atmospheric conditions (inversion layers). This review showed that while the spray drift for the 50 percentile (mean) is only 0.22% of application rate at 305 metres from the spray area—similar to their own results in Table 12—the 95 percentile has 1% of the application rate as spray drift. The amount of spray drift is dependent on the atmospheric conditions and the data in Table 12 should be considered to be for "recommended conditions" only.

Distance down wind, metres	Cumulative percentage probability			
	25%	50%	75%	95%
91	0.9%	1.2%	1.8%	3.0%
152	0.33%	0.5%	0.6%	1.0%
305	0.1%	0.15%	0.22%	0.35%

Table 12. Aerial spray drift as percentage of application rate from 36 applications using standard conditions and VLV (28 L/ha) application.

6.1.3 Spray drift from Ground and Aerial Application.

A field test was conducted to determined the spray drift from both ground and aerial application in a citrus grove in Florida (Salyani and Cromwell, 1992).

Four different application methods were examined, fixed wing and rotary wing (helicopter) aircraft as well as high volume and low volume ground applications. There were 3 replicates per treatment, except for ground high volume where there were 2 replicates. A fluorescent tracer dye was sprayed to the last four rows of trees in the orchard closest to the downwind edge under normal commercial conditions. Mylar targets were used to measure both the fall out spray and an air sampler used to measure the airborne drift.

Applications were made with the air rated as stable for both aerial applications and neutral to unstable for the ground applications. Application rates were 125, 159, 5083 and 673 L/ha for fixed wing, rotary, high volume and low volume respectively. Table 13 presents the data for the replicates giving the highest fallout drift as a percentage of the application rate.

There is considerable variation between replicates, ie from fixed wing at 48.8 metres downwind fallout drift was 5.1, 30.7 and 88.0 $ng.cm^{-2}$ for the three replicates. The high variation would support the approach by Bird *et al* (see above) of using statistical methods to present the data.

The data on drift deposit and collected was fitted to a second degree polynomial equation with R^2 >0.88 for all applications. Using these equations for aerial and ground application, Table 14 was generated by Environment Australia based on the polynomial given by the authors. Due to the high variations between replicates for each treatment, the polynomial from the replicate giving the highest spray drift was used in generating Table 14.

Distance	Aerial Application		Ground application	
downwind, m	Fixed wing	Rotary wing	High volume	Low volume
15.2	8.41%	2.69%	1.91%	3.08%
24.4	3.59%	1.60%	0.92%	1.41%
48.8	0.88%	0.58%	0.28%	0.42%
97.6	0.18%	0.16%	0.071%	0.12%
195.1	0.031%	0.033%	0.016%	0.031%

Table 13. Raw data expressed as percentage of application rate for the replicates giving the highest fallout drift. Results as percentage of application rate

Distance	Aerial Application		Ground application	
downwind m	Fixed wing	Rotary wing	High volume	Low volume
25	3.449	1.552	0.893	1.352
50	0.839	0.562	0.267	0.402
75	0.337	0.272	0.123	0.193
100	0.17	0.153	0.069	0.113
125	0.098	0.095	0.043	0.074
150	0.061	0.063	0.029	0.052
200	0.029	0.032	0.015	0.03
300	0.009	0.011	0.006	0.013
400	0.004	0.005	0.003	0.007

Table 14. Spray drift as a percentage of application rate. Generated from polynomial equations derived by Salyani and Camwell (1992), based on the data in Table 13. The polynomial for the replicate giving the highest spray drift was used.

Comparing the aerial fixed wing results in Table 13 and those in Table 12, there is considerable difference, with Table 12 showing considerably higher drift. It should be noted that the droplet sizes were different, with the data in Table 12 from 238 µm vdm and Table 13 at 264 µm vdm and the applications volumes were different, 28 and 125 L/hafor Table 12 and 13 respectively. Also, the areas treated were an open field for Table 12 and a citrus orchard (trees 3.7-4.3 m high) in Table 13.

It should be noted that the fitted polynomial results in Table 14 show that at 200-400 metres, there is very little difference between the aerial applications and low volume ground applications, with the lowest drift due to the high volume ground spraying. This is some what unexpected but is possibly due to droplet sizes, with the fine droplets expected for the low volume application.

Summary results from the USA Spray Drift Task Force[1] indicate that the results in Table 14 are reasonable for citrus applications using high volume application techniques. The data from the SDTF also show that apple orchards have less spray drift than citrus, except when dormant. From the summaries of the SDTF data approximately 1% of the application rate spray drift deposits at 30 metres (100 ft) from a citrus (grapefruit) orchard.

Include in the summary data from the SDTF is include information for boom sprayers and for wind speed of 18 kph (11 mph), cone nozzles application, as used for insecticides, the spray drift is 0.5% of application rate at 30 metres.

6.2 Conclusion from Spray Drift Studies

Recent literature studies on aerial spray drift from a number of experiments showed that the 95th percentile gave spray drift results of 0.35% of the application rate at approximately 300 metres. Thus one in twenty aerial applications results in >0.35% of the application rate as spray drift at 300 metres from the edge of the field being sprayed. Under adverse conditions, ie inversion layers, the 95th percentile for spray drift increases to 1% of the application rate.

[1] The USA Spary Drift Task Force is a consortium of 38 agricultural chemical companies, established in responce to US EPA data requirements. The studies set up by the task force were conduct in concultation with university and reseach institutions scientists and the US EPA.

In another study in an orange grove four different application methods were compared, fixed wing and rotary wing (helicopter) aircraft as well as high volume and low volume ground applications. This data showed that fixed wing aircraft gave the highest spray drift close to the last sprayed trees, with the other three methods giving similar spray drift and at 200 metres the aerial (fixed and rotary wing) and ground based low volume were similar and the high volume gave the lowest spray drift.

7 FIELD STUDIES

7.1 Determination of Azodrin Insecticide Residues in Soil from Louisiana

Azodrin was applied to bare Gallion silt loam soil (soil characteristics not given) at 5.6 kg/ha, then the soil sampled on 0, 7 and 30 DAT (Matras, 1972). The soil cores were divided into 0-7.5, 7.5-15, 15-30 and 30-60 cm increments, then extracted and analysed by GC.

There was 1.2 mm of rain on day 7 and 83 mm on day 30.

Monocrotophos was detected in the 0-7.5 cm samples, 3.45 and 0.30 ppm on days 0 and 7 respectively, with all other samples <0.01 ppm. While the study does not meet current requirements and minimal information has been reported, there is a clear indication of rapid degradation.

7.2 The Loss of Surface Residues of Azodrin from Soil

Field trials were carried out in England (soil details see Table 15) and Trinidad (see Table 9) using sandy loam soils (Elgar, 1976). The application in England was during winter with soil temperatures 1-10 C, soil temperature in Trinidad was not given.

	pH	Organic carbon	Clay	Silt	Sand
England	7.3	1.6%	18%	5.8%	76%

Table 15. Characteristics of sandy loam soil from Trinidad.

Monocrotophos was applied at 1.0 kg/ha to the soil at both locations. Samples were taken to 15 cm deep, mixed and analysed by GC. Sampling occurred at 0 and 4 hours after treatment and at 1, 2, 5, 7, 9 and 14 DAT at the English site, and 0, 2, 4, 7, 14 and 57 DAT at the Trinidad site.

The results for England show that the concentration in the soil decreased rapidly, these being 1.0, 0.7, 0.47, 0.4, 0.1, 0.07, 0.02 and <0.01 mg/kg for sampling taken at 0 and 4 hours after treatment and at 1, 2, 5, 7, 9 and 14 DAT respectively. While a half life was not calculated, it is estimated at approximately 1 day. For Trinidad the results, 0.25, 0.02, 0.01 mg/kg for samples taken on days 0, 2 and 4, with all others <0.01 mg/kg , clearly show significantly more rapid degradation than for the English site.

No metabolites were reported.

While the study does not meet current requirements and minimal information has been reported, there is a clear indication of rapid degradation, with a half life in the UK during winter of approximately 1 day.

7.3 Soil Fauna Trials - Analysis of Soil

As part of a trial on the effects of monocrotophos on soil fauna, degradation of monocrotophos in field conditions was studied. Monocrotophos was applied at 0.5 and 1.5 kg/ha to a crop of sugar beet growing in a clay soil, characteristics of which were not given (Elgar, 1976 A). The soil was sampled at 0, 2, 4, 9, and 14 DAT to a depth of 15 cm. A second plot at the lower application rate was sampled as before, then a second application was made 14 days after the first and the soil sampled at 14 and 28 again days later before a third application was made and the soil sampled at 14 and 28 days. Results for these tests are given in Table 16.

	Days from application						
Dose, kg/ha	0	2	4	9	14	28 (0-15 cm)	28 (15-30 cm)
0.5	0.25	0.17	0.12	0.08	<0.01	NS	NS
1.5	0.76	0.68	0.36	0.19	<0.01	NS	NS
0.5 (1st appl.)	0.25	0.16	0.09	0.07	<0.01	NS	NS
0.5 (2nd appl.)	0.23	NS	NS	NS	0.08	<0.01	<0.01
0.5 (3 rd appl.)	0.22	NS	NS	NS	<0.01	<0.01	<0.01

Table 16. Concentration of monocrotophos in clay soil from applications to sugar beets. NS = no sample taken.

As can be seen from Table 16, 4 days after treatment there was >50% reduction in the concentration of monocrotophos. Again, the study does not meet current requirements and minimal information has been reported. However, there is clearly rapid degradation of monocrotophos in the soil, with a half life of <4 days.

7.4 Application of Azodrin on Corn - A Florida Study

Monocrotophos was applied six times to mature corn at 1.12 kg ai/ha per application using a ground sprayer (Hi-boy) (Potter, 1978). There were two days between each application. The soil, a loamy sand (sand 82%, silt 11%, clay 7%, om 1.1%), was sampled 0.5 hours, 10, 20, 30 and 40 days after the last application.

The soil samples were extracted, the extract cleaned up by Florisil column before analysis by GC. The recovery for the method was low, 73 and 67% for fortification at 0.1 and 0.2 ppm. Also, there was a considerable delay between sampling the soil and analysis, the first sample was taken 20/5/1978 and analysed on 10/4/1980, nearly two years later. No storage stability data was presented.

The residues of monocrotophos found in the soil were 0.69, 0.23 and 0.05 ppm for samples taken 0.5 hours, 10 and 20 days after treatment. Samples taken 30 and 50 DAT had <0.03 ppm. This study does not meet current requirements and is not considered reliable. Never the less, it indicates rapid degradation despite the high application rate, almost 7 kg ai/ha in 12 days.

7.5 Residues in Soil from Six Aerial Application of Azodrin - A California Study

Monocrotophos was aerially applied six times to corn at 1.12 kg ai/ha every two to four days (Potter, 1978 A). The corn was growing in Hanford sandy loam (see Table 3 for details) and at the growth stage of corn was ‘in husks’ when the last application was made. Soil samples were taken 0.5 hours, 10, 20 and 48 days after the last application to a depth of 7.5 cm.

The soil samples were analysed using the same method as for the Florida study above. Recoveries were slightly better, 76% and 73% for fortification at 0.2 and 0.1 ppm respectively. Again there was considerable delay between sampling and analysis.

Residues of monocrotophos decreased rapidly, from 0.30 ppm at 0.5 hour to 0.04 ppm 10 DAT, with the other two samples being <0.02 ppm.

While study does not current requirements, it clearly again shows the rapid degradation of monocrotophos in soil.

7.6 Literature Reports

7.6.1 The fate of monocrotphos is a model rice fish farm

The fate of monocrotophos in a model rice-fish farm system has been studied (Tejada and Bajet, 1990).

A model system for rice-fish culture was established before being sprayed with monocrotophos at the recommended rate for rice in the Philippines (rates not given) either once or three times in the growing season, said to be typical usage in the Philippines. Samples of water and soil where taken at 0, 1, 3, 5, 10 and 15 days after treatment as well as rice and fish samples at harvest. After extraction and clean up, analysis was by GC. No recoveries were performed and the detection limit was not given in the report. Table 17 gives results.

Matrix and Application type	Days After Application						
	0	1	2	3	5	10	15
Water, single	0.50	0.1	0.02	0.01	NRD	NRD	NRD
Soil, single	0.011	NRD	NRD	NRD	NRD	NRD	NRD
Water, thrice	0.58	0.48	0.42	0.29	0.01	NRD	NRD
Soil, thrice	0.034	0.174	0.152	0.102	0.095	0.086	NRD

Table 17. Concentration of monocrotophos after either single or three applications in water and soil from rice paddy as mg/L. NRD = No Residues Detected

The half lives for water and soil samples were 0.9 and 9.7 days respectively for three applications and the half life in water for the single application was 0.5 days. But it should be noted that a visual examination of the data shows that for the first three days for the multiply application the degradation in water was slower than a half life of 0.9 days would indicate.

7.6.2 Dissipation of Monocrotophos in Chickpeas

The dissipation of monocrotophos on chickpeas has been studied (Singh and Gupta, 1981). Monocrotophos was applied to chickpeas in experiment field plots (Haryana, India) at several concentrations and the loss of active monitored over time. Analysis was by colorimetric method and bioassay. The half lives for the different applications ranged from 3.8 to 4.6 days. This study does not meet regulatory requirements and is not considered reliable.

7.7 Conclusion from Field Studies.

Six of the seven field studies presented were older than current standards and none of the studies meet the current requirements for details of reporting, methods used or analysis of application rates. However, all the older studies showed a consistent pattern, in that monocrotophos was degraded quickly, with half lives <7 days, and that there are no significant metabolites formed. In one study where soil was sampled at depth, no leaching was noted.

In a more recent literature study in rice paddies, the half lives were <1 and 9.7 days in water and soil respectively after 3 applications.

8 BIOACCUMULATION

The bioaccumulation of monocrotophos was studied according to US EPA proposed guidelines of 1978 (US EPA 1978) and ASTM proposed methods of 1979 (Boudreau, Forbis, Cranor and Franklin, 1981).

Sandy loam soil (sand 58%, silt 27% and clay 16%) was treated with radiolabelled monocrotophos at a nominal concentration of 5 mg/kg, then the soil aerobically aged for 14 days at approximately 11% soil moisture before being flooded with aerobic water for 3 days. To this soil water system was added fish (channel catfish, *Ictalurus punctatus*) then an accumulation phase which lasted for 28 days and followed by a depuration for 14 days in clean water.

Sampling of the soil occurred on days 0 and 14 of aging, days 1 and 3 of equilibration with water and days 1, 3, 7, 10, 14 and 22 of the accumulation phase. The water was sampled on days 1 and 3 of equilibration with water and days 1, 3, 7, 10, 14 and 22 of the accumulation phase. The fish were sampled at 1, 3, 7, 14, 21 and 30 days during the uptake phase and on days 1, 3, 7, 10 and 14 for the depuration phase. Whole fish, edible and non-edible tissues were analysed by radiometric analysis.

Radioanalysis of the soil on days 0 and 14 of aging showed that ^{14}C residues decreased from 3.8 to 1.5 mg/kg equivalents of monocrotophos. However, GC analysis showed 3.7 and <0.001 mg/kg of monocrotophos on day 0 and 14 respectively. The radioanalysis showed concentrations in water and fish showed a slow increase over the uptake phase, with maximums of 17 ug/L, 0.019 mg/kg 0.031 mg/kg, for water, fish fillet and viscera respectively as equivalents of monocrotophos.

As GC analysis failed to show that there was any monocrotophos present through the study in either the soil or water after the aging period, it is therefore concluded that this study is not an acceptable bioaccumulation study for monocrotophos.

8.1 Conclusion

The bioaccumulation study presented was found not to be suitable as a bioaccumulation study for monocrotophos due to the lack of any monocrotophos present after aging of the soil used. However, based on water solubility, low K_{oc} and ready soil degradation, significant bioaccumulation in the aquatic environment is not expected.

9 SUMMARY OF ENVIRONMENTAL FATE AND DEGRADATION

In Australia monocrotophos is used in cotton, beans (French), granny smith apples and some varieties of pears (some labels do not have any pome fruits), bananas, sunflowers, maize, millet, sorghum, soybeans sweet corn, wheat, triticale, panicum, potatoes, tobacco, tomatoes and for non-fruit bearing trees, with the major use in sorghum and sunflower crop for control of locusts. Application is normally by air for cotton, sorghum and sunflower. Ground based equipment is used for other crops.

All studies presented are old, pre 1980, and were not preformed to modern Guidelines or laboratory standards. Several are from the scientific literature and again have not been preformed according to current Guidelines. Despite this, the results are relatively consistent and gives a reasonable profile of the environmental fate of monocrotophos.

9.1 Hydrolysis

From three experiments it is concluded that in acidic conditions, pH between 3 and 8, hydrolysis is slow, 66-150 days and is classified as slightly hydrolysing (Netherlands classification). At higher pHs hydrolysis is quicker, the half life was 17 and 26 days at pH 9.0 in two studies, and is classified as moderately hydrolysing. Hydrolysis is unlikely to be a significant contributor to the overall degradation of monocrotophos at the normal environmental pH range (5-9).

9.2 Photolysis

Aquatic
Based on the single study presented there is no evidence that monocrotophos photolyses in water.

Soil
In the study presented, there was evidence that sensitised photolysis had occurred, with a significant increase in the rate of degradation between the sample exposed to sunlight and the dark control, with a half life of 3 days compared to 30 days.

It is concluded that there is no evidence in the studies presented by the registrants that direct photolysis will be a degradation pathway in the environment but indirect photolysis could increase the degradation rate in the environment.

9.3 Metabolism

Aerobic Soil Metabolism
The degradation of monocrotophos under aerobic conditions in soil is fast, with a half life of between <1 and 7 days, based on 5 different soils. The major product is carbon dioxide and non-extractable residues. Some minor metabolites were identified in some soils, with the N-hydroxymethyl derivative being the highest at 3.5% of the applied dose. The major degradation pathway appears to be direct metabolism to carbon dioxide or incorporation into the organic fraction of the soil followed by mineralisation.

No studies were presented that determined a half life. However, monocrotophos was shown to degrade rapidly under aquatic aerobic conditions but by contrast there was no degradation in natural river water at room temperature, consistent with the hydrolysis experiments. It is concluded that the limited studies show that in aquatic systems with high microbial activity, ie with soil/sediment, degradation could be rapid.

Anaerobic Aquatic Metabolism
No studies were presented that determined a half life or examined whether monocrotophos degrades under anaerobic conditions.

9.4 Mobility

Soil adsorption/desorption
The soil adsorption/desorption of monocrotophos was determined in four soils by the standard batch flask method. It was concluded that monocrotophos is only weakly adsorbed to most soils and is rated as being mobile in soils. There was significant desorption which confirms that binding is weak.

Leaching
In a column leaching study on the same four soils used in the adsorption/desorption study, most of the applied monocrotophos was found in the leachate and it was concluded that monocrotophos is mobile. However, using treated soil that was aerobically aged for 30 days, there were no monocrotophos or metabolites in the leachate, thus indicating that the rapid degradation will limit the extent of leaching that is likely to occur under field conditions.

Volatility from Soil
It has been calculated in the literature that monocrotophos is not volatile from soil, based on Henry’s law constant, modified for adsorption to soil.

Conclusion
It is concluded that monocrotophos is mobile in soil and that leaching is possible. However, the rapid degradation will limit the extent of leaching that is likely to occur under field conditions. Volatilisation from soil is not expected to be a significant route for the dissipation but volatilisation from other non-adsorbing surfaces cannot be ruled out.

9.5 Spray Drift

Recent literature studies on aerial spray drift from a number of experiments showed that the 95th percentile gave spray drift results of 0.35% of the application rate at approximately 300 metres. Thus one in twenty aerial applications results in >0.35% of the application rate as spray drift at 300 metres from the edge of the field being sprayed. Under adverse conditions, ie inversion layers, the 95th percentile for spray drift increases to 1% of the application rate.

In another study in an orange grove four different application methods were compared, fixed wing and rotary wing (helicopter) aircraft as well as high volume and low volume ground applications. This data showed that fixed wing aircraft gave the highest spray drift close to the last sprayed trees, with the other three methods giving similar spray drift and at 200 metres the aerial (fixed and rotary wing) and ground based low volume were similar and the high volume gave the lowest spray drift.

9.6 Field Dissipation Studies

Six of the seven field studies presented were older than the current standards and none of the studies meet the current requirements for details of reporting, methods used or analysis of application rates. However, all the older studies showed a consistent pattern, in that monocrotophos was degraded quickly, with half lives <7 days, and that there are no significant metabolites formed. In one study where soil was sampled at depth, no leaching was noted.

In a more recent literature study in rice paddies, the half lives were <1 and 9.7 days in water and soil respectively after 3 applications.

9.7 Bioaccumulation

The bioaccumulation study presented was found not to be suitable as a bioaccumulation study for monocrotophos due to the lack of any monocrotophos present after aging of the soil used. However, based on water solubility, low K_{oc} and ready soil degradation, significant bioaccumulation in the aquatic environment is not expected.

