Australian Government

Australian Pesticides and Veterinary Medicines Authority

CHEMICAL REVIEW PROGRAM

Environmental assessment report

Of

Fenamiphos

This Report was prepared for the APVMA by

Chemical Assessments Section,
Environment Protection Branch

of the

Department of Sustainability, the Environment, Water, Population and Communities

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Executive Summary

Fenamiphos is an organophosphate (OP) insecticide with particular activity towards soil borne parasitic nematodes. Environmental chemistry, fate and ecotoxicity data for the evaluation were provided by the Australian Pesticides and Veterinary Medicines Authority (APVMA) following their data call-in notice for fenamiphos. Additional data on the environmental fate, ecotoxicity and use of fenamiphos were obtained by the Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC, previously the Department of the Environment, Water, Heritage and the Arts) from Internet searches and other available literature.

Environmental fate

Fenamiphos and its main metabolite, fenamiphos sulfoxide (M01), are hydrolytically stable within the environmentally relevant pH range. In aqueous systems and on soil, breakdown of fenamiphos through photolysis is relatively quick (half-life <1 day). However, while the parent compound itself may not persist, it is rapidly converted to its M01 metabolite that appeared much more stable to photolysis (half-life up to 96 days with a 12:12 hour light:dark day).

In soil, fenamiphos is rapidly oxidised to M01 and then further oxidised to fenamiphos sulfone (M02). While half-lives of the parent compound in soil may be short (generally <1 week), loss of residues as the combined parent and M01 (a substance also biologically active), are much greater. Degradation often appeared biphasic. One study showed first half-lives from 6.1-17.5 days with second half-lives from 50-78 days. A second study with 16 soils at three temperatures showed degradation half-lives of combined fenamiphos and M01 residues averaging 66.3, 36.0 and 26.2 days at 16°C, 22°C and 28°C, respectively.

Volatilisation from the soil was shown to be negligible based on one laboratory study. Laboratory and modelling data showed fenamiphos to be moderately mobile in soil, but unlikely to leach significantly to groundwater. M01 was shown to be a mobile metabolite capable of leaching to groundwater. These findings were supported to some degree with a field dissipation study showing no movement of fenamiphos below 0-15 cm. M01 was the most mobile metabolite and the one produced in the largest quantities. Following a second application, M01 was found at the 45-60 cm layer with some detection as low as 75-90 cm. The field dissipation study showed half-lives for fenamiphos (16-17 days) longer than those found in the laboratory, while M01 was again more persistent with field half-lives of 71-77 days. Several groundwater monitoring studies confirm these findings.

Where conditions are suitable for leaching, fenamiphos residues (particularly as the M01 metabolite) can leach to groundwater. Soil half-lives as measured in the groundwater studies were generally biphasic. M01 was more persistent than parent fenamiphos. In three studies, fenamiphos had a first phase half-life of 3.4–14 days and a second phase half-life of 17.3–498 days. By contrast, M01 had a first phase half-life of 6.8–126 days and a second phase half-life of around 151–495 days. In one study, degradation followed first order kinetics with a half-life of 33 days for fenamiphos and M01, and 42 days for M02. The half-life in this study for total residues was 34 days. Residues were more persistent in the subsoil (>15 cm) than in the top 15 cm of soil.

Where released to water, fenamiphos may move to sediments where it will degrade slowly. In an aerobic system, the half-life in water was relatively short (<8 days) whereas that for the whole system was much slower (up to 111 days). In an anaerobic soil/supernatant water system, most of the parent was retained in the soil while significant amounts of M01 moved from the soil to the water phase. The degradation of fenamiphos under anaerobic conditions was relatively slow with a half-life estimated to be around 90 days.

Fenamiphos may bioconcentrate in exposed aquatic organisms to a moderate degree, but data provided show it to rapidly depurate once exposure ceases. Testing with earthworms suggests the substance will not bioconcentrate in these organisms.

Environmental toxicity

Fenamiphos and its major metabolites, M01 and M02, were very highly toxic to birds based on acute oral studies. While no toxicity data were available to birds for the two main metabolites for short-term dietary exposure or under chronic test conditions, fenamiphos was again shown to be very highly toxic to birds when consumed through the diet. Two reproduction studies (mallard duck and bobwhite quail) provided showed the main adverse effect being related to 14-day survivors in both studies with the lowest no observed effect concentration (NOEC) of 1.8 ppm (bobwhite quail).

Acute testing on fish resulted in relatively consistent LC_{50} values, indicative of very high toxicity to fish. The metabolites tested were substantially less toxic to fish than the parent compound. M02, the most toxic metabolite, was considered moderately toxic based on a single test to one species with an LC_{50} of 1200 µg/L. Only one longer-term fish study was provided (rainbow trout, early life stage) with exposure to fenamiphos. A NOEC of 3.8 µg/L from this study confirms fenamiphos as being highly toxic to fish.

Very few data were provided for aquatic invertebrates and only one standard study was provided using the parent compound. The results again show fenamiphos to be very highly toxic to *Daphnia magna* (LC_{50} 1.9 µg/L). M01 and M02 were also very highly toxic to aquatic invertebrates based on one study each to *D. magna*. Other metabolites tested (fenamiphos sulfoxide phenol, M12; fenamiphos sulfone phenol, M13; and fenamiphos phenol sulfonic acid, M24) were much less toxic (slightly to practically non-toxic). One study was provided for chronic toxicity to *D. magna* with a resulting NOEC of 0.12 µg/L and EC_{50} of 0.36 µg/L, again showing very high toxicity.

Only one study was provided for fenamiphos, M01 and M02 to a single algal species. Fenamiphos was moderately toxic while the metabolites were less toxic than the parent compound, with M01 being practically non-toxic and M02 being slightly toxic.

Fenamiphos and M01 were tested for toxicity to the sediment dwelling midge, *Chironomus riparius*. In the fenamiphos study, a very steep dose-response curve was observed and the NOEC for development was 20 µg/L with the EC_{50} falling between 20-40 µg/L (very highly toxic). M01 was also considered very highly toxic with a NOEC of 58 µg/L and EC_{50} of 95 µg/L.

A mesocosm study was undertaken where mesocosms were stocked with mature bluegill sunfish (15 males and 15 females per pond). The main initial effect was mortality of the fish at test concentrations >3.5 µg/L resulting in secondary effects on mesocosm structure. The NOEC was 3.5 µg/L.

Fenamiphos is very toxic to bees through both the oral and contact exposure routes. Several studies were performed on a range of non-target terrestrial arthropods with significant effects on adult mortality and reproduction at levels well below field spray rates (less than 1% of field spray rates). Based on soil-dwelling arthropod (Collembola) results, M01 and M02 were of a similar order of toxicity as the parent fenamiphos while M12 and M13 are less toxic. Fenamiphos demonstrated sublethal toxicity to earthworms at very low soil concentrations. In one acute study, the LC_{50} of fenamiphos was 888 mg/kg dw compared to a NOEC of 0.032 mg/kg dw based on worm weights. In a chronic 56-day study, numbers and biomass of offspring were significantly reduced at all application rates (NOEC <6 kg ac/ha). In a field study, some earthworm species were negatively affected by fenamiphos applications at 10 and 40 kg ac/ha (the only two rates trialled). Effects were noted up to 3 months after application.

Testing on soil microorganisms indicates no adverse impact on the soil nitrogen cycle up to 133 mg/kg dw soil (highest rate tested) is expected. However, some temporary increase in nitrate production may occur at these levels. A single screening level seedling emergence study at application rates up to 15 kg ac/ha showed no phytotoxic effects on all plant species tested (11 species consisting of 6 dicots and 5 monocots).

Environmental risk

Risk assessment based on current uses on labels considered for this review resulted in a potentially unacceptable risk to birds, aquatic organisms and terrestrial organisms including non-target arthropods and earthworms for the majority of approved use patterns for fenamiphos. With current information, mitigation of the risks associated with fenamiphos use is very difficult because:

- fenamiphos has been shown to be highly toxic to organisms in the environment
- while fenamiphos converts relatively rapidly to a major metabolite, this metabolite has been shown to be biologically active and toxicity to a number of environmental organisms is not remarkably less than the parent compound
- overall removal of fenamiphos and its metabolites from environmental media does not occur quickly. Therefore, the use of time-weighted average exposure concentrations does little to mitigate exposure and potential risk, particularly where repeat applications to crops occur.

Additionally, fenamiphos and its metabolites have been shown to leach to groundwater where conditions favourable for leaching exist. There is no information relating to likely vulnerable leaching sites in areas where fenamiphos is used to refine this component of the risk assessment.

Based on current information, DSEWPaC concludes the APVMA cannot be satisfied that use of fenamiphos in accordance with label instructions would not be likely to have an unintended effect that is harmful to animals, plants or things or to the environment. With the exception of two minor use patterns (mushrooms and strawberries), DSEWPaC has recommended cancellation of current fenamiphos uses.

1 Introduction

Fenamiphos is an organophosphate (OP) insecticide with particular activity towards soil borne parasitic nematodes, and to a lesser extent, sucking insects such as aphids and thrips.

In April 2003, the APVMA initiated its reconsideration of the approvals of the active constituent fenamiphos, the registrations of products containing fenamiphos, and the approvals of associated labels. The scope document states that the APVMA will review a wide range of aspects of active constituent approvals, product registrations and label approvals for fenamiphos, including the environment:

- acute toxicity to birds
- potential for groundwater contamination.

In order to assist the environmental risk assessment, large quantities of data have been provided to the APVMA. The environmental dossier provided by the main registrant was initially identical to that submitted to the European Union authorities in April 2002. At the request of DSEWPaC (then the Department of the Environment and Heritage), this was later supplemented with studies previously submitted to the United States Environment Protection Authority (US EPA) as part of the assessment of fenamiphos under the re-registration program. These studies, as well as selected studies published in the literature, have been assessed in this report.

Due to the large number of test studies reviewed in undertaking the assessment, this report is structured in the form of an overview report where study and literature data are summarised and the risk assessment is provided, and two technical reports addressing the environmental fate and environmental toxicity test data respectively. Readers should refer to the respective technical reports to obtain detailed information on test conditions and findings. Some metabolites are identified throughout the report. For representative structures, readers should refer to Appendix 1.

2 Chemical identity

Common name: Fenamiphos

Chemical name: Ethyl 3-methyl-4-(methylthio)phenyl-(1-methylethyl) phosphoramidate

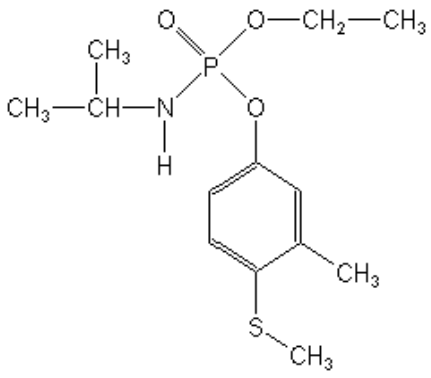
Trade and other names: Nemacur

Chemical family: Organophosphate

CAS registry number: 22224-92-6

Empirical formula: $C_{13}H_{22}NO_3PS$

Structural formula:



Molecular weight: 303.4

3 Physical and chemical properties

Reports for these were not submitted though results and references for many properties are available in the hydrolysis study of Arthur et al. (1999). These and data from other sources are summarised below.

Appearance:	Colourless crystals, technical material is a tan waxy solid (Tomlin, 2003)
Melting point:	49.2°C, technical 46°C (Tomlin, 2003)
Density:	1.191 at 23°C (Tomlin, 2003)
Vapour pressure:	0.12 X 10^{-3} Pa at 20°C (Tomlin, 2003)
	4.7 X 10^{-5} mmHg at 20°C (US EPA, 2002, Talbott and Mosier, 1987)
Water solubility:	400 mg/L at 20°C (Tomlin, 2003)
	558 mg/L at 20°C (Battor, Roith and Clay, 1984)
Partition co-efficient:	LogKow = 3.30 at 20°C (Tomlin, 2003)
Henry's law constant:	9.1 X 10^{-5} Pa m^3/mol at 20°C (Krohn, 1995)
	9.1 X 10^{-10} Atm m^3/mol at 20°C (Krohn, 1995)
	3.4 X 10^{-8} Atm m^3/mol at 20°C (Talbott, 1987)

According to the definitions of Mensink et al. (1995), fenamiphos is slightly volatile but moderately soluble in water. The Henry's Law Constant indicates it is very slightly volatile from water (Mensink et al., 1995). Tomlin (2003) also indicates it is soluble in dichloromethane, 2-propanol and toluene (>200 g/L), but only slightly soluble in n-hexane (10-20 g/L, all at 20°C).

4 Overseas regulatory activity

The APVMA scope document for the fenamiphos review summarises the international regulatory activity, as follows with some more recent information included.

United States

The United States Environmental Protection Agency (US EPA) has assessed the risks of fenamiphos and prepared an Interim Reregistration Eligibility Decision document for this pesticide (http://www.epa.gov/REDs/fenamiphos_ired.pdf). The report identifies risk mitigation measures needed to reduce risk, as well as data needed to better characterize risks.

After releasing the report, the US EPA announced (27 September 2002) the voluntary cancellation of all registered products containing fenamiphos. This action was apparently the result of a decision of the registrant to withdraw from the market, rather than meet the data requirements of the report.

Fenamiphos residues in food do not pose risk concerns; however, exposure to shallow water tables (less than 50 feet deep) and extremely vulnerable soils do pose risk concerns.

Although fenamiphos is not used in residential settings, golf course uses could lead to golfer exposure from residues on treated courses. EPA feels that the watering-in of fenamiphos following its application according to label directions adequately protects golfers from exposure.

The US EPA risk assessment showed acute and chronic risks exceed the Agency's level of concern for terrestrial, aquatic, and endangered species.

The following risk mitigation process was developed:

- The registrant has requested voluntary cancellation of existing fenamiphos product registrations.
- The registrant has agreed to cancel use, and formulation for use, of all of its existing fenamiphos registrations in areas with extremely vulnerable soils and shallow water tables effective as of May 31, 2005. Cancellation for use on all other soils will be effective as of May 31, 2007.
- For Manufacturing-use products ONLY -- all sale, distribution and use of existing stocks shall be prohibited for manufacturing, effective as of May 31, 2007.
- For End-use products ONLY -- all sale and distribution by Bayer of existing stocks shall be prohibited effective as of May 31, 2007. Sale and distribution of existing stocks by persons other than Bayer continue until May 31, 2008. Use of end-use products in the channels of trade may continue until depleted, except where prohibited on the label.
- Revised labels for all fenamiphos products have been submitted to the Agency in accordance with the registrant's request for an amendment of all of its existing registrations. Use of stocks in the channels of trade may continue until depleted, except where prohibited by the revised labels.
- The registrant has also agreed to produce no more than 500,000 pounds of fenamiphos manufacturing use products for use in the United States the first year of the phase out which ends May 31, 2003. Each subsequent year of the 5 year phase out, production will be reduced by 20% of the previous year's production.

European Union

The environmental dossier was submitted to the European Union authorities in April 2002.

The Netherlands, being the designated rapporteur Member State, submitted the draft assessment report on fenamiphos to the European Food Safety Association on 27 November 2003, and this information is obtained from their report. Following a quality check on the report, the peer review was initiated on 4 March 2004 by dispatching the report for consultation of the Member States and the applicant. Subsequently, the rapporteur Member State examined the comments received on the report and the need for additional data was agreed in an evaluation meeting on 27 September 2004. Remaining issues as well as further data made available by the notifier upon request were evaluated in a series of scientific meetings with Member State experts in April and May 2005.

A final discussion of the outcome of the consultation of experts took place with representatives from the Member States on 30 November 2005.

Fenamiphos can be used as nematicide and insecticide. However, during the peer review process the applicant stated that only the use as nematicide would be supported in the European Union review programme.

There were only two representative uses as nematicide as proposed by the applicant, comprising application by drip irrigation and ‘chisel application’ (spray application followed by incorporation into the soil) in bell peppers and tobacco, respectively. The application rates are 10 kg fenamiphos per hectare in bell pepper and 6 kg per hectare in tobacco.

Critical areas of environmental concern included:

- A high potential for ground water contamination by the metabolites of fenamiphos (and high acute toxicity of some of these metabolites);
- A high potential risk to fish-eating birds and mammals was identified based on FOCUS step 2 surface water PEC values for both representative uses.
- A high potential risk to fish and aquatic invertebrates was identified based on FOCUS step 2 surface water PEC values for both representative uses.
- A high risk to earthworms and other soil macro-organisms for the use in tobacco.

- A high risk to soil non-target microorganisms for the use in tobacco.
- Particular conditions proposed to manage the risk(s) identified included:
- The use of fenamiphos on bell peppers should be restricted to those greenhouses, which consist of permanent structures to protect terrestrial vertebrates.
- For the use in glasshouses the risk to earthworms and other soil organisms should be considered at Member State level.
- A waiting period before replanting or sowing of 8 months is advised for uses in the field.