9.8 Conclusion

Monocrotophos is readily degradable in soil and could degraded in aquatic environments but this appears to be dependent on the level of biological activity. It is unlikely to persist beyond 1 week following application in soil. Bioaccumulation is not expected. Due to the very rapid degradation in soil, leaching is not expected despite laboratory studies suggesting high mobility.

While monocrotophos is not volatile from soil, it could be slightly volatile from other surfaces.

10 ENVIRONMENTAL EFFECTS

Most of the following reports were previously submitted in the TGAC submissions, are from the ECRP data call-in or from the open literature. The US EPA's databases have been used as indicated.

10.1 Avian Toxicity

There were no studies presented that meet current international regulatory requirements.

10.1.2 OPP Database

A database from the Ecological Fate and Effects Division of the Office of Pesticide Programs, US EPA, to which Environment Australia has access, contains the presently known ecotoxicity endpoints for registered pesticides used in the US (referred to as OPP database). The database is compiled from studies reviewed by EPA in conjunction with pesticide registration or reregistration and studies performed by US EPA, USDA and USFWS laboratories which have been reviewed by Ecological Effects Branch biologists and judged to meet US EPA Guidelines and therefore acceptable for use in the ecological risk assessment process. The results for avian species from this database are given in Table 18 and are for studies that meet relevant US EPA Guidelines.

Species	% active	Age	LD50, mg ai/kg bw	Category	Guideline
Mallard	80	4 months	4.76	C	71-1
Canada goose	75	—	1.58	C	71-1
Golden Eagle	75	1 month	0.188	C	71-1
Californian quail	75	12 months	0.763	C	71-1
Japanese quail	75	2-3 months	3.71	C	71-1
Bobwhite quail	75	12-24 months	0.944	C	71-1
Chukar	80	4 months	6.49	C	71-1
Gray partridge	75	Adult	6.4	C	71-1
Turkey	75	6-18 months	2.00	S	71-1
Rock dove	75	Adult	2.83	C	71-1
House sparrow	75	Adult	1.48	C	71-1
House finch	80	Adult	8.1	S	71-1
Pheasant	80	7-8 months	2.83	C	71-1
Mallard	8.2	10 days	32 ppm	C	71-2b
Mallard	8.2 (?)	5 days	9.6 ppm	C	71-2b
Pheasant	8.2	10 days	3.1 ppm	C	71-2
Japanese quail	8.2	10 days	2.4 ppm	C	71-2a
Mallard (1981)	84.4	5 months	LOEC 3.0 1 generation	S	71-4b
Bobwhite Quail (1981)	84.4	5 month	LOEC 0.1 1 generation	S	71-4a

Table 18. Toxicity of monocrotophos to a range of birds. All studies have been reviewed by the US EPA and found to meet their Guidelines. All studies performed in 1984, except those indicated otherwise. C = core study, S = supplementary

It should be noted that the results in Table 18 appear to have been have been published in "Handbook of Toxicity of Pesticides to Wildlife" (Hudson, Tucker and Haegele, 1984), in which additional details were given. The acute LD50s were performed using measured doses in gelatine capsules, with two to seven animals at each of several (usually 4) doses. The LD50s are stated to be calculated by the method of Thompson. All studies where performed at a single laboratory (Denver Wildlife Research Centre).

The most sensitive species in Table 18 is the Golden eagle with LD50 = 0.188 mg/kg (CI 0.094-0.376), the only raptor in Table 18, which could indicate that raptors in general are more sensitive to monocrotophos than other birds. However, due to difficulties obtaining numbers of birds, only 6 birds were used in the calculations and the result may not reliable, even though the US EPA has reviewed the study and consider it meets the requirements of Guideline 71-1. Given the high degree of cumulative toxicity noted for mallards, there is additional concern for raptors. Additional data would be required to refine the hazard for raptors.

The acute dietary results in Table 18 (Guideline 71-2) are from the US Department of the Interior testing program and the results have been published (Hill, Health, Spann and Williams, 1975). These studies were performed in 1975 and reviewed by the US EPA in the same year as meeting requirements for Guidelines 71-2, 71-2a and 71-2b. As the methodology used does not significantly differ from current procedures and has been reviewed by a reputable agency, the results are considered acceptable. Note that the dietary acute results for ring-necked pheasant and Japanese quail in ppm is numerically similar to the oral acute results in mg/kg. This has significant implications for the dietary toxicity of monocrotophos to raptors, given that only the acute oral results for one species is available.

The chronic studies in Table 18 show a significant chronic effect at levels significantly below the acute figures for the tested species and highlight a major concern. These results indicate a high level of accumulative poisoning, especially for an OP, but as the results were only rated as being supplemental some care is required in using them. In addition, Environment Australia does not have access to the full reports and it is unclear as to what endpoint was used in the LOEC calculations. It is not possible to draw conclusions as to possible long term effects on bird populations from low level exposures, based on this data alone, but we have no other information.

10.1.2 Standard Literature Studies

There are several open literature reports are available and the ‘standard toxicity studies’ have been summarised in Table 19. Note that these results are all based on nominal concentrations.

Study Type	Species	Sex	Age	Results, mg/kg	Reference
Acute, single dose	Japanese quail	M, F	Adult	2.68	Lee and Weir, 1967
	Coturnix quail	F	—	4.21	Schafer and Brunton, 1979
	House sparrow	M, F	—	1.33	Schafer and Brunton, 1979
	Domestic fowl	M, F	3 months	6.7	Brown, 1970
	Starling	—	—	3.3	Schafer, 1972
	Starling	M, F	—	5.62	Schafer and Brunton, 1979
	Red-winged Blackbird	M	—	1.0	Schafer and Brunton, 1979
	Quelea	—	—	1.3	Schafer, Brunton, Lockyer and Grazio, 1973
Chronic, 30 days oral	Mallard	M, F	—	0.25 ppm EMLD	Hudson, Tucker and Haegele, 1984
Chronic, 21 days	Japanese quail			NOEC 0.5 LOEC 5.0 ppm	Shellenberger, Newell, Adams and Barbaccia, 1966

Table 19. Toxicity of monocrotophos to avian species. All result are nominal. ELDM = empirical minimum lethal dose

Comments on Table 19
-*Acute Results.*
The results for Schafer and Brunton used the Recommended Practice for Determining Acute Oral LD50 for Testing Vertebrate Control Agents (E555-75) of the American Society of Testing and Material. This is the basis of the current US EPA methods and as such is considered acceptable within the constraint that the method is older and results are nominal.

-*Chronic*
The chronic 30 day test in Table 19 is a subchronic test in which 6 birds were dosed (3M, 3F) by oral administration using geometrically spaced doses until levels were found that produced no death, 1-2

deaths and 3-6 deaths. The lowest oral dose that produced 1-2 deaths was called the empirical minimum lethal dose, EMLD. It was noted by the authors that this gives a high cumulative toxicity index (ratio of acute LD50 to EMLD) for an OP of 19 and indicates a high degree of cumulative action. This is not a standard test and there is no equivalent test in current international testing Guidelines. Nevertheless it does indicate that chronic exposure could result in a number of avian mortalities.

The 21 day chronic study in Table 19 used only 3 concentrations of monocrotophos in the feed. Effects on reproduction were determined, ie egg hatchability and fertility. The NOEC level was 0.5 ppm in feed, with the next concentration tested giving the LOEC of 5.0 ppm in the feed—greater than the LC50 in Table 19. The effect was relatively minor, reduced body weight in the first week of the test, which was partially regained during the following weeks. At 50 ppm no birds survived the test. It should be noted that this is a very old test and its reliability is questionable.

10.1.3 Other Literature Studies

The sensitivity of mallard ducks of various ages to monocrotophos has been studied as part of a study into the oral acute toxicity of 14 pesticides (Hudson, Tucker and Haegele, 1972). The birds used were aged 36 hours, 7 days, 30 days and 6 months and the results for monocrotophos were 5.86, 7.21, 5.10 and 3.36 mg/kg for each age group respectively. The methodology used would not meet current guidelines and the results are nominal. The pattern noted for monocrotophos, that of increasing LD50s to 30 days old then decreasing LD50s for older birds (convex pattern when graphed), was the same as for 7 other organophosphate insecticides tested, with 2 OPs showing a different pattern. The study does show that monocrotophos is highly toxic to birds of all ages and suggests old birds may be more sensitive than younger birds.

The repellency and hazard potential (Repellency/LD50) of monocrotophos was determined (Schafer, Bowles and Hurlburt, 1983). There is limited information presented on the methodology for determining repellency, which was based on older literature methods. The hazard factor calculated in this study indicates that the repellency of monocrotophos is not high enough to prevent poisoning occurring.

The percutaneous 24 hour LD50 for male mallards (54 weeks of age) was determined to be 30 mg/kg (CI 13.5-66.8) (Hudson, Haegele and Tucker, 1979). The methodology used was to apply to the feet of the birds (checked to ensure no cuts, cracks etc) a solution of monocrotophos in propylene glycol, then bagging the feet for 24 hours. After this the birds feet were washed with soapy water and the birds observed for signs of toxicity over the next 14 days.

The delayed neurotoxicity of monocrotophos in chickens has been studied (Jenkins, 1981). Chickens were orally dosed with monocrotophos, using capsules half filled with feed, at 0.03, 0.1, 0.3 and 1.0 mg/kg for 14 days. Hens in the high dose group showed marked signs of toxicity and were sacrificed after 3 days. While there were no mortalities in the lower dosed groups, there was a dose related inhibition of brain cholinesterase but neurotoxic esterase was unaffected. It was concluded that as neurotoxic esterase was unaffected, there was unlikely to be any delayed neurotoxicity from monocrotophos.

Following on from the above study, hens were orally dosed for 96 days at 0.03, 0.1 and 0.3 mg/kg (Jenkins, 1981 A). As there were no clinical signs of neurotoxicity after 78 days, the highest dose was increased to 0.5 mg/kg. For the highest dose group (0.3 mg/kg), egg production was lower than the control group but only significantly lower (p 0.05) for days 14-20. Definite effects of monocrotophos on egg production could not be determined from this study. There were no signs of delayed neurotoxicity.

Conclusion
Results in the literature for toxicity to birds indicate that monocrotophos can be rated (according to US EPA) as very highly toxic to birds by both the acute oral, based on reports for 18 species (LD50 of 0.2 to 6.49 mg/kg), and dietary routes of exposure, 3 species (LC50 range 2.4-9.6 ppm). For mallards in chronic (30 days) exposure, the "empirical minimum lethal dose", ie when first mortalities were noted in chronic 30 exposure, was very low, 0.25 ppm in the feed but for quail a 21 day dietary test showed that the LOEC was 5 ppm in the feed. The quail study is the oldest and the result is not considered reliable.

The repellency of monocrotophos was determined and the hazard factor (repellency/LD50) indicates that the repellency of monocrotophos is not high enough to prevent poisoning occurring. There was no sign of delayed neurotoxicity in a low dose feed study in chickens after 78 days.

10.1.4 Field Reports

Azodrin Quail Toxicity Study (semi-field study)
A simulated field study using California Valley Quail was performed in which the quail were caged in a cotton field and Azodrin (40% monocrotophos) was applied aerially at 1.12 kg/ha (450 g ai/ha) (Anonymous, 1968). This study was performed using a protocol suggested by the USDA. There were 2 male and female pairs per cage and two cages per treatment.

The different treatments consisted of contaminated feed and water (a small amount of feed, spread over the bottom of the cage, and the water were exposed to the spray), clean feed and water (water covered and then uncovered immediately after application) and controls. All feed hoppers were covered during spraying and then uncovered in the evening of the day of aerial application. Four days later the pens were moved to new ground and the procedures repeated for the next three applications. The application dates were 5 August, 9 August, 4 September and 9 September. Following treatment, the birds were observed twice daily for 5 days and then daily for the second application. All birds were classed as normal, sick (any abnormal movement) or dead. It should be noted there was no indication of the severity of abnormal behaviour in the sick birds. Any bird that died was replaced with a fresh bird.

All birds were oversprayed at 450 g ai/ha, 4 swaths at 35 feet intervals upwind to the caged birds with the last application directly overhead, then an extra swath was applied directly above a set of treatment cages, designated as 2X. This application pattern was repeated for each application and was designed to replicate head-land spraying. There was no vegetation within the cages but a wooden shelter (box) was provided. The results are summarised in Table 20 and gives the maximum number of sick birds in any observation, and the total number of dead birds during the observation period.

Spray No.	Date	Duration of observations	1X, 450 g ai/ha		2X, 450 g ai/ha	
			Cont. feed and water	Clean feed and water	Cont. feed and water	Clean feed and water
1	5 Aug	5 days	2 S, 2 D	1S	2 S	all normal
2	10 Aug	13 days	5 S, 1 D	4 S, 4D	2 S, 3 D	1S
3	4 Sept	5 days	3 S	5 S	7 S, 4 D	8 S, 2 D
4	9 Sept	5 days	5S	7 S, 3 D	7 S, 5 D	6 S, 5 D

Table 20. Observations of caged quail exposed to aerial application of monocrotophos at 450 g ai/ha. 8 birds per treatment. S = maximum no. of sick birds any observation, D = total dead birds over the entire observation period. 2X indicates that these cages received one additional application.

A few autopsies were performed on birds which had died and in most cases the intestinal tracts were empty. There was no analyses of cholinesterase from any of the birds.

There was considerable variation between the various treatments and no consistent pattern is apparent. Note that for all cages, including those with supposed clean feed, it was noted by the authors that the birds spilt seeds and ate these from contaminated ground. This could explain some of the variability seen in these tests.

In conjunction with the above study, additional tests were conducted to determine what routes of exposure were the most hazardous. In these tests the cages were positioned to include cotton plants, sufficient to give 50-60% coverage of the soil surface and no shelters (wooden boxes) were provided. During spraying the birds were confined to the end of the cage without plants, thus all birds received a topical application. The feed and water regimes were identical to that above. All of these results are given in Table 21.

		Duration of	1X, 450 g ai/ha		2X, 450 g ai/ha	
Spray No.	Date	observations	Cont. feed and water	Clean feed and water	Cont. feed and water	Clean feed and water
1	5 Aug	5 days	4 S, 4 D*	1S, 1D	3 S, 2 D	2 S, 3 D*

Table 21. Observations of caged quail in the second set of experiments, first spray, exposed to application of monocrotophos. 8 birds per treatment. S = sick birds, D = Dead birds. 2X indicates that

these cages received one additional application. Cages contained 50-60% cotton coverage. * One bird died at the end of the observation period from unknown causes.

The second application involved additional conditions, in that either the ground was covered (clean) or the feed was covered in order to determine whether the contaminated feed or ground was the most significant source of the toxicant. Birds lost at the end of the first spraying were not replaced. All birds received the same dose of 2X. Results are in Table 22.

First treatment	Second Treatment at 2X, 450 g ai/ha			
Cond. of water & feed and dosage	Cond. of ground	Cond. of feed	No. of birds	Observations
Contaminated; 1X	Clean	Clean	3	1 D
Contaminated; 1X	Contaminated	Clean	2	2 D
Clean; 1X	Clean	Contaminated	3	3 D
Clean 1X	Clean	Clean	4	1 S
Contaminated; 2X	Clean	Clean	3	N
Contaminated; 2X	Contaminated	Clean	4	1 D
Clear; 2X	Clean	Contaminated	4	4 D
Clear; 2X	Clean	Clean	3	N

Table 22. Observations of caged quail in the second set of experiments, second spray, exposed to application of monocrotophos. N = all birds normal, S = sick birds, D = Dead birds. Cages contained 50-60% cotton coverage.

The results of the second spray in Table 20, clearly implicated feed as a major source of toxicant, with all birds on contaminated feed dying by the fifth day but there was some what equivocal evidence about the effect of contaminated soil. The two birds that were on contaminated feed and water from 1st spray, then on contaminated ground but clean feed and water for 2nd spray, died at 1X rate in 2nd spray (100% mortality) but only 1 bird out of 4 birds died that received 2X dose in first spray and then under a similar situation for the second spray.

In the third and fourth sprayings (4 and 9 September) additional conditions were tested, 1) the soil was either covered or exposed (60% coverage with cotton plants in cages) and 2) additional cages were set up with 100% canopy coverage from cotton plants, all soil sprayed. There was 12 and 8 birds per treatment in groups 1 and 2 respectively. All feed and water was uncontaminated for both groups. Results in Table 23.

No. of birds	Spray date	% canopy cover	1X, 450 g ai/ha		2X, 450 g ai/ha	
			Clean Soil	Sprayed Soil	Clean Soil	Sprayed Soil
12	4 Sept	60%	1 S *	1S	all normal	4 s, 1 D
12	9 Sept	60%	2 S,	2 S,	2 S	2 S, 1 D
8	4 Sept	100%	—	5 S	—	7 S
8	9 sept	100%	—	7 S, 3 D	—	8 S, 3 D

Table 23. Observations of caged quail in the third and fourth sprayings in the second set of experiments exposed to application of monocrotophos at 450 g ai/ha. S = sick birds, D = Dead birds. 2X indicates that these cages received one additional application. * One bird sick 5 days after spraying, may not be treatment related.

Table 23 shows that soil could be a factor in the toxicity. It also indicates that the additional cotton canopy did not improve the survival of the birds, in fact it would appear that there was higher mortality in the 100% canopy cages.

An additional study was performed using pheasants (5 per treatment), which was set up in a similar manner to those for Table 23 with 60% cotton coverage of soil for the third and fourth spray, with birds either on contaminated or clean soil. These cages were sprayed using the 2X pattern. All feed and water was uncontaminated for both groups. There were no mortalities in any of the pheasants though one or two birds per cage were considered sick, especially in the sprayed soil cages. It is somewhat surprising that there was no mortalities for pheasants at 2X given the acute toxicity result in Tables 18 and 19 for pheasants compared to quail.

To draw an overall conclusion from these series of tests is somewhat difficult, due to the number of variables and the variability in the results but it is very clear that contamination of water and feed is the major route of intoxication in the birds.

Field trials with Azodrin and Nuvacron

The toxicity of monocrotophos to birds under field conditions was determined at two different sites in Germany (Ali-Dervish, 1970). At each site two formulations of monocrotophos, one Azodrin (40% ai) and the other Nuvacron (20% ai) were applied at 1000 g ai/ha to separated plots of maize together with control plots. Each plot was 1 hectare in size. The sites differed in that at site A there were a number of weeds seeding in the plots used (50% and 80% weed cover for Azodrin and Nuvacron respectively), while at site B there were less weeds (<10% at both plots) which were in flower. The number of dead and paralysed (unable to fly) birds were determined 1, 2 and 3 days after application of monocrotophos in each plot and in nearby hedges.

At site A, a total of 42 birds were either dead or paralysed in the Azodrin plot and 43 in the Nuvacron plot after 3 days, most of which were seed eaters (*Passer spp*.). At site B there was a total 9 dead or paralysed in the Azodrin plots and 4 in the Nuvacron plot after 3 days. It was concluded that monocrotophos can cause serious bird kills when birds feed on treated foodstuffs in the fields.

Field Investigation of Aerial Application of Azodrin on Cotton Fields

Six pheasants (3 adults, 3 chicks six weeks old) where placed into a cage in a cotton field prior to being aerially sprayed with Azodrin (monocrotophos) at 1 kg/ha (400 g ai/ha) (Bischoff, 1966). Two hours after application an additional cage containing 6 pheasants (3 adults, 3 six weeks old) was placed into the field. Insects killed were collected and force fed to an adult pheasant.

Four hours after application, 3 pheasants that received a topical dose appeared to be in distress (1 adult, 2 chicks) but recovered 24 hours later. No other pheasants showed observable symptoms. It was concluded that there was no indication that a hazard to birds existed but from these results a definite lack of hazard was not established. There were insufficient number of contaminated insects collected for the test due to the cotton crop having been sprayed five days previously.

Field Investigation in Arizona and California

Following a number of reports that Azodrin (monocrotophos) had caused a number of bird deaths, a study under practical field conditions was undertaken (Dorn, 1968). Fields in Arizona were checked for birds the day prior to application of Azodrin at 140-180 g ai/ha (applications were made at night) and then fields and surrounds surveyed for affected or dead birds. The bird population was mainly quail and doves. The number of affected birds is stated to have been minimal but the number affected was not given.

Similar field surveys were made in California and 25 blackbirds were killed in one cotton field containing standing water and cat tails (a weed) treated at between 1 and 1.4 kg ai/ha. In another cotton field 120 horned larks were found dead 5 days after Azodrin was applied at 1.5 pt of Azodrin (assuming this is 1.5 pints/acre of Azodrin, it equals 690 g ai/ha) based on statement of the aerial applicator (there was some confusion over whether there was any applications were made, the farmer claims none were made). Again there was standing water and numerous weeds in the cotton field.