5 Environmental exposure

As noted above, fenamiphos is an organophosphate (OP) insecticide with particular activity towards soil borne parasitic nematodes, and to a lesser extent, sucking insects such as aphids and thrips.

Based on information provided to the APVMA in response to a data call-in, the quantity of fenamiphos used in Australia in 2001 across the four products registered at that time was <40 tonnes. Use in 2000 and 2002 was well below this figure.

5.1 End use products

There were only 4 registered products containing fenamiphos at the time the scoping document was published in April 2003. Two of these were granular (GR) and two were emulsifiable concentrate (EC) formulations. The number of situations where these products are used is quite extensive.

Of the EC formulations, both containing fenamiphos at 400 g/L, one product includes use on bananas, citrus, grapevines, ornamentals, pineapples, potatoes, sugar cane, tobacco and tomatoes; whereas the other is limited to turf.

Likewise, the granular formulation containing 100 g/kg fenamiphos is also used in a wide variety of situations including the above except for citrus, grapevines and tobacco. By contrast, one granular product was registered for use only in the home garden on crucifiers, ornamentals and tomatoes.

Since the publication of the scoping document, fourteen additional products have been registered, all of which are 400 g/L EC formulations.

5.2 Application rates and use patterns

The following tables provide a distilled version of the approved uses of fenamiphos in Australia in liquid and granular form respectively. Except where noted the pests are soil borne plant parasitic nematodes. Application rates are in terms of product whereas the maximum rate has been calculated in terms of active constituent.

For the liquid formulation the maximum rate is 30 kg ac/ha as an overall treatment to citrus, followed by 24 kg ac/ha for aloe vera (overall treatment) and bananas (injected into the irrigation system–rate is probably actually much lower–see below). The rates for overall treatment for both the liquid and granular formulations on ornamentals are also high (range 12.5–25 kg ac/ha), with many other liquid rates being in the range 9.6-12 kg ac/ha. Exceptions are chrysanthemums (0.4 kg ac/ha), pineapples (maximum 4.8 kg ac/ha), potatoes (maximum 5.5 kg ac/ha, liquid rate), sugar cane (4 kg ac/ha) and turf (4.4 kg ac/ha). Granule rates are generally lower, particularly when these often are per treated hectare, with in many cases the whole area not being treated (such as band application). There are a couple of dipping products (aloe vera and banana planting material), whereas for mushrooms either the compost or the casing is treated.

Aerial application is unlikely, but is not expressly forbidden on the labels.

‘General instructions’ indicate that fenamiphos in liquid form should be applied to the soil surface by boom spray using flat fan nozzles and not exceeding 200 kPa to avoid spray drift. It should only be applied while the soil is moist at the surface after rain or irrigation, unless it is incorporated. Irrigation or rainfall is generally required within 24 hours of application to a soil surface. If applied pre-planting, fenamiphos should be incorporated to 10 cm as close to spraying as possible using a rotary hoe or discs.

In many cases a band treatment option is also approved for the liquid form (bananas, vegetables, perennial ornamentals, bulbs, pineapples, strawberries and tomatoes), while this is the sole option

for potatoes, sugar cane and tobacco. If banana rows are 2.5 metres apart, applying a 1-metre band spray close to the base of the stools, there would be 1 metre treated area and about 1.5 metre untreated, i.e. $^{1}/_{2.5}$ or about 40% of the total crop area would be treated. As a result, at 600 mL/100 m row the rate per hectare is 600 X 40/1000 or 24 L product/ha, equivalent to 9.6 kg active constituent (fenamiphos)/ha. Even the rate of 60 L product/ha of wetted area is expected to involve much less than 24 kg active constituent/ha as only a relatively small proportion per hectare would be wetted.

For treatment of vegetables, bulbs, strawberries, tobacco and tomatoes, the maximum application rate is 24 L product/ha with a band rate of 16 mL product per 10 m row. If it is assumed that the band width is 60 cm (as per label instructions) and there is a 1 m row spacing there will be 100 rows per hectare and at 160 mL per 100 m row the rate will be equivalent to 16 L product/ha, which correlates well with the 24 L product/ha for overall treatment, taking into account the 40% that is not treated. A narrower row spacing will increase the rate somewhat, but not above the overall treatment rate. Similar considerations apply for perennial ornamentals, though at twice the rate, and for pineapples at about half the rate.

For grapevines only the full width of the inter-vine row is treated. This means that in vineyards, typically planted at 3 to 3.5 metre row spacing with spraying no closer than 50 cm wide either side of the vines, about $^{2}/_{3}$ of the total crop area will be sprayed. It seems clear from the label that the 30 L/ha refers to a hectare of vines, and not treated hectare.

For use by trickle irrigation, watering (on citrus, grapevines, ornamentals, strawberries and tomatoes) should be commenced to moisten the soil prior to the product being injected into the system over as long a period as possible (minimum 30 minutes). Only for bananas is low-pressure mini-sprinkler or micro-spray irrigation allowed.

Table 1 – Liquid formulations use summary

CROP	RATE (product)	MAXIMUM RATE (kg/ha)	COMMENTS
Aloe vera planting material	1 L/100 L water	-	Immerse air dried or cured cups in dip solution for 30 minutes
Aloe vera	30 L/ha before planting or maintenance; 60 L/ha for infested established crop	24	Apply as an overall treatment by conventional spray–chemical must be washed off plant foliage within half an hour of treatment
Banana planting material	100 mL/100 L water	-	Immerse pared planting material in dip solution for 10 minutes
Bananas (QLD tropical areas), WA (Kimberley only)		24 (per wetted hectare) 9.6 (band)	For previously untreated ratoons, or when retreatment is late, or where nematode populations are high: Remove weed and trash and preferably apply just prior to, or just after the wet season (Dec or April).
	600 mL/100 m of row, OR		For row treatment apply to a 0.5 m band each side of the centre line
	6 mL per stool, OR		For individual stool treatment apply evenly in an area of 1 m^2 around the stool
	6 mL/m^2 of wetted area, OR		For low pressure mini-sprinkler or micro-spray irrigation, inject 6 mL of 400 g/L EC into the irrigation water for each m^2 of wetted area. Assume at least 1 m^2 is wetted for each metre of single row planted.
	60 L/ha of wetted area metered into the irrigation water[a]		For low pressure mini-sprinkler or micro-spray irrigation, meter 60 L of 400 g/L EC into the irrigation water for each hectare making same assumptions as above. For maintenance apply 3 treatments (as above and in August) at half this rate.
Bananas (QLD sub-tropical and NSW)	600 mL/100 m of row, OR	24	For row treatment apply to a 0.5 m band each side of the centre line with a tractor mounted boom
	6 mL/m^2 of wetted area		Inject 6 mL of 400 g/L EC for each 1 m^2 of wetted area using low pressure irrigation, e.g. drip, mini-sprinkler
Citrus	Initial rate 75 L/ha OR 7.5 mL/m^2 wetted area by trickle irrigation	30	Apply as an overall treatment or injection in spring and irrigate with at least 50 mm water (half this rate is used for maintenance)
Crucifers (e.g. cabbage, cauliflower, broccoli, turnip & Swedes)[b]	24 L/ha	9.6	Apply as an overall treatment pre-planting

CROP	RATE (product)	MAXIMUM RATE (kg/ha)	COMMENTS
Vegetables (beetroot, carrots, celery, cucurbits, endive, lettuce, onions, parsnips, sweet potatoes)[b]	24 L/ha OR 16 mL/10 m of row	9.6	Apply as an overall treatment pre-planting or pre-transplanting Apply on a 60 cm band pre-planting or pre-transplanting
Grapevines	30 L/ha; OR Trickle irrigation at 3 mL/m^2	12	Apply late September to moist soil of full width of cleared inter-vine row using a boom spray. Incorporate as soon as possible to a depth of 10-15 cm and no closer than 45 cm to the row. After treatment irrigate with 30-50 cm water. Apply to wetted area in late September
Mushrooms	65 mL/20 L water per tonne compost; OR 55 mL per tonne compost; OR 10 mL/bale of peat weighing 50-60 kg; OR 55 mL/tonne casing	-	Before peak heating at the last turn–set the spray in a Cook free-flow compost machine and apply while compost is being turned. After peak heating dilute in a convenient volume of water and spray compost Dilute in the volume of water per bale to prepare casing and incorporate thoroughly–do not treat both casing and compost
Ornamentals (annual)[b]	24 L/ha; OR Trickle irrigation at 16 mL/10 m of row	9.6	Apply as an overall treatment pre-planting Inject into irrigation system from 7 days before to time of transplanting
Ornamentals (perennial), nursery root stock[b]	Up to 48 L/ha in areas of known heavy infestation); OR Up to 32 mL/10 m of row	19.2	Apply as an overall treatment each spring and early autumn. The chemical must be washed off plant foliage by overhead sprinkler irrigation within 30 minutes of application. Apply each spring and early autumn–use highest rate in areas of known heavy infestation
Bulbs[c]	24 L/ha OR 16 mL/10 m of row	9.6	Apply as an overall treatment pre-planting Apply on a 60 cm band pre-planting or pre-transplanting
Chrysanthemums[d]	100 mL/100 L water OR 1 L/ha	0.4	Apply at 14 days intervals from the first sign of infestation using hollow cone nozzles. Use per hectare rate unless spraying to runoff.
Pineapples	Pre-plant bed treatment–250 mL/100 m of bed for a 1 m wide band	4.8	Apply evenly to moist soil at the final bed preparation stage choosing and adjusting a band width (e.g. if 0.75 m wide apply 190 mL/100 m of bed). Incorporate to 10-15 cm using rotary tillage equipment.
	Plant crop and ratoon crop foliar sprays–6 L/ha		Apply 5 sprays at 2-3 month intervals during the crop cycle from 1 month after planting, and a further 2 similar sprays immediately

CROP	RATE (product)	MAXIMUM RATE (kg/ha)	COMMENTS
			after plant crop harvest. Ensure spray runs into the leaf axils without overflowing onto the soil.
	Ratoon crop foliar spray only–12 L/ha		If nematodes have infested roots apply following harvest of plant crop and also at this rate 4-6 weeks later.
Potatoes	13 L/ha (rows 80 cm apart) OR 110 mL/100 m of row	5.2 5.5	Pre-planting–apply as a spray to a 45 cm band over the row and mechanically incorporate At emergence (red volcanic soils types only) apply to moist soil and irrigate immediately
Strawberries[b]	24 L/ha OR 16 mL/10 m of row OR Trickle irrigation at 16 mL/10 m of row	9.6	Apply as an overall treatment pre-planting. Apply on a 60 cm band pre-planting. Inject into irrigation system from 7 days before to time of transplanting.
Sugar cane	10 L/ha	4	Apply as a 30-40 cm band centred on the row at any time from planting to early tillering. Lightly incorporate with rakes, discs or tynes and if available apply 12-25 mm spray irrigation within 24 hours (irrigation/rainfall is needed for best results).
Tobacco[b]	24 L/ha in 150-300 mL water OR Band treatment 16 mL/10 m of row	9.6	Apply from 7 days before transplanting as an overall treatment or on a 60 cm band. Incorporate with rotary hoe or disc to 10 cm as soon as possible and then apply at least 25 mm of overhead irrigation.
Tomatoes[b]	24 L/ha OR 16 mL/10 m of row; OR Trickle irrigation at 16 mL/10 m of row	9.6	Apply as an overall treatment pre-planting. Apply on a 60 cm band pre-planting or pre-transplanting. Inject into irrigation system from 7 days before to time of planting
Turf	110 mL/100 m^2 or 1.5 L per bowling green	4.4	Apply in a convenient amount of water to wet turf/damp soil as an overall treatment each spring and repeat 5 weeks later. Irrigate immediately with a minimum of 15 mm water avoiding the formation of pools and puddles.

a) For WA (Carnarvon only) apply at a rate of 24 L/ha in September and in December/January for treatment of plant and ratoon crops only; b) Also for sucking insects e.g. aphids and thrips; c) Plant parasitic nematodes; and d) Leaf nematode

There is no indication on the labels as to the type of equipment that should be used for application of the granular formulations. It is expected machinery such as fertiliser spreaders or equipment used to sow small seeds, or specifically designed application equipment would be used. Again mechanical incorporation and/or incorporation by rainfall or irrigation is required (except for bananas and ginger), and band options are available for all but crucifers and ginger. In many cases

the rate is per treated hectare, and the applicator would need to make adjustments to the rate depending on the amount of soil that is not treated.

In the case of bananas, Duboisia, pineapples, potatoes and sugar cane, treatment is by bands only. Again, if banana rows are 2.5 metres apart, applying a 1-metre band spray close to the base of the stools, there would be 1 metre treated area and about 1.5 metre untreated, i.e. $^{1}/_{2.5}$ or about 40% of the total crop area would be treated. As a result, at 2.5 kg/100 m row the rate per hectare is 2.5 x 40 or 100 kg product/ha, which is equivalent to 10 kg active constituent/ha. The corresponding per stool rates has been estimated at 1500 stools per hectare.

For pineapples, it has been assumed that rows are 2 m apart and that the treated bands are 1 m wide, i.e. 50% of the area is left untreated. For strawberries a plant spacing of 50 cm has been assumed, i.e. 4000 plants per hectare.

Table 2–Granular formulations use summary

CROP	RATE (product)	MAXIMUM RATE (kg/ha)	COMMENTS
Bananas (QLD tropical areas), WA (Kimberley only)			For previously untreated ratoons, or when re-treatment is late, or where nematode populations are high[a] Remove weed and trash and preferably apply just prior to, or just after the wet season (Dec or-April).
	Mechanical applicator 2.5 kg/100 m row OR	10	Apply to a 0.5 m band each side of the centre line
	Hand application 25 g per stool	3.75	Apply evenly in an area of 1 m^2 around the stool For maintenance apply 3 treatments (Dec, April and August) at half this rate.
Bananas (WA Carnarvon only)	Hand application 10 g per stool	1.5	Apply 2 treatments per year, in September and either in December or April
Bulbs[b]	100 kg/treated ha	10	Apply granules post flowering and water thoroughly.
Carrots and parsnips[c]	90 kg/treated hectare	9	Apply granules evenly from 7 days before time of seeding. Incorporate granules 10-15 cm deep. Band treatment may be appropriate on lands or raised beds
Crucifers (e.g. cabbage, cauliflower, broccoli, turnip & Swedes)[c]	Up to 110 kg/treated ha (WA, 90 kg/ha in Vic, SA)	11	Apply granules evenly from 7 days before time of seeding or transplanting. Incorporate granules 10-15 cm deep.
Crucifers (for sugar beet nematode)	25 g/m^2 (50 g/kg, home garden)	12.5	Sprinkle granules evenly over the soil within 7 days of seeding or transplanting. Lightly rake in, and then water.
Duboisia[4]	110 kg/treated ha	11	Apply as a pre-plant and after 2-3 months in bands 1 m wide centred on the rows. Lightly incorporate and 12-25 mm rainfall or irrigation is necessary for best results.
Ginger (QLD)	110 kg/treated ha	11	Apply twice, in mid-November and late January

CROP	RATE (product)	MAXIMUM RATE (kg/ha)	COMMENTS
Ornamentals[c]	100-200 kg/ha	20	For annuals and perennials apply to moist soil pre-planting (100 kg/ha) and water. For perennials repeat in spring and early autumn, with 200 kg/ha used in areas of know heavy infestation.
Ornamentals[c] (herbaceous e.g. gerbera, dahlia, carnation, gladioli, chrysanthemum)	25 g/m^2 (50 g/kg, home garden)	12.5	Sprinkle granules evenly over the soil within 7 days of seeding or transplanting. Lightly rake in, and then water.
Pineapples	Pre-plant bed treatment only–1 kg/100 m of bed for a 1 m wide band	5	Apply evenly at the final bed preparation stage choosing and adjusting a band width (e.g. if 0.75 m wide apply 0.75 kg/100 m of bed). Incorporate to 10-15 cm using rotary tillage equipment.
Potatoes	100 kg/treated ha	10	Pre-planting as a 45 cm band over the row and mechanically incorporate. For a row spacing of 76 cm, apply 60 kg/ha
Strawberries[e]	1 kg/1000 plants or 1 g/plant	0.4	Apply granules to heart of infested plants and spray irrigate immediately.
Sugar cane	40 kg/ha planted	4	Apply as a 30-40 cm band centred on the row at any time from planting to early tillering. Lightly incorporate with rakes, discs or tynes and if available apply 12-25 mm spray irrigation within 24 hours (irrigation/rainfall is needed for best results).
Tomatoes[c]	110 kg/treated ha	9.6	Apply granules evenly to moist soil from 7 days before to time of planting. Incorporate granules 10-15 cm deep. Band treatment may be appropriate on lands or raised beds.
Tomatoes (root-knot nematode)	25 g/m^2 (50 g/kg, home garden)	12.5	Sprinkle granules evenly over the soil within 7 days of seeding or transplanting. Lightly rake in, and then water.
Woody ornamentals[c] (e.g. roses, camellia, hibiscus, ornamental peach)	25-50 g/m^2 (50 g/kg, home garden)	25	Apply before planting and again each spring and autumn. Lightly rake in, and then water.

a) For QLD sub-tropical and NSW apply 2/3 this rate to plant crop and subsequent ratoon crops; b) For plant parasitic nematodes; c) Also for sucking insects e.g. aphids and thrips; d) For root-knot nematodes; and e) For crimp nematode

5.3 Monitoring data

Because of its chemical characteristics, fenamiphos and its major degradates have the potential to leach to ground water in vulnerable areas. No Australian monitoring data are available or have been provided to the APVMA for this assessment. Several ground water monitoring studies from the US have been assessed and are reported in Appendix I. The following discussion on ground-water monitoring data available in the US has been obtained from these studies and the US EPA Office of Pesticide Program, Environmental Fate and Effects Division (US EPA, 1999).