At another site, Azodrin was applied to cotton fields at 1 lb/acre (450 g ai/ha) by ground rig. There were 160 pheasants observed sheltering in the fields (this was the only cover in area, other crops having been harvested), of which only one was noted as being sick.

Organophosphate Pesticide Wildlife Trials in Victoria Australia

Following reports of bird kills, magpies (trapped) and zebra finches (commercial) were used in trials to determine the toxicities of parathion, monocrotophos and gusathion (azinphos methyl) (Hanson, 1974). Only the results for monocrotophos will be considered here.

Caged finches, 2 per cage were placed in trees and then trees sprayed with Azodrin at 1.26 kg ai/ha (15 fl. oz of Azodrin per 100 gallons @ 300 gallon per acre). The finch cages were free of feed and water during spraying and clean feed and water added after spraying. Magpies were placed into their cages after spraying and fed contaminated grain by leaving it out in tray on the ground during spraying. There were no figures given for the residues on the grain.

After 3 days, 7 out of 24 magpies died and 6 out of 36 finches died. It should be noted that while magpies are omnivorous, their preferred diet is insects. The magpies were observed to be foraging for food in the grass and other vegetation within their cages and thus they may have avoided feeding on the grain in preference for foraged insects. As the birds were observed for only 3 days and other studies have shown that the dosed birds died up to 5 days after application, additional deaths may have occurred after the observation period.

Summaries of interviews with orchardists are also presented. These summaries tend to show that there are few birds in the orchards and few deaths in the orchards from use of OPs, including monocrotophos. However, one orchardist deliberately sprayed grapes with Azodrin on which birds were feeding, this lead to significant birds mortalities. Those birds that are there are occasional visitors and do not feed in the orchards. Another orchardist claimed that when he first used Azodrin he noted a number of song birds died in nearby shade trees.

Azodrin Wildlife Studies
This study examined the use of Azodrin (monocrotophos) in several orchards, 2 bearing citrus groves, seven non-bearing citrus groves and 2 non-bearing vineyards (Hughes, Baren, Feichtmeir and Hobson, 1971).

In the first bearing trial there were 84 nests in the orchard and on the day of spraying about 75% of the hatch was complete. This orchard was sprayed with 1.07 kg ai/ha of monocrotophos on 11 May. This sprayed block was compared to a ‘standard treatment block’, also having nesting birds present, which received phosphamidon (1.7 kg ai/ha) and Kelthane (dicofol, 6.7 kg ai/ha). Immediately after application of Azodrin there was one bird found sick with intoxication symptoms. There was no significant difference in the number of hatchlings that fledged between the treatment and standard orchards, with 21 and 23 dead birds in each orchard respectively. There was no non-treated control.

A second application of monocrotophos (3.4 kg ai/ha) to the same orchard occurred on 7 July. Subsequent checking of the orchard on 13, 16 and 24 July found a total of 11 feather piles, together with one paralysed and one dead rabbit and a dead ground squirrel. Also noted were several leaking irrigation pipes in the treated orchard. It was suggested that the dead birds had ingested monocrotophos via water in orchard, which could have been contaminated, and the carcases/intoxicated birds were subsequently predated. The rabbits and the squirrel could have ingested monocrotophos from sprayed shoots or ripe fruit on the trees but the carcases were not analysed for monocrotophos.

The second bearing trial there were no nesting birds present but there were a number of doves and quails noted that used the orchards for feeding and roosting. The orchards were sprayed with monocrotophos at 1.7 kg ai/ha in the morning and then the orchards were irrigated with sprinklers 6 hours later. The temperature reached 44 C on the day of spraying.

The sprayed orchard was searched twice on the days after treatment and 8 days later. A total of 25 dead birds were found together with 8 intoxicated birds, all but 4 were quail. Two of the intoxicated birds were found dead in the last search. There were no sick or dead birds outside the treated area, which was not sprayed with any insecticide. Analysis of the birds carcases showed that the seeds in the crops were from weeds and wild plants growing in nearby wasteland which was not sprayed. Residues in the bird crops were between 7.5-18 ppm Azodrin (3-7.2 ppm monocrotophos) in quail and for one dove analysed 43 ppm Azodrin (17 ppm monocrotophos). Water samples from the orchard after irrigation had 365 and 3 ppm of Azodrin (146 and 1.2 ppm monocrotophos) for the droplets on the leaf tips and from shallow puddles respectively.

It was considered that the birds died when they drunk water contaminated from the foliage. The hot weather, sprinkler irrigation and foliage close to the ground combined to create a situation conducive to the birds drinking water running off from the leaves that contained high concentrations of Azodrin.

Seven non-bearing citrus sites (immature trees?) were sprayed with monocrotophos at 0.22 or 0.28 kg ai/ha using straddle booms with one site being treated using handbooms. All of these sites are likely to be small trees. Many birds were observed both before and after application in these sites. No dead or intoxicated wildlife was observed in these groves.

The two non-bearing grape trials used young vines (1st or 2nd leaf stage) which were sprayed with Azodrin using straddle booms at 1.1 or 0.6 kg of Azodrin per hectare (0.5 and 225 kg ai/ha). Again there were no dead or intoxicated birds found.

Environment Australia has constructed Table 24 as a summary of these results.

Trial	rate used, kg ai/ha	Effects	Observations
Bearing No. 1, first treatment	1.07	21 Hatchlings dead	There was no difference between treatment with Azodrin and 'standard treatment'. No non-treated controls used.
Second treatment	3.4	11 feather piles, 3 mammals dead	Leaking pipes noted in orchard. Possibility that birds drunk contaminated water from puddles near the leaking pipes.
Bearing Trial No. 2	1.7	25 birds dead, 8 sick	Trees irrigated with sprinklers 6 hours after application. Dead and dying birds had monocrotophos in their crops. Authors considered that birds had drunk water from leaves or shallow ponds which were contaminated by runoff.
7 non-bearing citrus groves	0.22-0.28	No dead birds	Immature trees
2 non-bearing	0.225 and 0.5	No dead or intoxicated birds	Young vines

Table 24. Summary of results for Azodrin trials in orchards.

It is clear from Table 24 that the one factor that is associated with birds deaths is the presence of water in the treated orchards, either during or closely after spraying.

10.1.5 Literature Reports

Mass Mortality of Birds of Prey by Azodrin
During a plague of voles in Israel, farmers used Azodrin which lead to a mass mortality of raptors and owls (Mendelssohn and Paz, 1977).

During the winter of 1975, a plague of voles attracted large numbers of raptors and owls, mainly those wintering in Israel and on migration, to alfalfa fields in an 8 km^2 area. Because the voles reached densities of 2400 per hectare or more, which caused considerable damage to the alfalfa crops in the area, farmers sprayed the crop with Azodrin from the air at 4 L to 7 L per hectare (1.6 to 2.8 kg ai/ha) to control the voles. After this spraying, large numbers of dead and paralysed birds were found in fields and under roosts. The aerial application directly killed large flocks of birds feeding in the fields, mostly pipits and wagtails, larks, thrushes etc causing mass mortalities. In addition voles and birds were poisoned by eating contaminated food. Mammals were also affected, for example wild pigs and native cats, which were found dead in the sprayed fields. Birds of prey that fed on the carcases were also killed. The major number of deaths occurred after 4 km^2 were sprayed with Azodrin at these high rates.

Searches for dead and affected birds showed that 150 birds of prey died and 69 were paralysed but recovered and were released after treatment. Most of the birds affected were black kites, 75 dead but also a significant number of eagles, owls, buzzards, harriers and kestrels were affected. Based on the number of black kites observed at one roost before and after the spraying, it was estimated that approximately 300-400 birds of prey died due to this one application of monocrotophos.

Following this event, aerial application of Azodrin was banned but ground applications were not safer as freshly poisoned birds of prey were found after the ban on aerial applications.

Azodrin Poisoning of Waterfowl in Rice Fields in Louisiana
About 100 birds, mostly ducks and geese, were found dead or dying in a rice field in Louisiana (White, Mitchell, Kolbe and Ferguson, 1983). Analysis of the birds showed that all the dead birds had severely inhibited acetylcholinesterase (82-89% of normal) and their crops contained rice seeds with residues of monocrotophos of 0.65 to 110 ppm. Rice seeds sampled at the site of the die-off had residues of monocrotophos of 160-720 ppm. Monocrotophos is not registered for use in rice crops and further

investigations showed that rice seed was soaked in Azodrin and broadcast onto a field that had rice seedlings already growing (5-10 cm high). It was concluded that this may have been done with the sole intent of poisoning waterfowl feeding on the rice seedlings, which is a known illegal practice in the area.

Other literature
There are a number of other reports of monocrotophos being misused as an avicide, similar to that above (Flickinger, White, Mitchell and Lamont, 1984 and references there in).

Most recently a large number of Swainson's hawks, estimated to be in the tens of thousands, have been killed in Argentina after use of monocrotophos for control of grasshoppers in alfalfa crops (Anonymous, 1997). US investigators noted that there was a decrease in the numbers of hawks returning each year and in studying the migratory pattern with miniature satellite transmitters, they discovered the death of 4000 hawks in Argentina. The hawks were thought to be poisoned by direct exposure or by secondary poisoning when the birds ate contaminated grasshoppers. It was estimated that up to 20,000 hawks died, with the investigators finding 700 died at one roost alone. Monocrotophos was not registered for use in grasshopper control in Argentina and resulted in the withdrawal of monocrotophos in the affected region of Argentina.

These reports of wide spread avian impacts tallies with Environment Australia's experience which over the years has received a number of anecdotal reports of large avian mortalities when monocrotophos is used to control locusts or rats and mice in Australia. Also cotton farmers have indicated they are reluctant to use this active due to bird poisonings, as is the Australian Plague Locust Commission.

10.1.6 Conclusion-Avian Toxicity

Results in the literature for toxicity to birds indicate that monocrotophos can be rated (according to US EPA) as very highly toxic to birds by both the acute oral, based on reports for 18 species (LD50 of 0.2 to 6.49 mg/kg), and dietary routes of exposure, 3 species (LC50 range 2.4-9.6 ppm). For mallards in chronic (30 days) exposure, the "empirical minimum lethal dose", ie when first mortalities were noted in chronic 30 exposure, was very low, 0.25 ppm in the feed but for quail a 21 day dietary test showed that the LOEC was 5 ppm in the feed. While the result is not considered reliable, multi-generation tests (approximately 20 weeks exposure) on Mallard and Japanese quail, acceptable as supplemental studies by the US EPA, showed that effects occurred at low levels, at 0.1 mg/kg in feed for Japanese quail. However, the effect observed is not known.

Field reports indicate that monocrotophos has been associated with several incidents of bird kills in the USA and has been used as an avicide. Table 25 summarises all the field presented above. This table does not include one very complex semi-field study on quail (p 29) which examined a range of different exposures when monocrotophos was aerially applied at 450 or 900 g ai/ha to caged birds (quail and pheasants) to contaminated feed, water, soil, plants etc but the results were very variable and confusing. A similar but smaller study on pheasants at 450 g ai/ha showed limited toxicity.

Trial	rate used, kg ai/ha	Effects/Observations
Germany Site A Site B	1.0 1.0	>40 dead birds after 3 days in field with weeds seeding (>50% weed cover, site A). <10 dead if field relatively weed free (<10%)
Arizona	0.14-0.18	Minimal effect on local population of birds (quail and doves)
California Site 1 Site 2	1-1.4 0.32	25 blackbirds killed. Standing water and weeds in fields 120 horned larks died. Again standing water and weeds in fields.
Aust. Caged zebra finches and caged magpies	1.26	6 of 36 finches dead and 7 of 24 magpies dead after 3 days, all finches were directly exposure only and the magpies were direct exposure and fed contaminated grain.
Bearing No. 1 first treatment	1.07	21 Hatchlings dead. No non-treated controls used.
Second treatment	3.4	11 feather piles, 3 mammals dead. Leaking pipes noted in orchard. Possibility that birds drunk contaminated water from puddles near the leaking pipes.
Bearing No. 2	1.7	25 birds dead, 8 sick. Dead and dying birds had monocrotophos in their crops. Authors considered that birds had drunk contaminated water from leaves or shallow ponds, possibly due to hot weather.
7 non-bearing citrus groves	0.22-0.28	No dead birds but few expected to be exposed.
2 non-bearing	0.225 and 0.5	No dead or intoxicated birds but few expected to be exposed.
Israel Vole plague	1.6-2.8	Large no. of pipits and wagtails killed by direct application. 150 birds of prey (kites, eagles, owls etc.) found dead and 69 paralysed. Total of 300-400 birds affected by one application.
Louisiana rice fields	0.65 to 110 ppm in seed	100 ducks and geese died from deliberate poisoning of rice seed
Argentina	not known	Up to 20,000 hawks died when monocrotophos was misused to control grasshoppers in Argentina.

Table 25. Summary of the field studies presented. One very complex semi-field study has not been included.

The old field studies presented suggest that in areas where there was either food, ie wild seeds, or standing water which attract birds to either drink or feed in treated fields significant mortalities occurred at rates of 1 kg ai/ha and above. At lower rates the overseas field reports do not show a hazard but it is unclear if this is due to the lack of birds in the treated area or the birds did not receive a high dose due to the lack of feed or water in the fields. Birds entering recently sprayed fields were not affected, provided they did not feed or drink in the field. Feeding on sprayed locusts or rodents also leads to high mortalities. However, there is no evidence from the field studies that dermal exposure is a significant route of mortality. Importantly, data from the literature suggests that monocrotophos is palatable to birds above the lethal dosage.

There are anecdotal Australian reports of bird kills from label use of the EC, especially where birds are actively feeding on sprayed crops. Many growers consider it as causing significant birds kills. There are well documented reports of monocrotophos causing significant mortalities of Swanson's hawks in Argentina following use to control grasshoppers.

10.2 Aquatic Toxicity

There were six regulatory studies presented for fish, daphnia and alga. All others are from the scientific literature, the majority of which are old reports from the sixties and early seventies.

10.2.1 Fish

The toxicity of two formulations of monocrotophos, ULV 250 and SCW 20, to both rainbow trout and common carp, was determined according to OECD Guideline 203 (de Morsier, 1982, A, B and 1983). In all tests the concentration of solutions were determined at the start (time 0) and at the end of the testing period (96 hours) by GC analyses. Results were between 72-121% of nominal. The results for individual tests are given in Table 26. Note that the nominal results are by the author using the method of Spearman-Kaerber, while the calculation for the LD50 as active ingredient was performed Environment Australia by probit analysis using the 96 hours analytical results.

Test Species	Formulation	Results LC50 nominal mg/L **	Result LC50 measured ai mg/L *
rainbow trout	ULV 250	7.4 (CI 6.1-8.9)	1.69 (CI 1.21-2.2)
	SCW 200	30.8 (CI 24.5-37.5)	3-9.3 #
carp	ULV 250	12.1 (CI 7.1-35.7)	3.91 (CI #)
	SCW 200	431 (##)	64-116 #

Table 26. Toxicity of two formulation of Monocrotophos to rainbow trout and carp. * Result from measured concentrations of active, determined by probit. ** LD50 determined by Spearmen-Kaerber. # Confidence intervals could not be determined by probit analysis. ## determined graphically by probit between LC0 320 and LC100 580 mg/L.

10.2.2 Daphnia

The toxicity of monocrotophos technical (EC50) to *Daphnia magna* (adults) was determined according to OECD Guideline 202 (1984) (Kumar, 1996).

The 24 hour EC50 was determined as 0.02 mg/L (nominal), using technical material of 74.4% purity. The study was performed adequately but as the concentrations of solutions were not measured, it does not meet current requirements. It should be noted that it is currently normal to use a 48 hour EC50 figure for daphnia rather than 24 hours, given as an option in the 1984 protocol, as it often can take extra time for daphnia to fully show effects from chemical exposure in these static tests.

10.2.3 Alga

The growth inhibition EC50 for monocrotophos technical was determined according to OECD Guideline 201 adopted 1984, using the alga *Chlorella vulgaris* (Halim, 1996). The EC50 was determined as 6.8 mg/L (nominal). The study was performed adequately and there were no deviations from the protocol reported. Note this is considered to be a relatively insensitive species by the US EPA.

10.2.4 Literature Reports

Fish
The following table on fish toxicity (Table 27) has been taken from a published review on the toxicity of monocrotophos (Guth, 1994). The references quoted are those of Guth and those marked by an asterisk have been checked by Environment Australia. The above results of de Morsier are not included in Table 27.

Species	Test material	LC50 (96 hour) mg/L	Reference
Rainbow trout (*Salmo gairdneri*)	tech.	15	Swigert and Bowman, 1986
	WSC	5.2 (ai)	Johnson and Finley, 1980 *
	UBV 250	22	Bathe and Gfeller, 1980
Carp (*Cyprinus carpio*)	SWC 40	7.7 (72 h)	Dohke and Hatanake, 1977
Channel catfish (*Ictalurus punctatus*)	SWC 40	>49	Sachsse, 1972
	WSC	4.9 (ai)	Johnson and Finley, 1980 *
Bluegill sunfish (*Lepomis macrochirus*)	tech.	12 (ai)	Johnson and Finley, 1980 *
	WSC	4.0 (ai)	Cope 1965 *
Cichlid (*Tilapia mossanbica*)	tech.	10 (ai)	Joshi and Desai, 1981 *
	tech.	19 (LC100)	Mustafa, Anjum and Qadri, 1982 *
	WSC	17 (LC100) (ai)	Mustafa et al *
Guppy (*Poecillia reticulata*)	SCW 40	50	Sachsse, 1972
	WSC	23 (static renew) (ai)	Gupta, Mujumdar and Rao 1984 *
Fathead minnow (*Pimephales promelas*)	tech.	>50 (ai)	Johnson and Finley, 1980 *
Harlequin fish (*Radbora heteromorpha*)	EC	450 (constant flow) (= 180 ai)	Tooby, Hursey and Alabaster, 1975 *
Nile cichlid (*Tilapia nilotica*)	—	13.8 (48 h)	Tejada and Bajet, 1990 *

Table 27. Toxicity of monocrotophos technical and formulations to fish. * Report checked by Environment Australia.

- Comments on tests in Table 27.
All the fish toxicity results in Table 27 are assumed to be nominal and results for end use products appear as the active ingredient where indicated. The reports examined by Environment Australia were not done to standard methods and all results were reported as nominal.

Monocrotophos is rated as being practically non-toxic to moderately toxic to fish according to US EPA criteria.

Other Aquatic Organisms
Again Table 28 on toxicity of monocrotophos to aquatic organisms has been taken from a published review (Guth, 1994). The references quoted are those of Guth and those marked by an asterisk have been checked by Environment Australia. This does not included the studies for daphnia and alga reviewed above.

Species	duration of exposure h	Test material	Effect dose mg/L	Reference
Daphnia magna	24	EC	LC50=0.00024	Rawash, Gaaboud, El-Gayer and El-Shazli, 1975 *
	96	tech.	LC50=0.0034	Sanborn, 1979
Mosquito fly larvae *Culex pipiens*	24	EC	LC50=0.0016	Rawash et al, 1975 *
Freshwater shrimp *Gammarus fasciatus*	96	Tech	LC50=0.3	Johnson and Finley, 1980 *
Freshwater prawn *Macrobrachium lamerrii*	96	EC (36% ai)	LC50=1.9 ai	Nagabhushanam, Gyananath and Sarojini, 1983 *
Red crayfish *Procambarus clarki*	96	EC (38%)	LC50=1.3	Chang and Lange, 1967 *
White river crawfish	96	EC	LC50=0.034 (ai ?)	Carter and Graves, 1972 *
Shrimp, *Penaeus aztecus*	36	SD9129 (tech ?)	LC50=0.069 (flow through)	Butler, 1965 *
Oyster, *C. virginica*		SD9129 (tech ?)	shell growth, NOEC >1 (flow through)	Butler, 1965 *
Tubificid worm	72	tech	LC100=4 at 4.4 C	Naqvi, 1973 *
Scenedesmus subspicatus	72	tech.	EbC50=>100 NOE_bC= 100	Vail, 1992
South African clawed frog embryos	96	tech,	LC50>100 EC50 P[1]=2.87	Snawder and Chambers, 1989
Bullfog tadpole	96	EC	LD 50 = 185	Carter and Graves, 1972 *

Table 28. Toxicity of monocrotophos to a range of aquatic organisms. * Report checked by Environment Australia. P[1] Abnormal pigmentation.

Comments on Table 28
All the toxicity results in Table 28 are assumed for test material unless indicated as the active ingredient. The reports examined by Environment Australia indicate that these tests were not done to standard methods and as there was no analyses results given in any report, results are assumed to be nominal for the testing material, unless indicated otherwise.

The results for daphnia show considerable variation to that of Kumar (see above) and are more toxic by at least an order of magnitude. It is considered that part of this is due to the short duration of the test by Kumar, 24 hours versus 96 hours of Sanford and the use of juveniles (2-24 h old) by Rawash et al. The mosquito larvae are also very sensitive to monocrotophos. The macro-invertebrates show a range of sensitivities.