Evidence of leaching in the field exists but it is limited since monitoring for fenamiphos is available only from six states and often does not coincide with fenamiphos use areas. The two major

fenamiphos use states, California and Florida have monitored for this pesticide but fenamiphos is also used in 27 other states where no reliable monitoring data are available. The most extensive ground-water monitoring studies for fenamiphos presently available have been conducted in Florida by the registrant at the request of the US EPA and the State of Florida.

Occurrence in ground water

The information presented in Table 3 below is from several sources including registrant-conducted studies, US Geological Survey (USGS) monitoring, and state monitoring information. The US EPA note in their assessment that prospective and retrospective studies conducted by the registrant, and other studies conducted by the USGS, and the State of California are of high quality.

The other monitoring studies are stated to be of lesser quality, primarily because use areas did not necessarily coincide with monitoring sites.

Small-scale prospective monitoring

In 1992, the registrant agreed to conduct three prospective studies in major use areas: the Florida study began in 1995 and ended in 1996; the Georgia study on tobacco began in 1996 and was terminated recently; the California study on grapes began in October 1997 and is ongoing (only preliminary data had been received (August 1999) at the time of the report). The Agency worked with the State of Florida to design the prospective ground water study in that state, in accordance with Office of Pesticide Program requirements and requirements of Florida's Ground Water Management Plan.

Florida. Detections of fenamiphos in this prospective study on sandy soils at a citrus use site in the Central Ridge of Florida confirmed that fenamiphos and its degradates leach to ground water at high levels (Dyer et al., 1998). The study tracked the impact of a one-time use of Nemacur 3 on citrus, applied at an actual rate of 6.2 kg ac/ha to the study site and monitored over a 2-year period. Fenamiphos residues were detected in all onsite lysimeters, all nine onsite wells and all six offsite wells. Onsite residues at 489 days after treatment (DAT) were 0.16 µg/L for parent, 0.18 µg/L for M01 (see Appendix 1 for metabolite structures) and at 518 DAT, M02 was recovered at 0.2 µg/L. In the offsite wells, fenamiphos and M01 were recovered at 0.17 µg/L and 0.22 µg/L, respectively at 489 DAT while M02 was recovered at 1.93 µg/L at 553 DAT. Using a Limit of Quantitation of 0.1 µg/L for all pesticide analytes, maximum concentrations of fenamiphos, M01 and M02 ranged up to 0.58, 83.31 and 3.32 µg/L, respectively, in the surficial aquifer at 183 days after application. Total residues in one sample ranged up to 87.2 µg/L.

Although fenamiphos is no longer used on citrus in the Central Ridge area of Florida (as a result of the results of this prospective study) fenamiphos is still currently labelled for use on citrus in Florida and is used on other use sites where soils are sandy and ground-water tables are shallow. Citrus in Australia are also commonly grown on well drained (including sandy) soils. Sandy soils are commonly used for agriculture and are the dominant type of soil to which nematicides are applied. This study is the US EPAs only controlled field study investigating the impact of a one-time application of fenamiphos on ground-water quality in an area overlain by sandy soils. It is considered a suitable surrogate for other areas where sandy soils occur and ground-water tables are shallow, particularly in the southeast portion of the US.

Georgia. Fenamiphos was applied on June 5, 1996 to a 5-acre tobacco plot in Dooly County, Georgia (Dyer et al., 1999). Depth to ground water at the site varies from approximately 27 to 32 feet below the surface. Study results through June 2, 1998 indicate that fenamiphos and its M01 and M02 metabolites were found only sporadically in soil-pore water and ground water, at concentrations up to 0.2 µg/L. Data indicated that rather than leaching substantially, residues were primarily retained in the upper 30 cm of soil, where detectable levels have persisted over a two-year

duration. Total soil residues (fenamiphos + M01 + M02) on the day of application were 3.19 mg/kg in the 0-15 cm soil depth, or ~97% of the theoretically applied amount, based on the target application rate of 7.4 kg ac/ha.

Concentrations at this depth fluctuated, but declined to 1.04 mg/kg by DAT 34, and were at 0.17 mg/kg on DAT 727. In the 15-30 cm depth, total residues reached a maximum of 0.29 mg/kg on DAT 119, and declined to 0.07 mg/kg on DAT 727. In all samples, most of the total residue was in the form of M01. Total residues remaining in the top 30 cm at DAT 362 and 727 were 0.42 mg/kg and 0.24 mg/kg, or 13.2% and 7.5% of the amount applied, respectively. The importance of irrigation or rainfall during the first few weeks or months after application, was demonstrated in the Florida PGW study, and is a difference between the Georgia and Florida study designs. Persistence of residues for the duration seen in the Georgia study implies that in the absence of leaching, fenamiphos residues can accumulate in the soil column over years of repeated applications.

California. The California study on grapes began in October 1997 (Lenz et al., 2000). Fenamiphos was applied as a foliar banded spray at a rate of 8.3 kg/ha. M01 was the major contributor to residues found following fast initial conversion of fenamiphos to this metabolite. Residue movement through the soil profile was only measured once, at 29 DAT. There appeared to be some movement of residues through the soil profile with 0.46, 0.126 and 0.235 mg/kg found at 15-30, 30-45 and 45-60 cm respectively. However, the majority of residues remained in the top 0-15 cm soil layer. Detections in groundwater were infrequent. Parent fenamiphos residues were only found on 2 sampling days (17 DAT–3 wells; and 216 DAT–1 well), always at 0.05 µg/L or less. The biggest contributor to groundwater residues was M01. The highest residues of 2.13 µg/L in one shallow well were found at 302 DAT. Between 17 and 462 DAT, 240 samples were taken (120 each from deep and shallow wells) and M01 was detected in 39 samples. Of these 35 were <0.1 µg/L.

Small-scale retrospective monitoring

An earlier retrospective monitoring study documents the impact of multiple years of fenamiphos use on Florida citrus. In 1989, a small-scale retrospective study was requested by the State of Florida to support the registration of fenamiphos on citrus. The retrospective study was conducted by the registrant in Lake Placid, FL using fenamiphos (Nemacur 3) at a rate of 11.1 kg ac/ha in three separate applications from 1990–92 (Lenz et al., 1997). Fenamiphos had been applied annually to the grove at a rate of 3.36–5.04 kg ac/ha from 1985–89. Twelve monitoring wells were installed at the 10-acre (~4 ha) test site: six on-site and six down-gradient and off the treated site. The highest concentrations in the retrospective study were measured in the six wells located on the treated site, although fenamiphos and/or its two degradates were found in all wells monitored. The maximum concentrations of total fenamiphos reported in each of the six wells located on the treated site were 142, 65.5, 10.5, 2.7, 252.8, and 94.7 µg/L. The US EPA required that a ground-water label advisory be placed on the fenamiphos label because of this retrospective study, and along with the State of Florida, further required additional prospective studies be conducted to establish the relationship between use according to the label and ground-water quality.

General monitoring studies

Florida. Fenamiphos residues were detected in ground water on five out of seven golf courses in a study conducted by the USGS. Soils varied from fine sands with good drainage (citrus-growing soils) to Flatwoods soils with poor drainage. Maximum concentrations in ground water were 0.71, 0.75, and 0.10 µg/L for fenamiphos, M01, and M02, respectively (higher concentrations were found in the poorly drained soils). Ground water here would not be used for drinking water but persistent contaminants (such as the fenamiphos degradates) could eventually find their way into drinking water supplies.

California. Fenamiphos is on California's Ground Water Protection List. The List was created so that monitoring could be conducted for certain pesticides for which there were ground-water concerns. Samples were collected from 40 drinking water wells in six counties in the fenamiphos use area in 1990–91 and 1993–94. Using a detection limit of 0.1 µg/L, no fenamiphos residues were detected. Other monitoring has been conducted from the mid-1980s to the present. No detections were seen in any of these wells; detection limits varied from 0.05 to 100 µg/L.

Mississippi. A state-wide ground-water monitoring survey was designed to sample for pesticides in major crops such as cotton and soybeans. Fenamiphos is not widely used in the State and the primary crops are turf and ornamentals. Almost all of the reported monitoring was conducted in areas where fenamiphos was not used. At the time of reporting, 348 wells had been sampled and analysed for fenamiphos and its degradates. No residues have been detected using a detection limit of 5.0 µg/L for the parent.

Oregon. Since 1986 to the time of reporting, approximately 1,000 ground-water samples from public and private wells were analysed for parent fenamiphos only. Using a 0.2 µg/L detection limit, no residues were found.

Texas. From 1987 to 1988, 188 rural wells in eight counties were sampled. The analyses were made using an immunoassay screen for organophosphates including fenamiphos–no organophosphates were detected. Wells may have been near fenamiphos use areas in some counties but this cannot be confirmed.

Washington. Since 1988, 248 private drinking water wells in eight study areas have been sampled. Using a detection limit that varied from 0.12 to 0.3 µg/L, samples were analysed for parent fenamiphos only. No parent residues have been detected but it is not known whether there is any connection between the sampled wells and the fenamiphos use area.

The following table summarises these results:

Table 3: US Groundwater Monitoring Data for Fenamiphos and Degradates

Study	Well type	N. of wells sampled	Min. Detection Limit (µg/L)	No. of wells with detections	Concentration range (µg/L)
Florida (1989-92)	Monitoring	12	0.1 (all analytes)	12	0.1-24.0 (parent) 0.2-218.0 (M01) 0.1-27.0 (M02)
Florida (1995-96)	Monitoring	16	0.1 (all analytes)	9	0.10-0.58 (parent)
Florida golf course study (1992-94)	Monitoring/ irrigation	41	0.03 (parent) 0.2 (M01) 0.1 (M02)	8	0.03-0.71 (parent) 0.2-0.75 (M01) 0.1 (M02)
California (1985-94)	Drinking water	803	0.05-100 (parent) 0.05-57 (M01, M02)	0	None detected
Mississippi (1989-95)	Drinking water	348	5.0 (parent	0	None detected
Oregon (1986-95)	Drinking water	1000 samples	0.2 (parent)	0	None detected

Study	Well type	N. of wells sampled	Min. Detection Limit (µg/L)	No. of wells with detections	Concentration range (µg/L)
Texas (1987-88)	Drinking water	188	Immunoassay	0	None detected
Washington (1988-95)	Drinking water	248	0.12-0.3 (parent)	0	None detected

5.4 Wildlife incident data

There have been several incidents of adverse effects on wildlife attributed to fenamiphos. Concerning reports of bird deaths that may be associated with the use of fenamiphos products, the APVMA Adverse Effects Reporting Database records three incidents. These reports are in confidence so only limited details can be provided:

- Nemacur was applied to a school oval in Victoria. Wood ducks were on the oval prior to the chemical being watered in. 40 deaths were reported.
- On the day following application to an oval, 32 wood ducks were found dead.
- Following use of a product in carrots on the Mornington Peninsula, 12 birds were affected (Starlings and Indian Mynas). 2 birds died and analysis of the dead birds indicated the presence of fenamiphos.

Under their Pesticides Act 1999, the NSW EPA has investigated a number of incidents involving both illegal use of fenamiphos and reports of ducks being poisoned on various golf courses. No further details are provided here due to confidentiality provisions, although such incidents are occasionally reported in the press. For example, the Canberra Times (14 January 2001) reported the deaths of 32 wood duck following ingestion of chemicals on Highlands Golf Course near Mittagong (fenamiphos was not named, but suspected).

Fenamiphos was one of two chemical named as causing a mass fish kill (thousands of fish) in the Swan River in Perth (reported in The West Australian, Friday 21 November 1997) following application at the Belmont Park racecourse. This incident was possibly the result of a hose breaking resulting in many litres of the pesticide solution running into the river.

The US EPA report several incidents of bird deaths following use of fenamiphos (http://www.epa.gov/REDs/fenamiphos_ired.pdf). American Robins and Cedar Waxwings were killed following fenamiphos application to turf in Martin County, Florida (confirmed by tissue analysis). From 1994–96, the US EPA received several reports including poisoning of a Great Blue Heron, and in a separate incident, poisoning of 28 American Coot, both incidents occurring after application of fenamiphos to a golf course. In 1998, 28 birds were killed following wrongful use of fenamiphos on a kiwifruit orchard in California, and in 2000, a bird kill (320 birds mainly robins and bluebirds) was reported in California and associated with chemigation of a grape vineyard with fenamiphos. There is little doubt fenamiphos can cause fish kills. As reported in Patrick et al. (2001), since 1981 the US EPA has received numerous reports involving fish kills from fenamiphos uses. From 1990 to 1994, US EPA averaged three reports per year about massive fish kills (200-to-1000 dead fish) resulting from granular applications of Nemacur to golf courses in various counties of Florida.

6 Environmental fate

6.1 Hydrolysis

Two studies were provided. The first was a conventional study at pH 5, 7 and 9 while the second study explored the stability of fenamiphos and its two main metabolites, fenamiphos sulfoxide (M01) and fenamiphos sulfone (M02), at pH 4. Fenamiphos was shown to be relatively stable to hydrolysis at environmentally relevant pH and temperature conditions with half-lives of 245, 301 and 235 days at pH 5, 7 and 9 respectively. At pH 4, fenamiphos had a calculated half-life of 192 days. M01 and M02 were also stable to hydrolysis at this pH with calculated half-lives of 151 and 136 days respectively.

6.2 Photolysis

Four studies were provided assessing the photolytic stability of fenamiphos and some of its metabolites in water and on soil.

In water, fenamiphos was photodegraded with a half-life of around 7 hours with the main component in the organosoluble fraction being M01 and the major component of the aqueous fraction being M24. On soil, degradation appeared to be biphasic with a fast first half-life of around 2.3 hours. Quantum yield experiments with fenamiphos and subsequent modelling indicated that during the summer period, direct photodegradation in water is likely to be a significant removal process of fenamiphos in the environment. When considering latitudes more relevant to Australia, this is also likely to be a contributor in both spring and autumn as well as in winter for latitudes above 30^{o}S.

While the parent compound itself may not persist, it is rapidly converted to its M01 metabolite that appeared much more stable to photolysis. In the soil experiment, M01 was stable under the experimental conditions and a half-life calculated from when residue levels of this metabolite peaked was estimated to be around 187 hours. This stability was supported in a separate experiment considering photodegradation of M01 in sterile pH 7 buffered aqueous solution where under continuous irradiation the photolytic half-life of M01 was calculated as 1155 hours.

Another major polar photodegradate, M24, was studied for its photodegradation potential in a sterile pH 7 buffered aqueous solution and was shown to be stable under the experimental conditions. The half-life of M24 was calculated to be 768 hours.

6.3 Degradation in soil and water

6.3.1 Soils–aerobic

Three aerobic soil metabolism studies were provided and a further literature report obtained to characterize aerobic degradation of fenamiphos. From the laboratory data, 21 soils were tested under a range of temperatures (16-28°C). Fenamiphos was degraded relatively quickly through both abiotic means (oxidation to M01) and biotic means. Degradation of the parent compound was often biphasic in nature with short first half-lives in the order of 1 week or less. A general metabolic pathway, observed in all experiments, showed initial and extensive formation of M01, which was then either oxidized further to M02 or split in the phosphate group to M12. This metabolite was then further oxidized to M13, which is also formed from the cleavage of M02. Further degradation took place through fenamiphos sulfone anisole (M14) leading to mineralisation to CO_2.

The rapid formation of M01 (found in significant levels even at day 0), and the ecotoxicity of this metabolite makes it more meaningful to consider degradation of the combined residues of both

fenamiphos and M01, as just considering fenamiphos will lead to an underestimation of active residues in the risk assessment.

To illustrate this, DSEWPAC has re-calculated half-lives from one of the studies where degradation in four soils was considered. In this study, the initial half-lives of fenamiphos alone were rapid with a mean calculated half-life in soil of 0.9 days. However, when considering decline of combined residues of fenamiphos plus M01, the following results were found (DT_{50} = ln(2)/k):

Table 4: Phase 1 and 2 half-lives (combined fenamiphos and M01 residues) from four soils

	Phase	k	r^2	DT_{50} (days)
Soil 1	1st	0.1143	0.94	6.1
	2nd	0.0139	0.93	49.9
Soil 2	1st	0.0636	0.99	10.9
	2nd	0.0105	0.96	66.0
Soil 3[a]	1st	0.0899	0.95	7.7
	2nd			
Soil 4	1st	0.0395	0.98	17.5
	2nd	0.0089	0.96	77.9

a) Half-life based on residue data from day 0-30 only.