Interestingly all the tubificid worms tested died at 4.4 C with 4 ppm of monocrotophos but at 21 and 32 C there were no mortalities, although reversible morphological changes did occur at this concentration of monocrotophos (Naqvi, 1973).

Based on the results presented in Table 28, monocrotophos is rated as very highly toxic to aquatic micro-invertebrates, very highly toxic to moderately toxic to macro-invertebrates, practically non-toxic to frogs and moderately toxic to non-toxic to green algae.

—Chronic
No studies or literature reports were presented.

10.2.5 US EPA Databases.

The US EPA OPP database gives the results of toxicity to relatively few aquatic organisms and these have been listed in Table 29. It is noted that some of the endpoints in this table are identical to those by Johnson and Finley (1980) in Table 27, despite the fact that the studies in Table 29 are dated 1986.

Species	% active	Guideline	LC50, mg ai/L	Category
Rainbow trout	39.1	72-1d	5.2	C
Fathead minnow	100	72-1	50	S
Channel catfish	39.1	72-1	4.93	C
Bluegill sunfish	100	72-1a	12.1	C
Scud	100	72-2	0.26	C

Table 29. Toxicity of monocrotophos to a range of aquatic organisms from the US EPA OPP database.

The results from the US EPA ASTER database are summarised in Figure 1, which includes the data from Tables 27 and 28. It should be noted that the large range for some groups is due to an insensitive species. Also, the maturity of the test species is relevant, with early life stages in general being more sensitive. From Figure 1 the most sensitive organism is immature *Daphnia magna* with an EC50 of 0.24 µg/L (Rawash, Gaaboud, El-Gayer and El-Shazli, 1975). Fish in general are relatively insensitive.

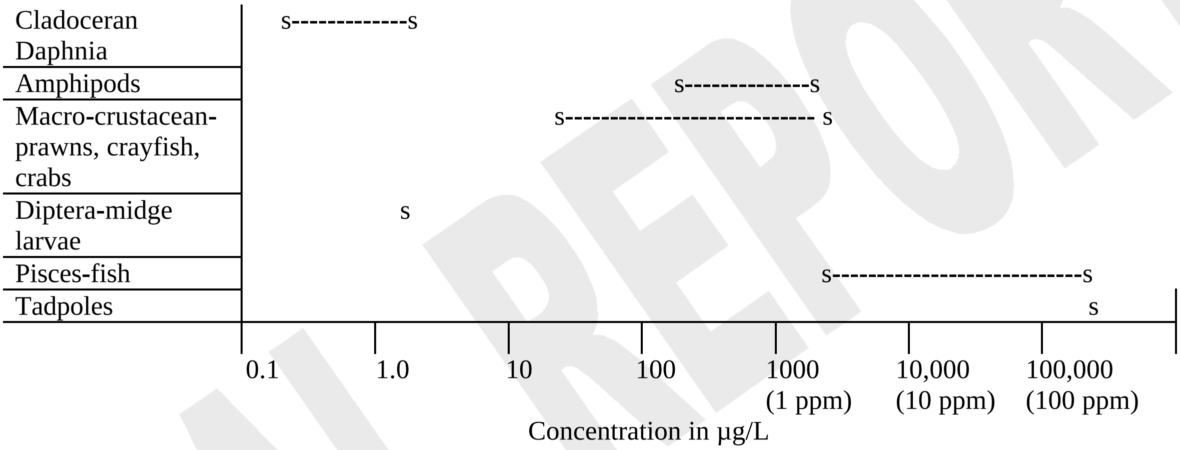

Figure 1. Graph of the toxicity of Monocrotophos to aquatic organisms from the US EPA ASTER data base together with those from Table 26 and 27. s-acute values (LD or EC50s). Positions are approximate only.

10.2.6 Summary of Aquatic Toxicity

Only a few modern test results are available but these are consistent with those from the older tests, both company and literature, and the toxicity (LC50 or EC50) to aquatic organisms ranges from 0.24 µg/L to 180 mg/L. Monocrotophos is rated according to US EPA classifications as very highly to slightly toxic, with invertebrates being the most sensitive class of organisms. The reported acute toxicity to daphnia is given as between 0.24-20 µg/L but no study meets current requirements and this is a significant data gap. Fish are the least sensitive, with a range of LC50s from 1.9 to 180 mg ai/L, based on 9 species, and monocrotophos is rated as moderately to slightly toxic to fish, again according to US EPA criteria. Several of these values are old, nominal and are considered not reliable but in the absence of other data, they will have to be used. Studies reviewed by the US EPA the Office of Pesticide Programs and that meet US EPA Guidelines show similar sensitivities for fish, LC50 between 5.2-50 mg/L, and invertebrates as more sensitive based on a single study for scud, LC50 of 0.26 mg/L.

Monocrotophos is rated as moderately toxic to one species of green algae, *Chlorella vulgaris* with EC50s of 6.8 mg/L (nominal) but non-toxic to *Scenedesmus subspicatus*, another green alga, where the EC50 was >100 mg/L and NOEC = 100 mg/L. The US EPA considers both as insensitive species.

Frogs seem to be insensitive to the effects of monocrotophos.

10.3 Non-target Invertebrates

10.3.1 Bees

Toxicity of Monocrotophos Technical to Honey Bee
The toxicity of monocrotophos to the honey bee, *Apis cerana indica F*, was determined using the dry film method, based on the CIB (Commentary on the Law Relating to Insecticides in India, Second Edition, March 1994) Guideline for testing toxicity of chemicals (Amutha, 1996).

Using water as the vehicle a thin film of the chemical was formed (from 1.0 mL of solution) on a glass jar (2 kg capacity) into which 25 bees were placed for 90 minutes and the number of bees that died within 24 hours recorded. The concentrations tested were 10, 20, 40, 60 and 100 ppm of monocrotophos. There were 4 replicates per concentration together with a control (distilled water) and positive control (endosulfan). The mortalities were corrected by comparison with controls (Abbott's formula) and the LC 50 (24 h) was determined as 31.7 ppm (27.3-36.7 ppm) using probit analysis.

It is more common to have acute oral and contact results which also allow for comparisons between chemicals. The method used is not standard and it is not possible to work out exposures to the bees or to relate the end points to field exposures. Environment Australia cannot use this study for regulatory purposes.

Evaluation of the Insecticide Monocrotophos (Azodrin) Against the Honey Bee Apis mellifera
Monocrotophos (in acetone) was applied topically to the abdomen of worker bees and the oral doses used a honey solution which was fed to groups of 10 worker bees (Felton, 1976). The mortality after 24 hours was recorded and the topical LD50 was 0.084 µg/bee and oral was 0.028 µg/bee. Monocrotophos is rated as highly toxic to bees by both the topical and oral routes.

Literature Reports
The 96 hour LD50 (contact) toxicity of monocrotophos using a dust formulation was determined as 0.35 µg/bee, with a slope of 7.8 (Atkins, Greywood and Macdonald, 1973). It is rated as highly toxic to bees from this route of exposure (Anderson and Atkins, 1968). There was very little difference in the toxicity of technical compared to formulated, LC50 of 4.1 and 4.41 mg/kg respectively, which corresponds to 0.139 and 0.149 µg/bee (Qadri, Sultana and Anjum, 1982). There was 100% mortality to bees within 1 hour when sprayed with monocrotophos (formulated as a 40% EC) at field rates for India (Bai and Reddy, 1977). Monocrotophos is know to have a residual effect which lasts for greater than 1 day (Anonymous).

The effect of different surfaces on the toxicity of monocrotophos has been studied (Mayland and Burkhard, 1970). Monocrotophos (383 µg per surface, corresponding to 0.5 kg ai/ha) was applied to a 100 mm diameter discs of filter paper, plastic, glass and rhubarb or 10 g samples of alfalfa, and four soils (silty loam, loam, sandy loam and sand). The percentage mortalities after 24 hours of exposure to the surfaces was 100% for plastic, glass, rhubarb and alfalfa surfaces, 1% for filter paper, similar to controls for all non-soil surfaces, and 92-99% for the soils tested but the controls for the soils showed relatively high mortalities as well (16-50%).

10.3.2 Other Invertebrates

Earthworms
-Acute Toxicity (LC50) Study of Monocrotophos Technical to Earthworm
The toxicity of monocrotophos technical to the earthworm (*Eisenia foetida*) was determined according to OECD Guideline 207 (1984) (Kumar, 1997).

The LC50 was determined as 197 mg/kg of soil (169-230 mg/kg), with results nominal. There were no deviations from the protocol and the study was performed adequately.

-Field Sampling of Earthworms
As part of the soil fauna trial of Elgar (1976 A, see p 17) earthworms were sampled and analysed for residues of monocrotophos. Following applications of monocrotophos (at 0.5 or 1.5 kg/ha) to the two plots, 1 application at a higher rate and 4 applications at a lower rate to plot 1 and 2 respectively, earthworms were sampled from the plots 21 weeks and 13 weeks after the last application for plots 1 and 2 respectively. There was no monocrotophos or the metabolite SD 11319 detected in any worms sampled. The detection limit was 0.01 and 0.02 ppm for monocrotophos and metabolite respectively.

-Literature
An LC50 of 35 mg/kg for the earthworm has been reported by Guth (1994), with a NOEC of 12.3 mg/kg, both of which are based on a company report to which Environment Australia does not have access (Vail, 1992 A). This result shows that monocrotophos is significantly more toxic than that above.

Lacewing (Chrysoperla carnea)
The toxicity of monocrotophos to the *Chrysoperla carnea* was determined using the dry film method based on the CIB (Commentary on the Law Relating to Insecticides in India, Second Edition, March 1994) Guideline for testing toxicity of chemicals (Dhanasekaran, 1997).

Using acetone as the vehicle, 2 mL of each test solution was added to a glass jar to form a thin film of the chemical into which 10 adult predators were placed for 6 hours and the number that died 12 hours after exposure recorded. The nominal concentrations in the test solutions were 1, 5, 10, 20, 30, 40 and 50 ppm of monocrotophos. There were 3 replicates per concentration together with solvent control and positive control (endosulfan). The mortalities were corrected for those in control (Abbott's Formula) and the LC 50 (12 h) was determined as 16.4 ppm (12.5-21.8 ppm) by probit analysis.

(Note comments at the end of the bee toxicity studies above about the usefulness of this result.)

Egg Parasitoid Trichogramma chilonis *Ishhii*
The toxicity of monocrotophos to the wasp *Trichogramma chilonis* was determined using the dry film method based on the CIB Guideline for testing toxicity of chemicals (Amutha, 1996 A).

Using water as the vehicle a thin film of the chemical was formed on a test tube (1.0 mL of solution per test tube) into which 15 adults were placed for 6 hours and the number that died 24 hours after exposure recorded. The nominal concentrations tested were 0.1, 0.2, 0.4, 0.6, and 0.8 ppm of monocrotophos. There was 3 replicates per concentration together with solvent control and positive control (endosulfan). The mortalities were corrected as before and the LC 50 (24 h) was determined as 0.3 ppm (0.25-0.37 ppm).

-Larval Parasitoid *Bracon brevicornis* Wesmael
The toxicity of monocrotophos to the wasp *Bracon brevicornis* was determined using the dry film method based on the CIB Guideline for testing toxicity of chemicals (Amutha, 1996 B).

Using water as the vehicle a thin film of the chemical was formed on a test tube (1.0 mL of solution per test tube) into which 15 adults (females) were placed for 6 hours and then feed a honey solution. The number that died 24 hours after exposure recorded. The nominal concentrations of the test solutions were 5, 20, 40, 60, 80 and 100 ppm of monocrotophos. There was 4 replicates per concentration together with solvent control and positive control (endosulfan). The mortalities were corrected as before and the LC 50 (24 h) was determined as 40.4 ppm (31.8-51.4 ppm).

Literature
Table 30 is taken from Guth's review (1994) on the toxicity of monocrotophos to insects. This is not inclusive and is only representative of the toxicity to non-target predatory insects.

Organism	Application	Effect	Dose, µg/insect
Ichneumonidae			
Campoletis persidtinctus	topical oral	LD50	0.04 0.0018
Campoletis sonerensis	topical residue on glass	LD50	0.0046 parasite 140 X more susceptible than host
Braconidae			
Apanteles marginiventris	topical	LD50	0.0015 cocoons tolerant
Apanteles congregatus	topical	LD50	0.0017
Apanteles plutellae	residue on filter paper	kill of adults at 0.05%, emergence at 0.05%	80% in 48 h 90%
Dermaptera			
Labidura riparia	residue on glass prey foliage	100% 90-100% 0%	6 µg.cm^{-2} each surface
Heteroptera			
Geocoris pallens	residue on paper foliage	LD50	67 µg.cm^{-2} 0.37 µg.cm^{-2}
Jalysus spinosus	topical	LD50	0.056
Neuroptera			
Chrysoperla carnea	residue on glass	LD50	0.52 µg/vial predator 150 X more susceptible than prey
Coleoptera			
Coccinella septempunctata	direct spray	LD50	0.0057% predator 3 X more susceptible than prey
Menochilus sexmaculatus	direct spray	kill of adults and larvae at 0.05%	83-85%

Table 30. Toxicity of Monocrotophos to various predators in laboratory studies. Taken from Guth, (1994).

Table 30 clearly shows that monocrotophos is a broad spectrum insecticide, consistent with its lack of compatibility in IPM programs.

Soil Micro-organisms

The effect of monocrotophos on a range of soil micro-organisms has been determined in a series of reports to Shell. These reports are internal studies of the company and have not been performed to modern standards. There is no analysis of the dosing material or of the final dose each test system received.

The tests show that monocrotophos has no effect on *actinomycetes* and fungi but did affect the numbers of bacteria in the soil at 4 times field dosage in the soil at 2.4 ppm (Rader, Love and Chai, 1977-1979 part III). There was no effect on the number of bacteria at the field rate (0.6 ppm). There was no effect on nitrogen fixation by *Nitrosomonas europaea*, *Pseudomonas denitrificans* and *nitrobacter spp* at 2.4 ppm (Rader, Love and Chai, 1977-1979 part I). Other studies showed that monocrotophos had no effect on proteolysis activity of the soil (Rader, 1979) or phosphatase activity of soil (Rader, 1979 A) at 2.4 ppm in the soil, 4X the field rate.

There was no effect on the nodulation of pinto beans at 2.4 ppm or on root-nodule forming bacteria (Rader, Love and Chai, 1977-1979 part I). The cellulose decomposition of *Trichoderme viride* was not affected at 100 ppm (Rader, Love and Chai, 1977-1979 part II). *In vitro* there was slight inhibition of cellulase activity at 4 ppm but not of a-amylase. At 1 ppm there was no effect on either enzyme.

10.3.3 Conclusion

Monocrotophos is extremely toxic to bees by all routes of exposure, based on 7 different literature reports. The only modern study used an Indian Guideline but it was not possible to determine that dose received by the bees from the dry residues on glass. Residues on foliage were very highly toxic to bees 24 hours after application (100% mortality).

The toxicity to earthworms was 196 mg/kg of soil for one test and 35 mg/kg of soil, reported in the company literature to which Environment Australia does not have access to. Both test are stated to be based on OECD Guideline 207. These tests rate monocrotophos as either slightly or moderately toxic to earthworms (Netherlands classification).

Based on the results of 15 reports, monocrotophos is very toxic to all the non-target invertebrates tested, in particular bees, lacewing and a range of other predatory insects. Some reports show that monocrotophos is more toxic to the beneficial insects than the pests. Again the only modern results are from 3 studies performed to Indian requirements and are difficult to relate or compare to results from other studies.

Monocrotophos has minimal effects on a range of soil micro-organisms and their biological activities at the concentrations expected in the soil following application at the label rate.

10.4 Mammals

Monocrotophos is extremely toxic to mammals by the oral route of exposure and is classified by the US EPA in Toxicity Category I, with LC50s of 18 mg/kg (US EPA Fact Sheet No: 71). The dermal toxicity is less, with an LD50 of 354 mg/kg. In Australia it is scheduled as S7.

10.4.1 Effect of monocrotophos on Australian Marsupial and Native Rodents.

The effect of dietary monocrotophos on the marsupial *Sminthopsis macroua* and Australian native rodents *Notomys alexic* and *Notomys mitchelli* was studied (Evans and Batty, 1986).

A single dietary dose of 80-100 mg/kg body weight caused death of *S. macroua* within 30 minutes with brain cholinesterase (ChE) inhibition of 66-69%; a smaller total dietary dose of 2 mg/kg bw at intervals over 18 days did not cause any deaths although the brain ChE was inhibited 92%. At the end of the 18 days of dosing some animals had developed tremors and were not eating their normal allocation of food.

In the second experiment the native rodents *N. alexic* and *N. mitchelli* were fed feed containing monocrotophos at 668 mg/kg ad libitum for 5 consecutive days. One animal, a *N. mitchelli* died at the end of the 5 days. All animals were off their feed in the treated groups and lost weight (mean weight loss of 14% and 12 % for *N. alexic* and *N. mitchelli* respectively) compared to controls. Inhibition of brain ChE was 64% and 56% for *N. alexic* and *N. mitchelli* respectively.

10.5 Phytotoxicity

The toxicity of monocrotophos is rated as moderately toxic to one species of green algae, *Chlorella vulgaris* with EC50s of 6.8 mg/L (nominal) but non-toxic to *Scenedesmus subspicatus,* another green alga, where the EC50 was >100 mg/L and NOEC = 100 mg/L. Monocrotophos is non-phytotoxic when used at the recommended rates although some varieties of apples, pears, cherry, peach and sorghum may show some injury (Tomlin, 1994).

10.6 Summary of Ecotoxicity

Monocrotophos is a highly toxic organophosphate insecticide. It is toxic to most organisms and in particular to birds.

10.6.1 Avian

Results in the literature for toxicity to birds indicate that monocrotophos can be rated (according to US EPA) as very highly toxic to birds by both the acute oral, based on reports for 18 species (LD50 of 0.2 to 6.49 mg/kg), and dietary routes of exposure, 3 species (LC50 range 2.4-9.6 ppm). For mallards in chronic (30 days) exposure, the "empirical minimum lethal dose", ie when first mortalities were noted in chronic 30 exposure, was very low, 0.25 ppm in the feed but for quail a 21 day dietary test showed that the LOEC was 5 ppm in the feed. While the result is not considered reliable, multi-generation tests (approximately 20 weeks exposure) on Mallard and Japanese quail, acceptable as supplemental studies by the US EPA, showed that effects occurred at low levels, at 0.1 mg/kg in feed for Japanese quail. However, the effect observed is not known.

Field reports indicate that monocrotophos has been associated with several incidents of bird kills in the USA and has been used as an avicide. Table 25 summarises all the field presented. This table does not include one very complex semi-field study on quail (p 29) which examined a range of different exposures when monocrotophos was aerially applied at 450 or 900 g ai/ha to caged birds (quail and pheasants) leading to contaminated feed, water, soil, plants etc but the results were very variable and confusing. A similar but smaller study on pheasants at 450 g ai/ha showed limited toxicity.

Trial	rate used, kg ai/ha	Effects/Observations
Germany Site A Site B	1.0 1.0	>40 dead birds after 3 days in field with weeds seeding (>50% weed cover, site A). <10 dead if field relatively weed free (<10%)
Arizona	0.14-0.18	Minimal effect on local population of birds (quail and doves)
California Site 1 Site 2	1-1.4 0.32	25 blackbirds killed. Standing water and weeds in fields 120 horned larks died. Again standing water and weeds in fields.
Aust. Caged zebra finches and caged magpies	1.26	6 of 36 finches dead and 7 of 24 magpies dead after 3 days, all finches were directly exposure only and the magpies were direct exposure and fed contaminated grain.
Bearing No. 1 first treatment	1.07	21 Hatchlings dead. No non-treated controls used.
Second treatment	3.4	11 feather piles, 3 mammals dead. Leaking pipes noted in orchard. Possibility that birds drunk contaminated water from puddles near the leaking pipes.
Bearing No. 2	1.7	25 birds dead, 8 sick. Dead and dying birds had monocrotophos in their crops. Authors considered that birds had drunk contaminated water from leaves or shallow ponds, possibly due to hot weather.
7 non-bearing citrus groves	0.22-0.28	No dead birds but few expected to be exposed.
2 non-bearing	0.225 and 0.5	No dead or intoxicated birds but few expected to be exposed.
Israel Vole plague	1.6-2.8	Large no. of pipits and wagtails killed by direct application. 150 birds of prey (kites, eagles, owls etc.) found dead and 69 paralysed. Total of 300-400 birds affected by one application.
Louisiana rice fields	0.65 to 110 ppm in seed	100 ducks and geese died from deliberate poisoning of rice seed
Argentina	not known	Up to 20,000 hawks died when monocrotophos was misused to control grasshoppers in Argentina.

Table 25 (repeated). Summary of the field studies presented. One very complex semi-field study has not been included.

The old field studies presented suggest that in areas where there was either food, ie wild seeds, or standing water which attract birds to either drink or feed in treated fields significant mortalities occurred at rates of 1 kg ai/ha and above. At lower rates the overseas field reports do not show a hazard but it is unclear if this is due to the lack of birds in the treated area or the birds did not receive a high dose due to the lack of feed or water in the fields. Birds entering recently sprayed fields were not affected, provided they did not feed or drink in the field. Feeding on sprayed locusts or rodents also leads to high mortalities. However, there is no evidence from the field studies that dermal exposure is a significant route of mortality. Importantly, data from the literature suggests that monocrotophos is palatable to birds above the lethal dosage.

There are anecdotal Australian reports of bird kills from label use of the EC, especially where birds are actively feeding on sprayed crops. Many growers consider it as causing significant birds kills. There are well documented reports of monocrotophos causing significant mortalities of Swanson's hawks in Argentina following use to control grasshoppers.

10.6.2 Aquatic

Only a few modern test results are available but these are consistent with those from the older tests, both company and literature, and the toxicity (LC50 or EC50) to aquatic organisms ranges from 0.24 µg/L to 180 mg/L. Monocrotophos is rated according to US EPA classifications as very highly to slightly toxic, with invertebrates being the most sensitive class of organisms. The reported acute toxicity to daphnia is given as between 0.24-20 µg/L but no study meets current requirements and this is a significant data gap. Fish are the least sensitive, with a range of LC50s from 1.9 to 180 mg ai/L, based on 9 species, and monocrotophos is rated as moderately to slightly toxic to fish, again according to US EPA criteria. Several of these values are old, nominal and are considered not reliable but in the absence of other data, they will have to be used. Studies reviewed by the US EPA the Office of Pesticide Programs and that meet US EPA Guidelines show similar sensitivities for fish, LC50 between 5.2-50 mg/L, and invertebrates as more sensitive based on a single study for scud, LC50 of 0.26 mg/L.

Monocrotophos is rated as moderately toxic to one species of green algae, *Chlorella vulgaris* with EC50s of 6.8 mg/L (nominal) but non-toxic to *Scenedesmus subspicatus*, another green alga, where the EC50 was >100 mg/L and NOEC = 100 mg/L. The US EPA considers both as insensitive species.

Frogs seem to be insensitive to the effects of monocrotophos.

10.6.3 Non-Target Invertebrates

Monocrotophos is extremely toxic to bees by all routes of exposure, based on 7 different literature reports. The only modern study used an Indian Guideline but it was not possible to determine the dose received by the bees from the dry residues on glass. Residues on foliage were very highly toxic to bees 24 hours after application (100% mortality).

The toxicity to earthworms was 196 mg/kg of soil for one test and 35 mg/kg of soil, reported in the company literature to which Environment Australia does not have access. Both test are stated to be based on OECD Guideline 207. These tests rate monocrotophos as either slightly or moderately toxic to earthworms (Netherlands classification).

Based on the results of 15 reports, monocrotophos is very toxic to all the non-target invertebrates tested, in particular bees, lacewing and a range of other predatory insects. Some reports show that monocrotophos is more toxic to the beneficial insects than the pests. Again the only modern results are from 3 studies performed to Indian requirements and are difficult to relate or compare to results from other studies.

Monocrotophos has minimal effects on a range of soil micro-organisms and their biological activities at the concentrations expected in the soil following application at the label rate.

10.6.4 Mammals

Monocrotophos is extremely toxic to mammals by the oral route of exposure and is classified by the US EPA in Toxicity Category I, with LC50s of 18 mg/kg (US EPA Fact Sheet No: 71). The dermal toxicity is less, with an LD50 of 354 mg/kg. In Australia monocrotophos is scheduled as S7.

In Australia tests on the native marsupial *Sminthopsis macroua* showed that at 80-100 mg/kg body weight caused death. A lower dose at 2 mg/kg bw at intervals over 18 days did not cause any deaths. The Australian native rodents *Notomys alexic* and *Notomys mitchelli* when fed monocrotophos at 668 mg/kg for 5 consecutive days showed reduced body weight and all animals were off their feed by the end of the testing period.

10.6.5 Phytotoxicity

Monocrotophos is non-phytotoxic when used at the recommended rates although some varieties of apples, pears, cherry, peach and sorghum may show some injury (Tomlin, 1994).

11 PREDICTED ENVIRONMENTAL HAZARD

11.1 Hazard arising from use

Monocrotophos is currently registered for use on cotton, beans (French), Granny Smith apples and some varieties of pears (some labels do not have any pome fruits), bananas, sunflowers, maize, millet, sorghum, soybeans, sweet corn, wheat, triticale, panicum, potatoes, tobacco, tomatoes and for non-fruit bearing trees by injection. It is used to control a wide range of chewing, sucking and boring pests (aphids, caterpillars, helicoverpa spp, mites, moths jassids, budworm, scale and stem borer) as well as locusts. The current major usage is for sorghum, sunflower, tomatoes and cotton, with soybeans, potatoes, and pasture as minor uses (see Table 1). Use in orchards is minimal. It seems to be used mainly as a back up spray when insect pressure and resistance levels are high, eg tomatoes 1997-98 or for control of locusts by landholders. It is not used by the Australian Plague Locusts Commission (APLC) for locusts control—it is considered to be too toxic for use by the APLC.

The maximum use rate stated on the label is 4.0 L/ha, corresponding to 1.6 kg ai/ha for *helicoverpa* in cotton, with lower rates for other pests in cotton. For orchards the maximum use rate is 2 L/ha for bananas and for Granny Smith apples and pears a spray rate of 100 mL/100 L of spray is given on the label. Assuming there is 2000 L/ha used in an orchard, an average rate, this corresponds to 2 L/ha of the formulation, ie 800 g ai/ha. For other crops the maximum rate is 250 mL/100 L or 2 L/ha. There are other uses on the label at different rates, for control of locusts (3 species) at either 350 or 700 mL/ha (lower rate for immature hoppers) for potatoes, soybeans pasture etc, tobacco at 300 mL/100 L for budworm, sunflowers at 1.8 L/ha and tomatoes at 2 L/ha, both for *Helicoverpa spp*.

The use pattern, as stated on the label, is as indicated by crop monitoring for cotton and with 10 days between sprays, on a weekly program basis for beans; every 7-10 days for potatoes and tobacco crops, 2 to 3 times per week during silking for sweet corn and for other crops as indicated by pest activity. It should be noted that tomatoes could have three crops per year in the tropics.

There is no information on types of spray equipment used; there is information concerning the use of low volume application equipment and ULV on some labels but this information is not consistent across all labels. Information on the size of spray droplets for aerial application is given as 100-150 µm vdm for low volume (LV) and 90-120 for ultra low volume (ULV) on some labels (Cyanamid and United Phosphorous). Current practice is to apply LV applications at 100-200 µm vdm.

Aerial application is normal for treatment of cotton, sunflowers, sorghum, bananas (limited use; the Farmoz label indicates 150-200 µm vdm for LV to bananas) and sometimes on tomatoes and potatoes using micronairs on fixed wing aircraft. Unlimited applications are allowed but for cotton normally 1-3 would be the maximum in one season. Locusts control is seasonally dependent and monocrotophos is used as needed.

The labels bans aerial spraying in Tasmania (without specific approval of the Registrar of Pesticides) and application by fogging machines and back mounted knapsacks is forbidden on two labels (Cyanamid and United Phosphorous) but not on others. Tractor powered sprayers and other ground based equipment are generally used for the other crops on the label. Traditionally application to orchards is by orchard air blasters using high volume equipment. However, many orchardists are now using low volume, and in some cases electrostatic ultra low volume equipment.

Applications to vegetable crops is normally by horizontal boom spray but taller crops, such as tomatoes and corn are sometimes sprayed using vertical boom sprays. Aerial application is used for some vegetable crops, especially processing tomatoes and in potatoes. One label bans aerial application on potatoes in NSW. Other types of sprayers are likely to be used in vegetable crops, particularly hand held types for smaller growers or for small plots. The maximum application rate on the label for these crops is 150 mL/100 L or 2 L/ha for use in tomatoes.

The following hazard evaluation follows the US EPA approach (Urban and Cook 1986) to establish a Q-value from the ratio of the Estimated Environmental Concentration (EEC) and lowest effects concentration, such as an LC_{50}. While Environment Australia has no formal framework for assigning levels of hazard for a given Q, it considers that the following would be an appropriate guide in this assessment:

For the establishment of hazard from acute toxicological end points under the various scenarios (ie direct overspray and 10% spray-drift), if:

- Q>0.5 then hazard is unacceptable,
- 0.1 Q 0.5 hazard may be able to be mitigated by some form of risk management, such as label restraints for a specific use, and

—Q<0.1, hazard is considered low (and may or may not require some form of risk management, such as general label restraints).

For the establishment of hazard for chronic exposure under the various scenarios,
—if using chronic data, Q>1 is unacceptable, and
—if using acute data, Q>0.1 is unacceptable.

11.2 Terrestrial organisms

11.2.1 Mammals

Terrestrial animals are at risk from monocrotophos when application of the chemical is in progress or afterwards by contact with sprayed surfaces or from consuming residues of the insecticide in feed and water. Aerial applications could overspray larger non-target organisms, such as marsupials but this is not considered a common occurrence due to the low height of the spray aircraft at application, ie close to crop height, and it is expected that these animals will move some distance from the area where spray operations are occurring, while smaller mammals will be undercover. Similarly, overspray by tractor powered equipment is considered unlikely as animals will move some distance from the area where spray operations are occurring or be undercover. Most mammals are not expected to be oversprayed directly.

It is difficult to assess the risk to larger terrestrial organisms that enter sprayed areas and are to residues. Residues on short grass are estimated at 340 ppm from direct application at the highest rate for cotton (1.6 kg/ha). As this is half the dosage used by Evans and Batty (1986) for an acute dietary study on native mammals with minimal effects noted (see p45) and as direct overspray of grass is not expected, except in pasture for locusts at a greatly reduced rate, the hazards is considered low. However, animals that enter recently sprayed areas are at some risk of exposure but as there are few, if any, reports of dead or dying animals from use in Australia, it is considered likely that the risk is relatively low at the rates used in Australia.

11.2.2 Birds

According to available literature reports and press reports, there have been a number of incidents of monocrotophos poisoning of birds in Australia and overseas when used according to label directions. Most of these reports involved birds either eating sprayed feed or drinking from water that has been oversprayed. The older field data examined (Table 25) clearly indicates that the birds that died were observed or had been feeding in treated areas or had drunk from water in fields following application.

The discussion that follows examines a number of situations where birds may be exposed to monocrotophos residues, and estimates the likely hazard from these situations.

Residues on Crops
Birds feeding on sprayed crops could also be exposed to residues of monocrotophos. There are a number of bird species that are pests in various crops, including orchards, sunflowers, sorghum etc. These species include silvereyes, parrots, lorikeets, rosellas, cockatoos, starlings, currawongs etc. Birds that are likely to be exposed to monocrotophos from feeding in sunflowers are galahs and sulfur-crested cockatoos and for sorghum red-winged parrots (Bomford, 1992). Other birds that could be exposed to monocrotophos are swamphens, maned ducks and magpie geese—all minor pests in pastures in Queensland— when feeding in pasture treated for locusts. The other currently used crops in Table 1 are not known to have birds as pests, although birds could use these crops for shelter, eg cotton.

Fruit crops and vegetable crops are normally treated by ground rigs of various designs and are likely to impact birds if foods used by birds such as insects or seeds are contaminated with monocrotophos. There is a significant hazard to birds for such exposure but it is difficult to calculate such exposure as it is dependent on the amount of cover, position of the birds etc., and whether the birds feed on the sprayed crops or drink water standing in the fields, see summary in Table 25. From this table, it is clear that at rates of 1.0 kg ai/ha or greater, and one case at 0.32 kg ai/ha, there is a very high hazard to birds when there is water or feed that birds consume in the treated fields. At lower rates the overseas field reports summarised in Table 25 do not show a hazard but there was no information on whether there were birds in the treated field or if they consumed or drunk any contaminated feed or water from the treated fields.

For fruit sprayed at 800 g ai/ha, the highest rate likely to be used, the concentration on the fruit is calculated as 10 ppm wet weight (80 ppm dry weight) from the modified Kenaga nomogram (Fletcher, Nellessen and Pfleeger, 1994). From the acute figure of 2.4 ppm for Japanese quail and assuming that these species ingest approximately 50% of their dietary intake as fruit, the only source of monocrotophos, the quotient is 2 and the hazard is unacceptable. Using the other species tested in Table 18, Q = 1.6 for pheasants (LC50 of 3.1 ppm), and for mallards (LC50 = 9.6 ppm, 5 days) Q = 0.5. While these species are not fruit eating, it is likely that the results cover the likely range of LC50s for a range of bird species. The hazard is high and unacceptable.

For quail, assuming that treated grain (70%) and small insects (30%) are the diet (from the *Wildlife exposure factors handbook*, US EPA 1993) and the crop is sprayed at 1.8 L/ha (720 g ai/ha, maximum rate for sunflowers), then the residues in small insects is 87 ppm and for grain 71 ppm (same as long grass, from the Kenaga nomogram) and the quotient is 32 for 50% of feed contaminated, using the acute dietary LD50 of 2.4 ppm. A similar calculation for sorghum using 280 g ai/ha (rate for locusts) gave a Q = 12 but residues on large insects (ie locusts) is 4 ppm and Q = 8.4. Using the LC50 for the mallard and the rate for locust control (280 g ai/ha), Q= 4.5 for small insects and 2.1 for large insects. The hazard is high and unacceptable for applications to sunflowers, sorghum and other crops.

Birds remaining in a sprayed area and are oversprayed or entering an area that has been recently sprayed could be exposed either dermally or orally from preening contaminated feathers. Based on the field trails on California quail (Section 0), which showed that a number of birds died from repeated sprays at rates significantly less than those used for cotton, this type of exposure could be hazardous to birds. This exposure is difficult to estimate and given the hazard as indicated above, the hazard due to dermal and oral exposure is expected to cause an increase in the overall hazard, especially at the high rate used in cotton.

Cotton crops are normally treated by aerial spraying and as cotton fields are close or near to rivers for irrigation (approximately 50% of cotton farms are within 300 metres of rivers in the upper Namoi, Macquarie, {O'Brien, 1996} and Gwydir river valleys {Boydell, 1997}), birds in the area of these rivers are at some risk. While it is unlikely that many birds species would be in the cotton fields, they are likely to be in and around the dams and possibly field margins on the cotton farms. Poorly controlled aerial application could result in them being directly sprayed or ingest contaminated insect/herbage. A high hazard is supported by anecdotal reports from cotton farmers that birds regularly die when this chemical is used.

Residues on Insects

Effects on birds are possible from birds eating insects that are dead or dying from the use of monocrotophos. Using the EPA food chain (Kenaga) nomogram, the concentration of residues on large insects from applications at 720 g ai/ha (maximum rate for sunflowers) is 10 ppm (wet weight, Fletcher, Nellessen and Pfleeger, 1994). Using the acute dietary results above for quail, Q = 4 for the worst case but assuming that 50% of the food is untreated and all the food is insects, Q = 2, and the hazard is expected to be high from dietary intake of residues on large insects. Small insects are more hazardous with residues of 87 ppm and the Q = 18 (50% of feed contaminated).

For locust control in sorghum, pasture etc, identified as a major use, the rate is 280 g ai/ha and hazard less, Q = 0.8 for quail (50% of feed contaminated, large insects). Using the acute dietary result for mallards (LC50 = 9.6 ppm) and large insects as the only feed, Q = 0.21 (50% contaminated). The use of monocrotophos in non-cropping areas, the highest rate for locust control (560 g ai/ha), is expected to cause significant birds mortalities (for quail Q = 1.6, large insects). As the lowest rate for locust control is 140 g ai/ha, the hazard is reduced by half and the hazard is more acceptable for large insects (Q = 0.4, quail). However, for small insects, ie early instar nymph or hopper stages for locust, the residues on the insects are calculated as 17 ppm with Q = 3.5 for quail (50% contaminated) and significantly above the level of concern.

From the results in Tables 18 and 19, raptors could be more sensitive to the effects of monocrotophos and therefore the hazard higher. A significant number of raptors eat insects and would likely prey on large insects, ie grasshoppers and locusts, including the nankeen kestrel, brown falcon, little falcon, black kite together with the rare square-tailed kite and grey falcon. Use of monocrotophos to control these insects could expose raptors to residues of monocrotophos. While the rates are low for locust and grasshopper control, ie 140 or 280 g ai/ha, there is no dietary endpoint for raptors. Comparing the acute single dose results for quail and pheasant with the acute dietary for these species and the acute results for Golden eagle, it may be concluded that the hazard to raptors is likely to be higher than for the quail calculations above. At the lowest label rate for small locusts, 350 mL/ha, (140 g ai/ha), the quotient for acute dietary exposure for small and large insects is 3.5 and 0.4 respectively using the LC50 for quail (50% of feed contaminated) and given the possible increased sensitivity of raptors, a significant hazard cannot be ruled out even at this rate. Also, as birds feeding on locusts tend to gorge themselves, the calculations may have underestimated the hazard to these birds. While the rate used is unclear, the large number of Swainson's hawks killed in Argentina would support the fact that a high hazard exists for raptors from the use of monocrotophos.

Further adding to the possible hazard is that insects contact monocrotophos through a variety of routes such as inhalation, contact and ingestion and as insects move through areas of high and low exposure. As some locusts are likely to receive higher doses than others, it may be that these insects are eaten preferentially by scavenging birds. Also, because insectivores are attracted to locusts plagues, they can encounter high levels of exposure. This has been noted for fenitrothion, another organophosphate used for locust control by the APLC (application rate is 270 to 380 g ai/ha—similar to monocrotophos), where the APLC has reported contamination of black kites of up to 90 ppm in the stomach contents (Bunn, Best, Chapman, and New 1993).

Locust control is a major use for monocrotophos (approximately 50% of total use) and is mainly used with sorghum and sunflowers crops in Queensland. There is some use of monocrotophos as a perimeter spray around these crops but it is unknown whether this acts as a deterrent or as a toxic zone for the locusts. If this is a toxic zone and causes toxic effects on the locusts, the dose picked up by the locusts is unknown and the hazard cannot be determined. As noted above direct band spraying of the hopper stage with the lowest rates could cause significant mortalities to birds feeding on the dead and dying locusts depending on the size of the hoppers and significant mortalities are possible at the higher rates used for mature locusts.

An endangered bird at risk from use of monocrotophos is the Plains-wanderer (*Pedionomus torquatus*), which lives in areas of sparse native grassland and similar vegetation. It is an insectivore and could be exposed to residues of monocrotophos when it is used as a perimeter spray or when feeding on locusts that have been sprayed on native grasslands. The minor sorghum growing areas and grasslands in Western and South-West NSW overlap with the main range for the Plains-wanderer which is sparsely distributed throughout SW Queensland. A recovery plan has been developed for the Plains-wanderer, which listed the main threats as habitat clearance for agriculture and overgrazing, by stock and rabbits, with locust spraying a suspected additional factor. One of the objectives of the recovery plan is to shed more light on this latter question (Garnett, 1992). Use of monocrotophos in non-cropping areas, the likely habitat for the Plains-wanderer, could potentially impact the survival of the Plains-wanderer and is of concern.

Environment Australia concludes the use of monocrotophos for locusts control is unacceptable at all but the lowest rate (140 g ai/ha) and for use on the larger adult locust only provided that additional label restrictions and other controls are used to limit the avian exposure. In addition, monitoring studies should be undertaken to better define the hazard to raptors and other birds that feed on locusts.

Conclusions for Avian Hazard

In conclusion, the overall hazard to birds appears high and unacceptable, especially to birds that consume insects, seeds etc that are directly oversprayed by the chemical. Use of monocrotophos to control locusts at the higher rate is likely to represent a very high hazard to avian predators of locusts and is unacceptable. This hazard has occurred in Argentina, where large numbers of Swainson's Hawks died following application of monocrotophos to control grasshoppers and led to use of the chemical being restricted/banned. At the lowest label rate for small locusts, 350 mL/ha, (140 g ai/ha), the quotient for acute dietary exposure using the LC50 for quail (2.4 ppm, 50% of feed contaminated) for small and large insects is 3.5 and 0.4 respectively and indicates a high to moderate hazard. Given the possible increased sensitivity of the raptors, a significant hazard cannot be ruled out, even for large insects. Anecdotal evidence also suggests significant mortality after use in cotton and for locust control in Australia.

The weight of evidence indicates use of monocrotophos poses a high hazard to birds, and it is difficult to defend its continued use. Unfortunately most of the evidence is old and from overseas, with local reports of bird mortality largely anecdotal, though consistent and derived from a number of sources. If uses are to be retained, these should be at the lowest rate (140 g/ha) and closely controlled, eg. under permit, with conditions that require close monitoring of hazard to birds so that the hazard posed by use on these crops may be better defined. As noted above, this is of particular importance for use for control of locusts and other pests in sorghum, sunflowers and pasture/rangelands.