A similar result was found in a study on one US soil where a half-life for fenamiphos alone was found to be around 7 days but that with combined residue values of fenamiphos and M01 was 55.9 days.

In one study considering 16 soils at three temperatures (16°C, 22°C and 28°C), half-lives were related to temperature with average half-lives of combined fenamiphos and M01 residues of 66.3, 36.0 and 26.2 days at the low, medium and high temperatures respectively.

In one study (literature report) considering degradation of fenamiphos, M01 and M02 in surface and subsurface soil, DSEWPAC calculations determined that in the surface soil, the half-life for dissipation of total residues was between 23-77 days and these results fit well with the other laboratory data assessed. In the subsurface soil, degradation was slower and a half-life of 124 days was calculated. The subsurface soil was from a depth of 25-50 cm.

In addition to these results, modelling was performed to estimate half-lives of M01, M02, M12 and M13 based on measured data in one of the soil degradation studies. The mathematical evaluation of the experimental data was done with the ACSL Optimize Software package and all reaction steps were assumed first order. This modelling determined DT_{50} values for M01 to range from 5.5 to 47.8 days, M02 from 13.6-51.1 days, M12 from 1.6-12.0 days and M13 from 8.6-18.5 days.

For comparison, DSEWPAC re-calculated the half-life values for M01 from this experiment by taking the natural log of concentrations. In general, degradation seemed biphasic and the following 1st and 2nd half-lives were calculated:

Table 5: Recalculated half-life values for M01

	Soil 1	Soil 2	Soil 3[a]	Soil 4
1^{st} half-life (days)	10.4	14.5	11.9	16.7
r^2	0.99	0.96	0.91	0.98

	Soil 1	Soil 2	Soil 3[a]	Soil 4
2nd half-life (days)	57.8	63.6	-	79.7
r^2	0.99	0.97	-	0.96

a) Degradation was not obviously bi-phasic in this soil. Peak concentrations occurred after 1 day and declined relatively constantly until day 60. Residues at day 120 were around the same as the day 60 results (~2% AR).

Generally, residues peaked between days 1 and 2 (day 4 in Soil 4), and the first faster rate of degradation was completed by around day 14. This suggests that M01 would be reduced to half its peak concentration before degradation slows.

Degradation of M12 and M13 were also considered based on experimental results from 1 of the 16 soils used in one of the degradation studies described above. In this experiment, M13 was subject to the best mineralisation with around 51% CO_2 produced after 90 days (compared to around 38% for M12). Actual half-lives of these compounds were not determined in this experiment, but were calculated from 3 soils to be 1.6-12.0 and 8.6-18.5 days respectively.

6.3.2 Soils–anaerobic

In one study, biotransformation of fenamiphos was studied in a North American soil under anaerobic conditions. Fenamiphos was aged under aerobic conditions for 6 days prior to establishing anaerobic conditions. At the start of the anaerobic phase of the experiment, levels of fenamiphos had reduced to <40% of their initial levels, but following establishment of anaerobic conditions, degradation of the parent compound slowed considerably and the estimated half-life of fenamiphos was around 90 days based on combined levels of parent found in both the extracted soil and supernatant water.

While the half-life for the main metabolite, M01, was not considered in the test report, levels of this substance peaked on the day anaerobic conditions were established, then fell following first-order kinetics. DSEWPAC estimated a half-life of this metabolite when conditions were anaerobic of around 65 days based on residue levels in both the extracted soil and supernatant water.

In a separate modelling study using the experimental results of this experiment, the half-life of M01 in anaerobic soils was calculated to be in the order of 20 days. However, this modelling only considered residue levels in the extracted soil. In the supernatant water (anaerobic), the concentrations of M01 were around an order of magnitude higher than those of fenamiphos in the water. This suggested they were being formed in the soil compartment and partitioning to the water column, so by disregarding these levels, the modelling approach may have overestimated the rate constant used for half-life prediction.

6.3.3 Water–aerobic

One study was provided investigating the aerobic aquatic metabolism of fenamiphos in two sediment/water systems. The test substance was applied to the water column and disappeared from this media by adsorption to the sediment and through degradation. Dissipation half-lives for fenamiphos from the water columns in both systems ranged from 3.6-7.9 days and for the whole system, from 9.3-111 days. The sediments in both systems were anaerobic and fenamiphos proved to be much more persistent in this media.

M01 was again the predominant metabolite in both systems. However, in the sediments, this degradation pathway appeared less significant than in aerobic soils due to the increased persistence of fenamiphos.

6.3.4 Water–anaerobic

No data were provided for this end-point.

6.4 Mobility

6.4.1 Volatilisation from soil

Guth et al. (2004) state that, based on direct measurements, no noticeable volatility can be expected from compounds with a vapour pressure below 10-3 Pa from soil and 10-4 Pa from crops, and this is fully confirmed by indirect measurements. Vapour pressures reported in Section 3 above for fenamiphos show it to be between 1.2 X 10-2 to 6.3X10-3 Pa.

While this indicates potentially slight volatilisation from soil, one study provided considered the volatility of fenamiphos from the surface of a sandy loam up to 168 hours after application. There was no significant volatility from the soil surface with accumulated radioactivity over the entire 7 days of testing for two replicates being <0.1% AR. The material balance of the soil was 98.9% AR indicating no significant loss of radioactivity due to poor retention of volatile organics in the traps. Therefore, it appears there is a low propensity for fenamiphos to volatilise from bare soil.

Some volatilisation from plants cannot be ruled out in the event of application being intercepted by foliage.

6.4.2 Adsorption/desorption

Adsorption/desorption of fenamiphos was considered in two batch equilibrium studies with 20 soils.

Fenamiphos had a range of koc values from 76.2 to 1431.9. For the majority of results (15 of 20 soils), medium mobility was observed (koc between 150 and 500) based on the ranking classification of McCall et al. (1980). The highest value was the only one representing low mobility and this soil had a high clay and silt content (98.3% combined). Fenamiphos was classed as having high mobility in four soils (koc 50-150), although in two of these, the koc was >140 making it borderline medium mobility. The arithmetic mean koc for all 20 soils was 303.4 (geometric mean koc 244.7) indicating medium mobility.

In addition, the main soil metabolites were tested for their adsorption/desorption characteristics in batch equilibrium studies with 6 soils for each metabolite considered. Both metabolites were more mobile than the parent compound. M01 was more mobile than both fenamiphos and M02. The range of koc values for M01 was from 37.1-299.7 (geometric mean 84.8). Three of the six soils tested had koc values indicative of very high mobility while two had koc values indicative of medium mobility. In comparison, koc values for M02 ranged from 52.4-397.5 (geometric mean 156.1). Three of the koc values were indicative of high mobility with the other three indicative of medium mobility.

6.4.3 Leaching potential

To further investigate the mobility of fenamiphos and its two main soil metabolites, two aged column leaching studies were assessed. One of these also considered leaching of un-aged residues within the overall experiment. In all, 5 soils were tested.

In one test (2 soils), with incubation up to 63 days, it was shown that fenamiphos does have leaching potential where soils have characteristics supporting leaching (sandier with lower organic carbon and microbial biomass). With unaged residues, around 80% of radioactivity in the soil column was attributable to parent compound, but only 3.4% applied residue (AR) was found in leachate of the most susceptible soil (depth 30 cm). After 15 and 63 days ageing, M01 and M02 accounted for the majority of radioactivity. M01 in particular appeared the most mobile metabolite.

In the most susceptible soil, in the order of 57% AR was found in the leachate after 15 days ageing, and 53% AR in the leachate after 63 days ageing. The majority of this (up to around 85%) was found to be M01.

In the second experiment (3 soils, soil columns of 30 cm), following a 30 day ageing process, unchanged fenamiphos accounted for 45.6% AR and M01 accounted for 46.9% AR with no other metabolite found at levels >3% AR. Following leaching of the columns (with around 1160 mL of 0.01 N $CaCl_2$ over 2 days), both fenamiphos and M01 were found distributed through the columns, although most of the fenamiphos was restricted to the top 12 cm of the column while M01 was much more evenly distributed. Between 16.2 and 63.8% AR was recovered in the leachate, and M01 overwhelmingly accounted for leachate residues. Of the total amount of radioactivity found in leachate, M01 accounted for 80-90%. Unchanged fenamiphos accounted for 0-13.7% of radioactivity in leachate while M02 (2-4% total AR), M12 (1.8-4% total AR) and M13 (<2% total AR) were less significant metabolites.