11.2.3 Bees and other Terrestrial Invertebrates

Bees are at risk if spraying occurs when they are present in the crop. Using the application rate in orchards at 720 g ai/ha, the same as for sunflowers, and the method of Urban and Cook, the estimated dose is 4.3 µg ai per bee, and from the topical LD50 of 0.084 µg ai per bee (see p 42), the Q = 50. In order to limit the exposure of bees to the pesticide, the crop should not be sprayed when there are bees present, when the crop (or ground covers) are in flower or if likely to be in flower shortly afterwards. The half life of degradation of monocrotophos on vegetation is not known and based on the results of the toxicity of thin films (Section 0) and residues on alfalfa to bees (Section 0), sprayed crops could affect bees for at least 7 days after spraying. Therefore, in order to protect bees plants that are expected to flower within 7 days should not be sprayed.

Spray drift is expected to be extremely toxic to bees. The aerial spray drift studies (see p 16) showed that for the 95th percentile, the spray drift at 300 metres was 0.35% of the application rate and for cotton at 1.6 kg ai/ha, bees 300 metres away would receive 5.6 g ai/ha, which corresponds to 0.033 µg ai per bee and Q = 0.4. This level indicates that bees closer than 300 metres to the application site in cotton are likely to show some toxic effects from use of monocrotophos in cotton. A similar calculation for sunflowers at 720 g ai/ha gives a Q of 0.18 and while a hazard at 300 metres exists, it is considered acceptable. At 150 metres the Q = 0.52 and the hazard is unacceptable. For sorghum at 150 metres and 280 g ai/ha Q = 0.2 and the hazard to bees is acceptable. The hazard from aerial spray drift to bees is high at the higher rates and likewise for other non-target insects but is acceptable at rates used for locusts control, 280 g ai/ha, with a buffer zone of 100 metres or greater.

The spray drift from orchards is given in Table 14 and at a distance of 25 metres, the spray drift is 0.89% of the application rate and for orchards at 800 g ai/ha, the dose per bee is 0.042 µg ai and Q = 0.5. At 50 metres the spray drift is 0.267% and Q = 0.15. Given that the data used for the above calculations were from citrus orchards and that the SDTF results show that pome fruit orchards have less spray drift, the direct hazard to bees is moderate and acceptable with label restraints.

The studies in Table 30 show that a number of terrestrial insects that are sensitive to monocrotophos. Spray drift from cotton and sunflowers is expected to be toxic to a range of insects at 300 metres away, with *Apanteles spp* the most sensitive to topical applications (see Table 30). Using the rate for sorghum of 280 g ai/ha, Q = 3.8 for *Apanteles spp* at 300 metres away and even at the lowest rate, 140 g ai/ha, the hazards to these insects is high. Other terrestrial insects are less sensitive and the hazard is likely to be similar or lower than that for bees above.

It is very difficult to relate the end points in the thin films tests on page 43-44 to application rates. Again the result in Table 30 are more useful, with residues on foliage non-toxic to *Labidura riparia* at 6 µg.cm^{-2} (corresponding to 600 g ai/ha) but toxic to *Geocoris pallens* at 0.37 µg.cm^{-2} (LD 50; corresponds to 37 g ai/ha). It should be noted that with the same surface residues on glass (6 µg.cm^{-2}) there were 100% mortalities to *L. riparia*. While it is not possible to generalise on the non-target invertebrate mortalities from surface residues, sensitive insects are likely to be affected.

Considering the data available in Table 30 a high hazard is expected to other terrestrial invertebrates such as predatory mites which is consistent with monocrotophos' lack of compatibility with IPM programs. However, after the residues have degraded, insects from other areas are expected to recolonise the treated areas and there is unlikely to be any long-term damage to most non-target terrestrial invertebrate populations.

11.2.4 Soil Invertebrates

Earthworms and other soil dwelling invertebrates could be exposed to the pesticide, and at an application rate of 1.6 kg ai/ha, the top 5 cm of soil would contain monocrotophos residues at 2.4 mg/kg of soil (assumes no crop cover, density of soil 1300 $kg.m^{-3}$). As this concentration is significantly below the EC50 significant effects on earthworms are not expected. However, it should be noted the tested earthworm, *Eisenia foetida,* is normally considered insensitive to chemicals. Other soil invertebrates may be significantly affected unless they can move away from the sprayed areas or have become resistant in the past. There are no toxicity data available for these organisms and the hazard cannot be determined but may be expected to be high.

11.2.5 Conclusion

There are sufficient reports from overseas of adverse effects in a variety of situations that hazard to birds from Australian usage of monocrotophos may be expected.

The overall hazard to birds appears high and unacceptable, especially to birds that consume insects, seeds etc that are directly oversprayed by the chemical. Use of monocrotophos to control locust at the higher rate is likely to represent a very high hazard to avian predators of locusts and is unacceptable. This has occurred in Argentina, where large numbers of Swainson's Hawks died following application of monocrotophos to control grasshoppers and led to use of the chemical being restricted/banned. At the lowest label rate for small locusts, 350 mL/ha, (140 g ai/ha), the quotient for acute dietary exposure for small and large insects is 3.5 and 0.4 respectively indicates a high to moderate hazard using the LC50 for quail (2.4 ppm, 50% of feed contaminated). Given the possible increased sensitivity of raptors, a significant hazard to these birds cannot be ruled out, despite the lower rates. Anecdotal evidence also suggests mortality after use in cotton and for locust control in Australia.

The weight of evidence indicates use of monocrotophos poses a high hazard to birds, and it is difficult to defend its continued use. Unfortunately most of the evidence is old and from overseas, with local reports of bird mortality largely anecdotal though consistent and derived from a number of sources. If uses are to be retained, these should be at the lowest rate (140 g/ha) and closely controlled, eg. under permit, with conditions that require close monitoring of hazard to birds so that the hazard posed by use these crops may be better defined. As noted above, this is of particular importance to use for control of locusts and other pest in sorghum, sunflowers and pasture/rangelands.

The hazard to bees and to other terrestrial invertebrates is high, particularly from aerial application. Even at the lowest rate for locust control there is a high hazard to sensitive non-target insects but repopulation from untreated areas is expected to limit any long-term damage to these insect population. There is expected to be a high hazard to soil invertebrates but there are no toxicity data for these organisms. Terrestrial mammals are not expected to show significant affects when monocrotophos is used according to current label directions.

If use of the chemical is to be retained, the current label warning with regard to bees should be strengthened and modified to read:

> Do not spray any plants in flower or if flowering expected within 7 days, including ground covers, or while bees are present. Spray drift is also highly toxic to bees and at hundred of metres distance.

11.3 Aquatic organisms

11.3.1 Direct over spray

Aquatic organisms are very sensitive to the toxic effects of monocrotophos, based on the ecotoxicity data reviewed. Direct application to a body of water 15 cm deep at the highest rate in cotton of 1.6 kg ai/ha is calculated to give a concentration in the water of 1.07 mg/L. Even at the lower rate of 720 g ai/ha used in orchards and for sunflowers, the concentration in water is 0.48 mg/L and the hazard to most aquatic organisms is high.

Application by boomspray and orchard air blasters is unlikely to result in direct overspray. However, aerial application, which is possible in a number of crops (see section 5.1), could lead to such direct overspray and is of concern. A concentration of 1.07 mg/L in shallow water from application at the highest rate used in cotton is likely to cause mortalities in sensitive fish species (Q = 0.6), based on the tests reviewed (see Tables 26, 27 and 29). There were no regulatory studies presented on the degradation in water but literature results indicate that rapid degradation in water/sediment systems can be expected and therefore chronic effects in fish are unlikely.

Effects on daphnia (most sensitive species tested EC50 = 0.24 µg/L) from direct overspray are likely to be severe, with Q = 4400 for the highest rate in cotton. Significant effects are likely on other aquatic invertebrates. Chronic effects could be expected at these high concentrations (see 0 below).

11.3.2 Spray Drift

10% Spray drift onto pond

Spray drift is of major concern for aquatic organisms. Using the US EPA assumption of 10% spray drift (Urban and Cook), this provides a concentration of 107 µg/L for a shallow pond 15 cm deep for the maximum rate for cotton of 1.6 kg ai/ha. This is below to the EC50 for the most sensitive fish, rainbow trout, Q = 0.06 (see p 38) but well above the EC50 for daphnia, Q = 440, and the hazard to daphnia is high. There are no reliable endpoints for Australian freshwater macro-crustacea but using the most sensitive species tested, white river crawfish as a surrogate, the Q = 3.1 (LC50 = 34 µg/L, assumed to be ai) and the hazard high. [Freshwater macro-crustacea such as yabbies (*Cherax destructor*) and the endangered species, Murray River crayfish and Tasmanian White crayfish, are important Australian species.]

At the lower rate for orchards and sunflowers (720 g ai/ha), the concentration in shallow water (15 cm) from 10% spray drift is 48 µg/L. There is still a high hazard to aquatic invertebrates (Q = 200 for daphnia) and to other crustacea.

The hazard to aquatic invertebrates from 10% spray drift is therefore considered unacceptable and further refinements to accurately determine the hazard are required.

11.3.3 More Realistic Spray Drift Scenarios

The following discussion examines the hazard from spray drift under more realistic conditions, starting from the highest application rate and working through to the lowest.

Aerial Applications

Most aerial applications in Australia are done using fixed wing aircraft. Application by helicopter is not significant and therefore this report will concentrate on fixed wing application.

Some land-use considerations

Aerial application is the normal practice for applying pesticides to cotton, sorghum and sunflowers, the major crops using monocrotophos. The major cotton growing areas in Australia is northern NSW and central Queensland with WA as a minor area. Sorghum is mainly grown in central and southern Queensland and northern NSW, with minor crops in west and southwest NSW and Northern Territory. Sunflowers are mainly grown in central Queensland and northern NSW, with minor areas in and around southern Queensland, southwest NSW, Victoria and southeast SA. There is considerable overlap in the main growing areas for these crops and it is not unusual to see cotton and sorghum in the same district and likewise sorghum and sunflowers.

Cotton is grown as both an irrigated and dryland crop. Significant numbers of cotton fields are close to water, especially the irrigated fields, and for the lower and upper Namoi, 36% and 48% of the fields are within 300 metres of a waterway respectively (O'Brien, 1996) and 56% for the Gwydir valley (Boydell, 1997). Other cotton growing regions are likely to be similar with a high percentage of cotton fields within 300 m of waterways. Environment Australia recognises that some of these waterways are drainage systems but a number are expected to be natural streams/rivers. Sorghum and sunflowers are mainly grown as dryland summer crops where summer rain occurs, often in districts where dryland cotton is also grown. Sorghum is sometimes irrigated but this is more as supplemental water during dry spells.

O'Brien (1996) gives some indication of the potential problems associated with pesticide applications in the Namoi River. Firstly, aerial applications are widely used on irrigated farms because ground rigs can not easily access wet fields, and spray can be applied comparatively quickly. However, even in dryland cotton, 75% of the total number of farmers aerially spray 50% of their farm with insecticides. In certain situations, this may be more of an environmental concern because these farms are reliant on summer rainfall and subject to the vagaries of storms, do not to practice water recycling and can be situated on old river channels more prone to flooding. A similar situation exists with sorghum and sunflowers.

Secondly, although aerial spraying should be practised under environmental conditions which ensures minimum spray drift, in practice 3-10% of farmers (or their aerial operators) would spray in "unfavourable" conditions. Further, 15-20% of farmers (or their aerial operators) have sprayed during inversions, although they would try to avoid such practices; reports of such practices continue, but at reduced rates. Farmers also spray under gusty conditions, noticeably more so in dryland cotton (20%) compared to other cotton farmers (6-7%). If rain appeared likely, 77% of farmers in the Upper Namoi and 55% of dryland farmers would continue to spray, compared to 11% and 13% of farmers in the Macquarie Valley and Lower Namoi.

Thirdly, and the most disturbingly, O'Brien states that the "application of pesticides while irrigating is almost common practice with as many as 90 per cent of Lower Namoi farmers and 73 per cent of Upper Namoi farmers spraying while water is in the furrows". Near 80% of farmers in the Macquarie Valley also do this. Further, most cotton farmers irrigate shortly after spraying, with little delaying irrigation after a spray. In essence, farmers irrigate and spray to suit the crop requirements with little concern to modify irrigation and spray schedules to mitigate off-site movement and effects of the applied chemicals.

Boydell (1997) in a cotton farm review and audit of cotton farmers in the Gwydir Valley showed that 48% of irrigated cotton farmers are within 100 meters of a waterway, some of which are minor creeks but all flow into the major rivers. For dryland cotton farms, 90% are further than 300 metres from waterways. All of Gwydir's irrigators could contain 25 mm rain event after irrigation within the tailwater system but no dry land cotton grower has tailwater systems. Most growers do not have the entire farm under cotton, with approximately 60% of irrigators having between 20-60% of the land under cotton and even less for the dryland growers. Most irrigators aerially spray their crops while 70% of dryland cotton applied <50% of their insecticides by air. Spraying under unfavourable conditions was very similar to that in the Namoi River valley, given above. No growers interviewed would spray under unfavourable conditions, but 50% dryland and 41% of irrigators would continue to spray despite the likelihood of rain. All cotton irrigators would spray while irrigating and none would consider delaying irrigating after spraying. As above, farmers irrigate and spray to suit the crop requirements with little concern to modify irrigation and spray schedules to mitigate off-site movement and effects of the applied chemicals.

The cotton industry has recognised that farming practices must become more responsive to community concerns, and has therefore worked with the Land and Water Resources Research and Development Corporation (LWRRDC) to implement a research program which is addressing the movement, fate and effects of pesticides in the riverine environment. The industry is also developing a Best Management Practices Manual (BMPM) for Growers[2], which has been released. It sets out principles and practices for good communication, pesticide application, farm design, IPM, and soil and water management.

While the cotton industry has developed BMPM which will help to limit the environmental exposure, such measures are not in use for sorghum or sunflowers and are currently only used by the better and more progressive cotton growers.

[2]Published by the Australian Cotton Industry in association with the Australian Cotton Growers' Research Association, Cotton Research & Development Corporation and Cotton Australia. Further information is available from 1) Allan Williams, Executive Officer, Australian Cotton Growers Research Association, "Kia-Ora", Narrabri, NSW 2390; or 2) Peta Slack-Smith, Projects Officer, Cotton Research & Development Corporation, PO Box 282, Narrabri, NSW 2390

Cotton

The data from aerial spray drift studies in Table 12 has been use to construct Table 31, which gives the concentration in water 15 cm deep and the quotient for daphnia following aerial spraying at 1.6 kg ai/ha. It should be noted that as this is for four parallel swaths and with a vdm of 238 µm, Table 12 could underestimate the spray drift under more usual conditions of use, including the lower droplet size range recommended in the current labels for monocrotophos (droplet size 90-120 m for ULV and 100-150 m for LV).

Distance down wind, metres	Cumulative percentage probability 25%	50%	75%	95%
91	9.6 **40**	12.8 **53**	19.2 **80**	32.0 **133**
152	3.5 **15**	5.3 **22**	6.4 **27**	10.7 **44**
305	1.07 **4.4**	1.6 **6.7**	2.3 **10**	3.7 **16**

Table 31. Estimated Environmental Concentration (EEC, g/L) of monocrotophos in water 15 cm deep from application at 1.6 kg ai/ha and corresponding quotient for *D. magna* in bold (EC50 = 0.24 g/L) . Quotient is EEC/EC50. Calculated from Table 12. Dark shading is Q > 0.5, light shading = 0.1<Q >0.5.

It should be noted that although Table 31 is approximate and may not represent the worst case. Also, there are such a large number of variables with respect to spray drift that the results still can only be considered as indicative of the expected situation in the field. Table 31 indicates that there is a high hazard to daphnia, the most sensitive of the aquatic organisms tested.

For fish, the highest concentration in water in Table 31 (32 ppb) is significantly below the LC50 for the most sensitive fish species, rainbow trout (1.69 ppm). There is not expected to be any hazard to fish from aerial spray drift.

As a worst case, ie spraying under still or windy conditions, the summarised results from literature spray drift studies indicate that approximately 1% of the application rate could be expected to occur as spray drift at a distance of 300 metres from the application site (Bird et al, 1996). Using this figure the concentration in water 15 cm deep is 10.7 µg/L and the quotient for daphnia is 44, which indicates a very high hazard. (Note that in 1994/1995 4 out of 10 aerial operators in the Namoi valley admitted spraying in adverse weather conditions {O'Brien, 1996} but for the Gwydir valley in 1996/97, no aerial operators would spray under inversion conditions {Boydell, 1997}). This together with the smaller droplet size used in Australia indicate that there is an unacceptable hazard to daphnia and most likely other aquatic invertebrates to beyond 300 metres from the edge of the aerial sprayed zone. It should be noted that these results are based on Table 12, which is for EC placement sprays (28 L per hectare, 238 m vdm), and the use as a ULV (see section 0) would be expected to result in higher spray drift.

Further refinements to Hazard

The above calculations were for water 15 cm deep, which is relatively shallow and for lentic water bodies, ie ponds/billabongs. While ponds etc are expected to be deeper than 15 cm, this is a reasonable depth given that the edge and surface of pond are likely to be the most productive (productivity at depth is limited due to turbidity and resulting low light levels). For the major cotton growing areas, Macquarie, Gwydir and Namoi River valleys in NSW and the Emerald and Goondiwindi areas in Queensland, the maximum depth of rivers in these regions would be around 1-2 metres. However, it should be noted that these rivers are turbid and often have little, if any flow, and could therefore be considered a series of lentic billabongs. To refine the hazard assessment 30 cm deep water has been used in the hazard calculations for Table 32.

Distance down wind, metres	Cumulative percentage probability 25%	50%	75%	95%
91	4.8	6.4	9.6	16
	20	**26.5**	**40**	**63**
152	1.8	2.7	3.2	5.4
	7.5	**11**	**13.5**	**22**
305	0.54	0.8	1.2	1.8
	2.2	**3.3**	**5**	**8**

Table 32. EEC (g/L) of monocrotophos for water 30 cm deep from application at 1.6 kg ai/ha and corresponding quotient for daphnia (in bold). Calculated from Table 12. Dark shading is Q > 0.5, light shading = 0.1<Q >0.5.

The quotient in Table 32 for daphnia clearly shows that there is an unacceptable hazard to beyond 300 metres from the application site for cotton at the maximum rate. From Table 28 it is clear that daphnia are the most sensitive organisms tested but a number of aquatic invertebrates are expected to be sensitive to monocrotophos. Table 33 gives the quotient for a number of aquatic invertebrates using the 95 percentile figures from Table 32. It should be noted that none of the tests for aquatic invertebrates in Table 28 were considered robust, with all being for nominal concentrations and none would meet the current requirements. The results in Table 33, apart from the result of Kumar (1996) which is considerably higher than the other results for daphnia but is not considered reliable, support the finding that there is an unacceptable hazard to aquatic invertebrates from applications to cotton at the highest rate.

Distance down wind, metres	Species, test duration and LD50		
	Daphnia magna, 96 h 3.4 µg/L	*Daphnia magna,* 24 h 20 µg/L *	*Culex pipiens,* 24 h, 1.6 µg/L
91	4.7	0.8	10
152	1.6	0.27	3.4
305	0.53	0.1	1.1

Table 33. Quotient for variety of invertebrates in water 30 cm deep from application at 1.6 kg ai/ha using 95% percentile results from Table 30. * Result is not considered reliable. Dark shading is Q > 0.5, light shading = 0.1<Q >0.5.

As adsorption of monocrotophos to sediment is not expected, due to the relatively low Koc (see Table 11), the results in Tables 32 and 33 are not mitigated for adsorption to sediment. Also, tests on the degradation in natural river water failed to show any degradation after 8 weeks. However, the degradation of monocrotophos could be rapid, based on the limited results for one rice study under tropical conditions, with half lives between 0.5-0.9 days (see Section 0). It was concluded that high microbial activity is required for rapid degradation, ie as in a rice paddy. While degradation in the river and other waterways in cotton growing areas are expected, it is considered that this is unlikely to be rapid enough to limit the acute hazard indicated in Tables 32 and 33.

In order to account for the lower droplet sizes recommended for Australia on the labels (100-150 m as LV spray), and as another measure for spray drift, the US EPA AgDRIFT model has been used. The model is based on the data from Bird et al (1996) and is for the 90th percentile of spray drift. Note that use of AgDRIFT has not yet received approval for use in the regulatory decisions in the US EPA. Table 34 gives the concentration in water 30 cm deep together with the quotient for a range of invertebrates from AgDRIFT (Tier 1 level, fine spray 119 m   vmd).

Distance down wind, metres	EEC in water 30 cm deep, µg/L	Species, test duration and LD50		
		D. magna,0.24 µg/L	*C. pipiens*, 1.6 µg/L	*D. magna* 3.4 µg/L
100	55.4	231	35	16
150	42.5	177	27	13
300	26.5	110	17	8

Table 34. Quotients for variety of invertebrates in water 30 cm deep from AgDRIFT applications at 1.6 kg ai/ha using fine spray. Dark shading is Q > 0.5, light shading = 0.1<Q >0.5.

As is clear from Table 34 when the fine droplets recommended for applications of monocrotophos the spray drift are considered, the hazard to aquatic invertebrates is significantly increased. Note that the AgDRIFT model uses the 90th percentile for aerial and therefore one in ten applications could exceed the hazard indicated.

Tables 32-34 are for the highest rate used in cotton, 1.6 kg ai/ha, to control large helicoverpa larvae. However, on the label there are lower rates for small helicoverpa, the lowest 2 L/ha (800 g ai/ha), and the same rates for rough bollworm, cotton looper and tipworms. While this is half the rate used in Tables 32-34, halving the quotient in these Tables would still indicate a significant hazard to aquatic invertebrates.

Currently the cotton industry is introducing its BMPM that suggests a buffer zone of 300 metres for aerial spraying (page AP 10 of BMPM). Environment Australia does not have spray drift data for beyond 300 metres available to it from the open literature. (The limited information in Table 14 is considered reliable for cotton.) Given the relatively large values of the quotient in Tables 31-34 at 300 metres and the exponential fall off of spray drift with distance, the buffer zone of 300 metres suggested in the cotton BMPM for aerial spraying is not considered sufficient to limit the environmental impact to a satisfactory level for the 95 percentile, ie 1 in 20 applications. Also, with the current droplet size recommendations on the label, the hazard under Australian usage was shown by AgDRIFT to be higher. Therefore, Environment Australia cannot support the continued use in cotton by aerial application under the current conditions of use.

Environment Australia has also used AgDRIFT to model placement spraying, a technique used to minimise spray drift. Even with a lower application rate (1.0 kg/ha) and a very large droplet size spray (500 m vmd) the concentration in water (30 cm deep, 300 metres away) was determined to be 0.68 g/L and Q = 2.8 and 0.4 for *D. magna* and *C. pipiens* respectively. The hazard remains high and unacceptable even under these extreme conditions. Environment Australia can not support the continued registration of monocrotophos in cotton.

Sorghum and Sunflowers

The major areas where sorghum and sunflowers are grown are expected to have flowing streams and rivers in years with normal rainfall patterns. It is expected that for these water courses a depth of 15 cm may be considered reasonable, especially those near of the fields, where most of these are expected to be drainage streams. The hazard is calculated in Table 35 for application to sunflowers at 720 g ai/ha (maximum rate for helicoverpa control in sunflowers), Table 36 is for sorghum at 280 g ai/ha, the maximum rate for locust control and Table 37 is for application at 140 g ai/ha, the lowest rate for sorghum and gives the quotient for both *D. magna* and *C. pipiens*. Currently there is no best management plan for these crops, with the use of buffer and other control measures determined by the aerial applicator and the growers.

Distance down wind, metres	Cumulative percentage probability 25%	50%	75%	95%
91	4.32 **18**	5.76 **24**	8.64 **36**	14.4 **60**
152	1.584 **6.6**	2.4 **10**	2.88 **12**	4.8 **20**
305	0.48 **2**	0.72 **3**	1.06 **4.4**	1.68 **7**

Table 35. EEC (g/L) of monocrotophos in water 15 cm deep from application at 720 g ai/ha to sunflowers and corresponding quotient for daphnia (in bold. EC50 = 0.24 g/L). Quotient is EEC/EC50. Calculated from Table 31. Dark shading is Q > 0.5, light shading = 0.1<Q >0.5.

Distance down wind, metres	Cumulative percentage probability 25%	50%	75%	95%
91	1.68	2.24	3.36	5.6
	7.0	**9.3**	**14**	**23**
152	0.62	0.93	1.12	1.87
	2.6	**3.9**	**4.7**	**7.8**
305	0.19	0.28	0.41	0.65
	0.8	**1.2**	**1.7**	**2.7**

Table 36 EEC of monocrotophos in water 15 cm deep from aerial application at 280 g ai/ha to sorghum and corresponding quotient for daphnia (in bold. EC50 = 0.24 g/L). Quotient is EEC/EC50. Dark shading is Q > 0.5, light shading = 0.1<Q >0.5.

Species	Distance down wind, metres	Cumulative percentage probability 25%	50%	75%	95%
D. magna	91	3.5	4.6	7	11.5
	152	1.3	2.0	2.4	3.9
	305	0.4	0.6	0.9	1.4
C. pipiens	91	1.1	1.4	2.1	3.5
	152	0.39	0.58	0.7	1.2
	305	0.12	0.18	0.26	0.4

Table 37. Quotient for both *D. magna* and *C. pipiens* in 15 cm deep water from aerial application at 140 g ai/ha to sorghum. Calculated from Table 31. Dark shading is Q > 0.5, light shading = 0.1<Q >0.5.

As for the situation for cotton, there is expected to be a significant hazard to daphnia and other similar aquatic invertebrates from aerial applications of monocrotophos for the 95th percentile to sorghum and sunflowers beyond 300 metres away. Even using deeper water, ie 30 cm, the hazard remains high or using the less sensitive end points in Table 28 for mosquito larvae (*C. pipiens*, LC50 = 1.6 µg/L) and *D. magna* (LC50 = 3.4 µg/L) the hazard in Tables 35 and 36 for the 95 percentile remains high but Table 37, shows that at the lowest rate, the hazard is more acceptable for *C pipiens* at 300 metres (Q = 0.2). However, Environment Australia does not have information of the distance that sorghum and sunflower fields are from natural watercourses but it is expected that a significant number will be within 300 metres of natural waterways.

Also, with the droplet size recommended in the label and the use of ULV applications, both of which use significantly smaller droplets than that used for the hazard calculations, the hazard under Australian usage is expected to be higher than in Tables 35-37. Using AgDRIFT and the fine spray in the Tier 1 assessment, the spray drift from application to sorghum at 280 g ai/ha has been calculated together with the quotients for *D. magna* and *C. pipiens*. These results are presented in Table 38.

Distance down wind, metres	Species, test duration and LC50: *D. magna*,0.24 µg/L	*C. pipiens*, 1.6 µg/L	*D. magna* 3.4 µg/L
100	40.4	6.05	2.85
150	31.0	4.65	2.19
300	19.3	2.89	1.36

Table 38. Quotient for range of invertebrates in 30 cm deep water from aerial application at 280 g ai/ha to sorghum. Calculated from AgDRIFT for fine spray. Dark shading is Q > 0.5, light shading = 0.1<Q >0.5.

From Table 38 it is clear that even at the lowest label rate, 140 g ai/ha, ie half the values in Table, there is likely to be a significant hazard to aquatic invertebrates from spray drift. When the above points are considered, the environmental hazard from spray drift for the current aerial use in both sunflowers and sorghum is unacceptable.

As for cotton, Environment Australia has examined the spray drift hazard using placement spraying, a technique to minimise spray drift. Using coarser droplets (350 m vmd), the hazard is significantly reduced and at 150 and 300 metres away the concentration in water from spray drift is calculated as 1.5 and 0.77 g/L for application at 280 g ai/ha. This indicates that with the use of placement spray technologies and other measures to limit the amount of spray reaching non-target areas, the use of monocrotophos at the lowest label rate (140 g ai/ha) may be acceptable.

Other crops

The considerations above for sorghum and sunflowers are expected to apply to aerial application to tomatoes. Given the normal variation between aerial applications and spray drift being strongly dependent on droplet size and wind speed at the time of application, the difference in application rates for tomatoes, maximum rate 800 g ai/ha, and that in Table 35 is not considered significant. It should be noted that in the season 1997-98, a year of significant problems with resistant *helicoverpa spp*, monocrotophos was applied to approximately 20% of the tomatoes processing crop in Australia at least once or twice but it is not known if this was by aerial application or not (Jean Bentley from Institute of Horticultural Research, Victoria Agricultural, personal communication).

Soybeans are aerially treated and are grown under irrigation or in areas with reliable summer rainfall. These areas are similar to that for sorghum and sunflowers and have been given previously. There are clear instructions on the label for aerial application. The rate is about half that used in Table 35, 360 g ai/ha, and thus spray drift hazard, as given by the quotient in Table 35, is also reduced by a factor of 2. Note that Tables 36 and 38 are approximate for soybeans. Again, with the droplet size recommended in the label and the use of ULV applications, the hazard under Australian usage is expected to be higher. The hazard for aerial application to soybeans remains high and unacceptable.

There are other crops on the label that could be aerially treated with monocrotophos, eg potatoes and pastures, but these are within the rates given above and the hazard is expected to be similar. The remaining crops in Table 1 (Section 0) are normally treated using boom sprayers or possibly misters.

Even considering the large droplet technologies discussed previously, unless the higher application rates for these crops can be reduced to 140 g ai/ha (350 mL/ha), Environment Australia cannot support the use of monocrotophos in these crops.

11.3.4 Ground Based Spraying

Pome fruit orchards applications.

The agricultural assessment indicated that currently monocrotophos is not used in pome fruit orchards to any great extent and this use is expected to decline as IPM systems are incorporated into the operations of these orchards. This is in part due to the phototoxicity to certain varieties of apples and pears and to its high toxicity to terrestrial invertebrates and lack of suitability for use in IPM programs. However, monocrotophos may still be occasionally used as a resistance control measure to control the build-up of resistant insect populations. Note that orchards uses are not included on the Ciba-Geigy label.

Land use considerations

Pome fruits are grown in a number of locations with considerable variation in land use adjacent to these crops. No data exists for the occurrence of these crops close to water bodies, but Environment Australia expects that ponds and drainage channels (both man-made/modified or natural) would be a common feature of the landscape in which pome fruits are grown, with subsequent movement of applied chemical into “natural” receiving waters such as swamps, marshes, lakes and rivers. Indeed, it is likely that man-made drainage channels would frequently be within 10 m of the crop, but are of less concern than natural waterbodies because of their expected lower biodiversity and ecological significance.

The spray drift from orchards application using high volume applications is given in Table 14 as a percentage of the application rate. The application rate for pome fruit on the label is given as 100 mL/100 L spray volume (40 g ai/100 L) and using 2000 L/ha as a typical spray volume in an orchard, the rate is 2 L/ha, ie 800 g ai/ha. Note that large orchard trees (pears, nuts etc) and citrus could be sprayed at higher rates. Table 39 gives the concentration in water 15 cm deep and the quotient for daphnia.

Distance downwind	Spray drift, % of appl. rate	EEC, in water 15 cm deep µg/L	Quotient, daphnia EC50 = 0.24 µg/L
25	0.893	4.76	19.8
50	0.267	1.42	5.9
100	0.069	0.34	1.5
200	0.015	0.08	0.33
300	0.006	0.032	0.13
400	0.003	0.016	0.07

Table 39. EEC of spray drift from orchard air blaster using an EC formulation at 800 g ai/ha together with acute quotient for daphnia in water 15 cm deep. Based on Table 14. Quotient is EEC/EC50. Dark shading is Q > 0.5, light shading = 0.1<Q >0.5.

The results in Table 39 shows that there is a high hazard to daphnia and other aquatic invertebrates up to 200 metres away from the site of application. It should be noted that the data in Table 13 are for citrus orchards with dense foliage and other orchards could have different levels of spray drift. As apples trees could be treated in the early season for codling moth, (green tip to early petal, Thwaite and Penrose, 1997), Table 39 may not be the worst case and is therefore not mitigated further. Using the other toxic end points in Table 28, there is a hazard at 100 metres away, Q = 0.2 for *C pipiens*, which is more acceptable but the hazard remains high at 50 metres, Q = 0.9. As there is no rate per hectare given on the label and the actual rate is dependent on the volume of spray used, Table 39 is considered to be approximate to allow for different application rates that are actually used.

Table 39 clearly shows that there is a significant hazard to daphnia and other very sensitive aquatic organisms from use of monocrotophos up to 200 metres in orchards from application as a high volume spray. While it may be possible to mitigate the hazard at 200 metres with the appropriate label statements and buffer zones etc, it is unlikely that these will reduce the hazard to acceptable levels for aquatic areas within 100 metres.

In contrast to the above, the US EPA AgDRIFT model was developed from the results of the Spray Drift Task Force in which a range of orchards crops were treated by a conventional airblast sprayer. The crops treated were dormant apples, grapefruit and small grapefruit, pecans, oranges, almonds, grapes (wrap-around sprayer and airblast) and apples. The first 5 rows of trees adjacent to the open field were treated in each type of orchard and the end 12 rows for grapes. There was one orchard row between the first row sprayed and the open field. The results showed that pome and stone fruit (trees of moderate size) together with grapes gave similar spray drift while citrus and tall trees (ie larger [older style] pear trees) also gave similar spray drift. Therefore the US EPA model groups orchard crops into 3 groups, dormant trees, pome and stone fruit including grapes (normal orchard), with citrus grouped together with tall trees. The results from the 3 groups were then averaged and the model fitted to the experimental data. Note that use of AgDRIFT has not yet received approval for use in the regulatory decisions in the US EPA and should therefore be used with some caution.

The results in Table 40 are for pome and stone fruit trees of a modern orchard at 0.80 kg ai/ha, Table 41 is for tall trees (ie pears) at 1.6 kg ai/ha (tall pear pears could be sprayed up to 4000 L/ha) and Table 42 is for dormant spraying of apples trees at 0.8 kg ai/ha. (This use is considered to be unusual but could occur to control early season mites or as a pre-season spray). These Tables are for 30 cm deep water to represent a substantial stream and the quotients for *D. magna* and *C. pipiens.*

Distance downwind	EEC in water 30 cm deep µg/L	Quotients,		
		D. magna, EC50 0.24 µg/L	C. pipiens, EC 50 1.6 g/L	*D. magna* EC50 3.4 µg/L
25	0.237	0.99	0.15	0.07
50	0.078	0.33	0.05	0.02
100	0.023	0.10	0.01	0.01
200	0.006	0.03	0.00	0.00

Table 40. EEC of spray drift from orchard air blaster in normal pome fruit trees using an EC formulation at 800 g ai/ha together with acute quotient for daphnia in water 30 cm deep. Dark shading is Q > 0.5, light shading = 0.1<Q >0.5.

Distance downwind	EEC, in water 30 cm deep µg/L	Quotients,		
		D. magna 0.24 µg/L	C. pipiens, 1.6 g/L	*D. magna* 3.4 µg/L
25	7.66	31.92	4.79	2.25
50	3.24	13.50	2.03	0.95
100	1.12	4.67	0.70	0.33
200	0.33	1.38	0.21	0.10
300	0.16	0.67	0.10	0.05

Table 41. EEC of spray drift from orchard air blaster in tall trees using an EC formulation at 1.6 kg ai/ha together with acute quotient for daphnia in water 30 cm deep. Dark shading is Q > 0.5, light shading = 0.1<Q >0.5.

Distance downwind	EEC, in water 30 cm deep µg/L	Quotients,		
		D. magna 0.24 µg/L	C. pipiens, 1.6 g/L	*D. magna* 3.4 µg/L
25	9.4	39.17	5.88	2.76
50	3.5	14.58	2.19	1.03
100	1.1	4.58	0.69	0.32
200	0.31	1.29	0.19	0.09
300	0.15	0.63	0.09	0.04

Table 42. EEC of spray drift from orchard air blaster in dormant apple trees using an EC formulation at 800 g ai/ha together with acute quotient for daphnia in water 30 cm deep. Dark shading is Q > 0.5, light shading = 0.1<Q >0.5.

Table 40 shows that there is a limited hazard to aquatic invertebrates with any species whose EC50 is >1 g/L unlikely to be affected at 25 metres from the orchard. For invertebrates that are very sensitive to monocrotophos, the results show that there could be significant effects on these organisms. Note that the AgDRIFT model is based on the average spray drift from apples and stone fruit orchards and spray drift not worst case, and therefore the results from the model may not be fully protective of the environment. Environment Australia therefore considers that use of monocrotophos in apples and stone fruit orchards might be acceptable but at rates lower than are currently used. However, considering the lack of quality data, the level of hazard and that use is declining in favour of chemicals more suitable for IPM, Environment Australia would favour the removal of pome fruit use from the label.

In contrast, Table 41 shows that for tall trees, ie older style pear trees, there is a considerable hazard that extends to 100 metres for the least sensitive end point for *D. magna*. Even allowing for lower application rates, to 800 g ai/ha, the hazard is high. For organisms that are more sensitive, the hazard is very high and unacceptable. A similar hazard is evident in Table 42 for dormant spraying of apple trees and represents an unacceptable use pattern. Environment Australia cannot support use of monocrotophos for larger type trees or for spraying before full leaf cover based on current information and modelling capacity.

The degradation of monocrotophos could be rapid, based on the limited results for one rice study (see Section 0), with half-lives between 0.5-0.9 days. However, a test in natural river water failed to show any degradation after 8 weeks and it was concluded that high microbial activity is required for rapid degradation, ie as in a rice paddy. As most pome fruit orchards are in the cooler temperate areas of Australia and are likely to have relatively lower microbial activity compared to a rice paddy in the tropics, the degradation of monocrotophos in waterways is expected to be slower than 1 day, ie half life >1 day. Effects on the sensitive organisms are still expected for several days after the spray drift event in still water.

-Other considerations

Orchards are present in a range of landforms ranging from river flats to rolling hillsides but mostly they require good drainage and therefore there is likely to be drainage channels etc close to the orchards. These drain into natural waterways or ponds. During periods of low flow, natural streams are likely to be shallow and 15 cm would appear to be a reasonable worst case. At other times they are likely to be deeper, ie 30-60 cm. The effect of increased water depth has not been considered.

While the above hazard calculations are for ponds, a ‘pulse’ of contaminated water is likely in flowing streams and the acute hazard calculations are used as an approximation of this ‘pulse’. For ponds receiving runoff from orchards or from streams near orchards, further dilution is expected and as these ponds are likely to be significantly deeper, the hazard should be reduced. As this depends on the other land uses in the area, hazard calculations for such situations are site specific and a general case is difficult to derive.

Other Orchard Spray Equipment
The efficacy report clearly identifies that spray equipment other than the high volume conventional sprayers is increasingly being used by orchardists. Table 43 gives the results for LV application, again from Table 14 and is for citrus, not pome fruit.

Distance downwind	Spray drift, % of appl. rate	EEC, in water 15 cm deep µg/L	Quotient,	
			daphnia, EC50 = 0.24 µg/L	mosquito larvae, LC50 = 1.6 µg/L
25	1.352	7.21	30.04	4.5
50	0.402	2.14	8.92	1.3
100	0.113	0.6	2.5	0.4
200	0.03	0.16	0.67	0.1
300	0.013	0.07	0.29	
400	0.007	0.04	0.17	

Table 43. Estimated concentration of spray drift from LV application using monocrotophos EC at 800 g ai/ha together with acute quotient for daphnia. Quotient is EEC/EC50. Dark shading is Q > 0.5, light shading = 0.1<Q >0.5.

Table 43 clearly shows that there is a significant hazard to daphnia and other very sensitive aquatic organisms from use of monocrotophos up to 300 metres away in citrus orchards from application as a low volume spray, with a high hazard at 100 metres. Using the other toxic end point in Table 42, there is a hazard up to 200 metres away and a high hazard less than 100 metres, quotients of 1.3 and 0.4 at 50 and 100 metres respectively. Note that this is based on application to citrus and is similar to the results in Table 39 based on orchard air blast equipment used in citrus. Given that the results for spray drift from pome fruits and low volume applications are similar in citrus, it is expected that for pome fruits low volume would be similar to the AgDRIFT model results in Tables 40-42.

Electrostatically charged sprays are expected to limit horizontal movement and localise the spray to surfaces in and beside the orchard. There is minimal use of this type of sprayer in Australia. The spray drift is expected to be less than that given in Tables 39-42.

11.3.5 Vegetable Applications by boom spray.

Recent literature reports have shown that as close as 1.7 metres to the spray boom there is less than 2% spray drift for ≥ 95% of insecticide applications using cone nozzles, even in winds of 20 km/hr (Longley, Cilgi, Jepson and Sotherton, 1997). Another figure used by Environment Australia for spray drift from boom spray 5 metres away from the site of application is 1%, based on studies done on herbicides (Marrs, Williams, Frost and Plant, 1989). It should be noted that these studies were performed using fan nozzles whereas insecticides are sprayed using cone type nozzles—it is expected that the cone nozzles produce a finer droplet and therefore this will underestimate the amount of spray drift that occurs. The SDTF results for boomsprayers show that using cone nozzles with a breeze of 18 km/h, there is 0.5% spray drift deposited at 30 metres from the sprayer. It should be noted that the results are for a cleared field and under normal conditions, with a crop in the field which is expected to trap the spray drift more effectively, a lower level of spray drift is expected. Based on these results Table 44 gives the quotients for daphnia and mosquito larvae for boom spray application at 2 L/ha (800 g ai/ha), the maximum rate for tomatoes, in 15 cm deep water.

Distance from boomsprayer	spray drift	EEC in water, μg/L	Quotient, mosquito larvae LC50 = 1.6 μg/L	Quotient, daphnia EC50 = 0.24 μg/L
1.7 metres	2%	10.7	6.7	44
5 metres	1%	5.35	3.3	22
30 metres	0.5%	2.2	1.4	11

Table 44. Quotient for daphnia and mosquito larvae at 800 g ai/ha for boom spraying. Figures are for 15 cm deep water. Dark shading is Q > 0.5, light shading = 0.1<Q >0.5

Table 44 clearly shows that the spray drift from boom sprayers is less that from orchard air blasters under the same conditions. Using similar arguments as before for orchards, using deeper water (30 cm), the quotient for the worst situation in Table 44 becomes 22 and at 30 metres 5.5 and the hazard is very high. There are uses on the label for lower rates but even allowing for 30 cm deep water and the lowest rate on the label, that for lucerne (250 mL/ha, 125 g ai/ha), the Q = 3.5 and 1.7 at 5 meters and 30 metres respectively for daphnia and Q = 0.52 and 0.22 respectively for mosquito larvae. At 280 g ai/ha, the median label rate for locust, the quotient for daphnia is 7.7 and 3.8 for 5 and 30 metres away respectively and Q = 1.2 and 0.5 respectively for mosquito larvae. The hazard is high and is of concern, especially at the higher rate. At the lowest rate for locust (140 g ai/ha) the hazard could be acceptable with suitable label statements for some aquatic invertebrates but not for the more sensitive species.

The AgDRIFT model for boom spraying has two types of boom sprays, a low boom and a high boom. The low boom spray is the typical tractor mounted boom spray at 40 cm (20 inches) and the high boom is 1.25 metres (50 inches) and is based on ultra low volume application, ie fine droplets. The high boom conditions are typical for sorghum, sunflowers and cotton use. Note that this is for the 90th percentile from the experiments run on the sprayers in a paddock in the US and that AgDRIFT has not yet received approval for use in the regulatory decisions in the US EPA. The results for application at 800 g ai/ha are given in Table 45 for both low and high spraying.

Spray type	Distance from Sprayer, metres	EEC	Quotient	
			D. magna 0.24 μg/L	*C. pipiens* 1.6 μg/L
Low boom	5	8.75	36.5	5.47
	15	4.69	19.5	2.93
	30	3.00	12.5	1.88
	100	1.12	5.04	0.76
High Boom	5	63.67	265	39.8
	15	30.63	128	19.1
	30	17.31	72.1	10.8
	100	4.68	19.5	2.93

Table 45. Quotient for D. magna and C. pipiens at 800 g ai/ha for boom spraying under two different use patterns. Figures are for 15 cm deep and are from AgDRIFT. Dark shading is Q .0>0.5.

As can be seen in Table 45, boom spraying presents a significant hazard to aquatic invertebrates from either high or low boom at the highest rate. Even allowing for the lower rates on the label, 280 g ai/ha and less, Table 45 indicates that a high hazard exists for *D. magna*, using the most sensitive endpoint. For *C. pipiens* at 140 g ai/ha the hazard is more acceptable at 30 metres for low boom spraying (Q = 0.33) but not for the most sensitive species. Note that the results from the AgDRIFT model in Table 45 are similar to those in Table 44, based on literature results. The hazard is more acceptable for low boom spraying at the lowest rate 140 g ai/ha, provided there are additional label warnings to minimise the hazard further.

As vegetable crops are grown on a very wide range of locations, including river flats, a number of vegetable plots are likely to be in close proximity waterways and drainage channels and therefore the application of monocrotophos by boom sprays could cause significant hazard to aquatic organisms. However, given that the distance at which there are possible effects on aquatic organisms is significantly less than for either aerial or orchard air blast sprayers, the hazard is more localised and less likely to significantly effect overall populations of invertebrates in the area. Use monocrotophos by boom sprayers may be acceptable, provided the application rates can be lowered to 140 g ai/ha and that a relevant label warning is added. However, it should be noted that a high hazard to birds remains for control of locusts in both cases (see Section 0).

This conclusion appears anomalous compared with that for use in apple and stone fruit orchards, it could be due to the fact that the orchard model is based on averaged results while the boom spray is for the 90th percentile. This underlines the caution needed with use of these models.

11.3.6 Other Uses

There are a range of other crops listed on the label, these include pastures, lucerne, a range of cereal crops and tree injections. The application methods used for these crops have been covered in the above hazard calculations and the conclusions therein apply. The exception is for tree injections, where providing the label instructions are followed and that all the product is contained within the holes drilled into the tree, the environmental hazard could be minimal.

11.3.7 Algae

Monocrotophos is rated as moderately toxic to one algal species (EC50 of 6.8 mg/L, see Section 0). As direct application to water is not expected and the spray drift studies show that the concentration in shallow water from aerial spraying on cotton at 50 m downwind is 32 µg/L for the 95 percentile, see Table 29, greater than two orders of magnitude below the algae EC50, effects on algae are unlikely.

11.3.8 Chronic Effects

Once in the aquatic environment, monocrotophos is not expected to persist for an extended period, but the degradation rate is considered dependent on the level of microbial activity. The field studies showed the degradation was fast in more biologically active waters, ie rice paddies, but slow in natural water. Monocrotophos in high microbially active aquatic systems is expected to degrade rapidly, with a half-life calculated as approximately 2 days under tropical conditions but this figure is not reliable as it is based on very limited data. There was no data for more typical agricultural sediment/water systems in temperate conditions. Chronic effects from spray drift cannot be ruled out.

Using the highest level of spray drift in the previous section, from Table 34 of 26.5 g/L, it takes 8 half lives to reduce the concentration in water to one tenth of the acute LC50 for *C. pipiens* and 10 half lives for the most sensitive results for *D. magna*. (Note that although there are no chronic effects data, a common 'rule of thumb' is to assume that chronic effects are approximately one tenth of the acute effect.) Using a half-life of 2 days, this corresponds to 12 days for *C. pipiens* and 16 for the daphnia. This very rough calculation shows that chronic and subchronic effects on aquatic invertebrates are possible from aerial applications but less likely from ground based applications.

11.3.9 Runoff and Leaching

Runoff from areas where monocrotophos has been applied could be significantly contaminated. The K_{oc} indicates weak binding to soil particles. Assuming that 10% of the application at 1.6 kg ai/ha (maximum rate for cotton) runs off during a rainstorm within 2 days of application, all the runoff is collected and forms a pond 15 cm deep and the area treated equals the area of the pond, then the concentration of monocrotophos in the pond water is 107 µg/L.

Using a more realistic figure of 5% of the applied monocrotophos runs off (Zubkoff, 1992), that only 10% of the catchment is treated with monocrotophos and the water is 30 cm deep, the concentration in the runoff water is 2.8 µg/L for the maximum rate in cotton (Further refinements would require computer modelling based on real world data of the catchment and land uses). The quotient for daphnia is high (12) and likewise for mosquito larvae (1.8) and a high hazard to aquatic invertebrates exists. Despite the rapid degradation in soil (half-life between 1-7 days), which will limit the time when runoff will be problematical, runoff from cotton areas treated with monocrotophos is likely to be hazardous to aquatic invertebrates.

A similar calculation as above using the lower rate for locusts control of 280 g ai/ha gives a concentration in runoff of 0.49 µg/L and while the hazard for daphnia and sensitive invertebrates is high, Q = 2, less sensitive invertebrates such as mosquito larvae will only be minimally effected, Q = 0.3. The hazard appear to be more acceptable but considering that runoff could be prolonged and therefore results in chronic exposure, the hazard is still considered to be high and of concern.

At the lowest rate for locusts control (140 g ai/ha) the hazard is more acceptable (half of the Q values above), although the hazard for very sensitive species remains high.

11.3.10 Multiple applications

The above analysis is for a single application but in practice there are expected to be multiple applications. According to the labels these are within 4 days for cotton (Ciba Geigy) or 10 days between applications (other labels); for sunflowers 7-10 days intervals; for sorghum, tomatoes and potatoes as required (in Victoria only 4 sprays per season) and for orchards within 10 days is minimum period given. It is expected that in most situations there would be at least 7 days between sprays. Given that the degradation rate in water is unknown, there could be a high hazard from multiple applications and a chronic hazard as well. As there is a high hazard from spray drift and further applications would increase that hazard, the hazard from multiple applications appears unacceptable.

11.3.11 Conclusions for Aquatic Hazard

Overall, there is a high aquatic hazard to sensitive invertebrates from spray drift for all aerial applications. There is moderate and just acceptable hazard for boom spray applications at rates of 140 g ai/ha, provided suitable measures to reduce spray drift are in place. There is also a potentially high hazard from runoff if rain occurs within days of application for rate > 280 g ai/ha.

Aerial Application
Apart from direct overspray, the hazard to fish is considered to be acceptable. However, using the figures from Tables 31-34, the hazard to aquatic invertebrates is unacceptable to beyond 300 metres for all aerial application rates when used according to the current label directions. At the lowest rate examined, 140 g ai/ha, the hazard to less sensitive aquatic invertebrates was acceptable at 300 metres but only with placement spraying (vmd 350 m). It should be noted that a high hazard exists from runoff at high rates as well.

The newly proposed Best Practices Manual for Cotton Growers[2] has a guideline for a buffer of 300 metres downwind for all aerial applications. While adoption of this would reduce the hazard to environmentally sensitive areas, additional measures such as reduced applications rates and placement spraying is required to reduce the hazard to more acceptable levels. As it is unlikely that the rates in cotton can be reduced sufficiently, aerial application of monocrotophos to cotton is likely to cause significant impacts on aquatic invertebrates 300 metres and beyond from the application site and is therefore unacceptable.

As most other crops do not have a best practices guideline and the condition of use is up to the individual grower, current aerial application to other crops is considered unacceptable for all rates. However, if the rates could be lowered to 140 g ai/ha and placement spraying is used, then the hazard may be moderated to being just acceptable.

In conclusion Environment Australia considers that an unacceptable hazard exists through aerial application of monocrotophos, due to both spray drift and runoff, when use according the current label. While we are not aware of any actual aquatic mortality incidents due to monocrotophos, continued regular use of monocrotophos according to the current label is difficult to defend, based on the risk assessment. Environment Australia cannot support its continued use by aerial application, except at the lowest rate together with other mitigating factors such as large droplets and buffer zones.
Orchard Air Blast Equipment
The analysis using the AgDRIFT for spray drift from the US EPA showed that for apple and stone fruit orchards, the spray drift from orchard air blast sprayers is acceptable. For larger trees and dormant spraying the hazard was high and extended to beyond 100 metres from the orchard. From the agricultural assessment and other information, the use on pome fruit orchards is declining with the introduction of IPM. To encourage IPM, all uses in orchards should be removed from all labels. Environment Australia notes that this is already the case with the label from Ciba-Geigy.

Boom Sprayer
Tables 43 and 44 clearly shows that the spray drift hazard to aquatic invertebrates from boom sprayers is high, especially at the higher application rates. However, as it is expected that in the vast majority of cases that crops are unlikely to be within 30 metres of waterways, use of monocrotophos by boom

sprayers may be acceptable provided that the rates are reduced to 140 g ai/ha. In addition, the growers should not use monocrotophos near or under conditions that allow for drift onto waterways or other sensitive areas. Runoff remains a potential problem for rate >280 g ai/ha and Environment Australia cannot support the use of monocrotophos by boomspray unless the rate is reduced.

11.4 Desirable terrestrial vegetation

As direct application to desirable terrestrial plants and vegetation is not expected and monocrotophos is non-phytotoxic when used as directed (Tomlin, 1994), although some varieties of apples, pears, peach, cherry and sorghum may suffer slight injury, significant effects on desirable plants are considered unlikely.

11.5 Hazard arising from formulation, handling and disposal

The hazard from formulation of the TGAC in Australia is expected to be minimal. As this is expected to be done in suitable facilities, with relevant environmental controls to limit environmental exposure and with waste water treated before discharge to the environment—monocrotophos is expected to degrade during normal sewage treatment (a very high microbial system)—the environmental hazards are expected to be minimal. Any spills are expected to be cleaned up and treated according to the MSDS.

12 CONTROLS/LABELLING

Use of monocrotophos in Australia is to be phased out over a year with all sales to stop on 31 December 2000. No commitment to provide data was given and products and the active constituent registrations were cancelled on 9 December 1999. Therefore, no controls or labelling changes are necessary.

13 CONCLUSION

Monocrotophos is an organophosphate and is extremely toxic to aquatic invertebrates, birds and mammals. It is used to control a wide range of chewing, sucking and boring pests (aphids, caterpillars, helicoverpa spp, mites, moths jassids, budworm, scale and stem borer) as well as locusts. Monocrotophos is not compatible with IPM programs. It seems to be used mainly as a back-up spray when insect pressure and resistance levels are high.

Monocrotophos is readily degradable in soil and could degraded in aquatic environments but this appears to be dependent on the level of biological activity. It is unlikely to persist beyond 1 week following application in soil. Bioaccumulation is not expected. Due to the very rapid degradation in soil, leaching is not expected despite laboratory studies suggesting high mobility.

The chemical is extremely toxic to birds, mammals and aquatic invertebrates. Its toxicity to birds when it is incorporated into the diet is very high. There are a number of reports from overseas and anecdotal Australian reports on large numbers of bird kills having occurred from use of this chemical. The overall hazard to birds appears high and unacceptable, especially to birds that consume insects, seeds etc that are directly oversprayed by the chemical. Use of monocrotophos to control locusts at the higher rate (280 g ai/ha) is likely to represent a very high hazard to avian predators of locusts and is unacceptable. At the lowest label rate for small locusts (140 g ai/ha) a high to moderate hazard was indicated based on the toxicity testing. However, as there was some indication of an increased sensitivity of the raptors, a significant hazard cannot be ruled out when used for locusts control, despite the low rate. Anecdotal evidence also suggests significant bird mortalities occur after use in cotton and for locust control in Australia.

The weight of evidence indicates use of monocrotophos poses a high hazard to birds, and it is difficult to defend its continued use. Unfortunately most of the evidence is old and from overseas, with local reports of consistent bird mortality largely anecdotal though derived from a number of sources.

Mammals are not expected to be significantly exposed to the chemical unless they enter an area recently sprayed. However, the direct application of monocrotophos to aquatic systems is expected to significantly effect aquatic invertebrates.

Apart from direct overspray, the hazard to fish is considered to be acceptable. However, the hazard to aquatic invertebrates is unacceptable to beyond 300 metres for all aerial application rates when used according to the current label directions. At the lowest rate examined, 140 g ai/ha, the hazard to less sensitive aquatic invertebrates was acceptable at 300 metres for but only with placement spraying (vmd 350 m). It should be noted that a high hazard exists from runoff at rates > 280 g ai/ha.

The newly proposed Best Practices Manual for Cotton Growers[2] has a guideline for a buffer of 300 metres downwind for all aerial applications. While adoption of this would have reduced the hazard to environmentally sensitive areas, additional measures such as reduced applications rates and placement spraying would have been required to reduce the hazard to more acceptable levels. As it is unlikely that the rates in cotton could be reduced sufficiently, aerial application of monocrotophos to cotton was likely to cause significant impacts on aquatic invertebrates 300 metres and beyond from the application site and use is therefore considered unacceptable. As most other crops do not have a best practices guideline and the conditions of use are up to the individual grower, current aerial application to other crops is considered unacceptable for all rates. However, if the rates could have been lowered to 140 g ai/ha and placement spraying used, together with conditions of use such as those for cotton, then the hazard may have been moderated to being just acceptable.

Calculation for the spray drift from conventional high volume orchard air blast equipment shows there is a high hazard to daphnia up to 200 metres away in shallow water at the highest rate (800 g ai/ha) and only decreases to acceptable levels at 300 metres away. For less sensitive aquatic invertebrates, there is a high hazard at 50 metres, which decreases to an acceptable hazard at 200 metres away. It should be noted that this is based on citrus orchard spray drift data and a lower hazard is expected for orchards with less dense foliage, ie pome fruit trees.

Using the US EPA AgDRIFT model shows that the spray drift from conventional air blast spraying of pome and stone orchards is acceptable at 25 metres for most aquatic invertebrates and for the most sensitive invertebrate at 100 metres away. For other orchards crops, ie tall trees and citrus, the spray drift was high and the hazard unacceptable up to 200 metres away for a number of aquatic invertebrates. In addition, the AgDRIFT model showed that dormant spraying of apples gives a similar level of drift as for tall trees and citrus and is therefore considered unacceptable. It should be noted that this model is fitted to experimental data from a range of orchards and is therefore considered to be of high quality. However, the orchard results are for the average situation, not worst case, and therefore the results from the model may not be fully protective of the environment.

Given that there is a broad range of locations where pome fruit orchards are situated and that a number are expected to be close to waterways, the hazard is considered to be moderate for modern style orchards with smaller trees and close planting. However, for other orchards crops, especially those with tall trees, and for dormant spraying the hazard is high and unacceptable. While the degradation of monocrotophos is expected to be rapid, there was no reliable data on the rate of hydrolysis and it is unknown how long the toxicity will last.

The spray drift hazard from boom sprayers is less that from orchard air blasters under the same conditions but a significant hazard to aquatic invertebrates remains. The AgDRIFT model for boom sprayers showed that at the higher application rates (800 g ai/ha), there was a hazard to aquatic invertebrates within 100 metres of the boomsprayer. The spray drift hazard to the sensitive aquatic invertebrates species extends to beyond 100 metres. However, at 280 g ai/ha the model showed that the hazard is acceptable at 100 metres and just acceptable to 30 metres. As it is expected that in the vast majority of cases that crops are unlikely to be within 30 metres of waterways, use monocrotophos by boom sprayers might have been acceptable provided that the rates were reduced to below 280 g ai/ha. In addition, there would have needed to be a label statement to prevent growers from using monocrotophos near by or under conditions that allow for drift onto waterways or other environmental sensitive areas.

Runoff is a potential problem and calculations showed that runoff from treated areas could cause acute toxic effects to sensitive aquatic invertebrates. As there were no chronic aquatic studies, default values were used in calculations which showed that chronic effects to a wide range of aquatic invertebrates were possible. The hazard due to runoff from areas treated with monocrotophos according to the current labels is high and considered unacceptable.

In conclusion, there is a high hazard to birds from the current use of monocrotophos when avian food items are sprayed. Spray drift from aerial and orchards air blast spraying represents a significant hazard to aquatic invertebrates. Runoff from recently treated areas was identified in the hazard assessment as being hazardous to aquatic invertebrates from both acute and chronic toxic effects. While the NRA is aware of no actual aquatic mortality incidents, anecdotal reports of wide spread bird deaths are a clear indication that unacceptable birds mortalities do occur. The weight of evidence indicates use of monocrotophos poses a high hazard to birds, and it is difficult to defend its continued use. Clearly aerial application should be banned or at the very least severely restricted as there are less toxic chemicals available.

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Part I - Effect on nodulation of Pinto beans and on the nitrogen fixation bacteria.
Part II - Effect on decomposition of cellulose in soil.
Part III - Effect of compounds on the populations of microorganisms and the O_2 /CO exchange in treated soil.
Part IV - The effect of compounds on soil nitrification.
Part V - Details of methods used in part II.

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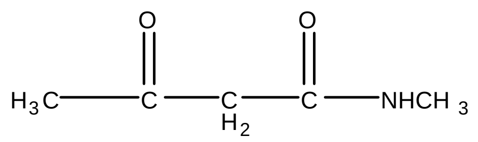
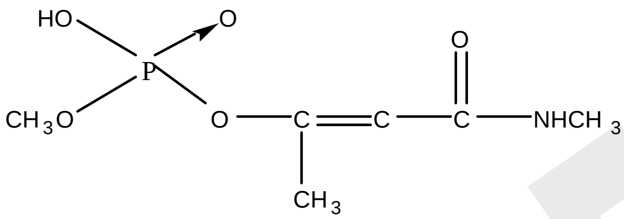
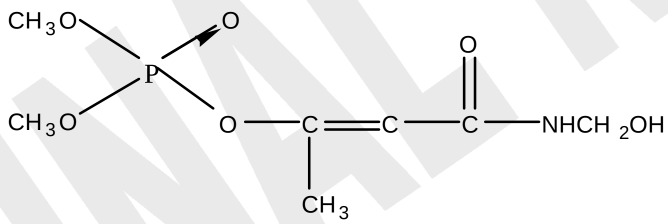
APPENDIX 1



Acetoacetamide, N-methyl, SD 9112



SD 11191, Monodesmethyl monocrotophos
Crotonamide, 3-hydroxy-N-methyl, metyl hydrogen phosphate



SD 12657,
3-Hydroxy-N-hydroxymethyl-cis-crotonamide, dimethyl phosphate