6.4.4 Lysimeter/field leaching studies

No studies were provided.

6.4.5 Modelling studies–groundwater contamination

Modelling studies were submitted where concentrations of fenamiphos and its main metabolites were predicted in groundwater recharge based on FOCUS-PEARL. Two use patterns were considered, namely tobacco in fields or sweet peppers in greenhouses in Southern Europe. Half-life data for fenamiphos, M01 and M02 were used based on laboratory generated aerobic soil metabolism data for four soils (see Technical Report for further details) and rate constants were estimated for each step with the assumption of first order kinetics. Of the nine standard scenarios developed by the European Union FOCUS working group on groundwater, the four Southern European scenarios were used. Simulations were carried out over 26 years. The concentrations in percolate in 1 m depth were evaluated. For the tobacco scenarios, the results showed that for fenamiphos, no concentrations exceeding 0.001 μg/L were expected. For M01, the 80th percentile concentrations ranged from <0.001–1.3 μg/L while for M02, they ranged from >0.001–1.2 μg/L. For the greenhouse (sweet pepper) scenarios, all metabolite concentrations were predicted to be <0.001 μg/L.

For Australian conditions, a simple model was used to assess groundwater contamination potential of 29 pesticides, including fenamiphos, in the Swan Coastal Plains area of Western Australia. The model assumed linear sorption, with sorption being at equilibrium and reversible, first-order degradation kinetics and that the pesticides leached by steady piston water flow. For fenamiphos, a representative Koc of 100 and a field half-life of 43 days were chosen. Using the model, cumulative probability values for six of the modelled pesticides (fenamiphos, simazine, metribuzin, linuron, fenarimol and metalaxyl) were >0.80 indicating high potential for groundwater contamination below 300 cm.

Based on data evaluated for this assessment, the choice of Koc used in this model is possibly too low. The data described in adsorption/desorption above show a geometric mean and arithmetic mean of 20 Koc values to be 244 and 303 respectively. In addition, the half-life used is probably too high for fenamiphos. The koc and field half-life values chosen for the model are probably more representative of the M01 metabolite, and this chemical has been shown to be mobile through soil in laboratory testing.

DSEWPAC has undertaken some simple modelling on the leaching potential of fenamiphos and M01 using a groundwater ubiquity score (GUS) approach based on Gustafson (1989).

Based on the available Koc data, modelling was performed with the 10th and 90th percentile values for both fenamiphos (n = 20) and M01 (n = 6). Half-lives were based on field data (described below). These were generally in good agreement with the range of laboratory data for M01, but tended to show longer half-lives for fenamiphos than laboratory data.

The following results were obtained with the model:

Table 6: Groundwater ubiquity scores for fenamiphos and M01

	koc	**DT_{50}**	**GUS**	**Probably attribute**
Fenamiphos	138	16.8	2.3	Borderline leacher
	389	16.8	1.7	non-leacher
M01	41	73.8	4.5	Leacher
	263	73.8	3	Leacher

The results of this modelling indicate that, even with the 10th percentile Koc, fenamiphos is at worst a borderline leacher. This is supported by column leaching studies where some unchanged parent was found in one soil leachate at 30 cm, but in other soils, no fenamiphos was found. Conversely, M01 is classed as a leacher regardless of Koc. Again, this is supported by column leaching studies where it was the dominant metabolite found in leachate from tested soils.

6.5 Fate and behaviour in air

The calculated Henry's Law Constant of $9.1x10^{-10}$ atm.m^3/mol (calculated from VP/Sol) is indicative of very slight volatility from water. The range of vapour pressures reported in Section 3 above are indicative of slight to moderate volatility. Therefore, when released to either soil or water, the compound is unlikely to partition to any significant extent to the atmosphere.

While no experimental data for degradation in the atmosphere were provided, this was considered through modelling. Based on the AOPWIN program (Atmospheric Oxidation Program for Microsoft Windows 3.10, Version 1.87), rate constants for reaction of fenamiphos, M01 and M02 were generated and atmospheric half-lives calculated based on reaction times with the diurnally and seasonally averaged concentration of tropospheric hydroxyl radicals (1.5 X 106/cm^3). The half-lives were calculated to be 1.65, 1.0 and 1.88 hours for fenamiphos, M01 and M02 respectively, indicating these compounds are unlikely to persist in the atmosphere.

6.6 Accumulation/bioaccumulation

6.6.1 Bioaccumulation

One study was provided measuring the bioconcentration (including uptake and depuration) of radiolabelled fenamiphos in bluegill sunfish (*Lepomis macrochirus*). A single exposure concentration of 0.8 µg/L was tested based on a pilot study to determine the 7 day LC_{50} to this species, with the test exposure rate set at around 10% of this value.

Exposure was for 28 days followed by a 14 day depuration period. Steady state concentrations in the fish appeared to be reached after around 7 days exposure. In the edible portion, after 7 days, the concentration of ^{14}C-fenamiphos was 24 µg/kg and was still 20 µg/kg at the end of the exposure period. Levels in the viscera peaked at 7 days (230 µg/kg) and had declined to 93 µg/kg after 28 days. Consequently, whole fish residues also declined from their peak of 87 and 89 µg/kg at days 7 and 14 respectively to a level of 58 µg/kg at day 28. Following the commencement of depuration, residues were eliminated very quickly from the fish, and at the day 3 sampling time, no quantifiable residues were found.

Kinetics data were calculated and for the whole fish, a bioconcentration factor of 110 and depuration half-life of 0.22 days were determined. Fenamiphos can be considered slightly to moderately concentrating in fish. Once exposure ceases, any accumulated compound is expected to rapidly depurate from the organism.

Fenamiphos is not expected to be accumulated by earthworms following exposure through soil.

6.6.2 Modelling studies–soil concentrations

Modelling studies were submitted where concentrations of fenamiphos and its main metabolites were predicted in soil based on FOCUS-PELMO. Two use patterns were considered, namely tobacco or sweet peppers in greenhouses in Southern Europe. Half-life data for fenamiphos, M01, M02, M12 and M13 were used based on laboratory generated aerobic soil metabolism data (see Technical Report for further details) and rate constants were estimated for each step with the assumption of first order kinetics. Of the nine standard scenarios developed by the European Union FOCUS working group on groundwater, two Southern European scenarios were used. Simulations were carried out over 1 year. The concentrations in the top 20 cm soil layer were evaluated. For the tobacco scenarios, maximum fenamiphos concentrations were reached after 4 days (42-55 µg/kg). The highest residues were predicted from M01, peaking at 386-487 µg/kg after 28-50 days. For use on sweet pepper in glasshouses, maximum fenamiphos concentrations were reached after 2 days (199-214 µg/kg). The highest residues were predicted from M01, peaking at 2473-2606 µg/kg after 50 days.

6.7 Field dissipation studies

One field dissipation study was provided considering the dissipation of fenamiphos from two sites where application was by spray to established turf plots. At both sites, two applications were made with a 6 month interval between applications. The rate was 11.2 kg ac/ha. Samples were analysed to determine the kinetics of fenamiphos, including the half-life of the parent compound and formation of M01 and M02. Leaching potential was also considered.

For unknown reasons, the application rate achieved at one of the sites was very low at both applications. However, despite the very low application rates achieved at this site, dissipation of fenamiphos followed a steady first-order process. In contrast, dissipation at the second site was more erratic. After the first application, high levels of fenamiphos were found at day 0 with a very rapid drop initially before following a more gradual decline. Based on the fenamiphos residue data following the first applications, half-lives were calculated to be 16.2-17.0 days for fenamiphos, 70.7-77 days for M01 and 34.5-84.5 days for M02.

At no time did fenamiphos migrate lower than 0-15 cm. M01 was the most mobile metabolite and the one produced in the largest quantities. Following a single application, neither M01 nor M02 were found below 60 cm in the soil, and generally, residues of these metabolites were restricted to the top 45 cm. After the second application, much higher concentrations of M01 was found at the 45-60 cm layer with some detections as low as 75-90 cm.

In addition, several groundwater monitoring studies were provided measuring residues in soil and groundwater from Florida, Georgia and California in the United States. The results with respect to groundwater findings have been summarised above in Section 5.3 and the data show that where conditions are suitable for leaching, movement of fenamiphos, and particularly M01, to groundwater can occur over time.

The soil results from these studies were variable, reflecting different soil characteristics. Fenamiphos, M01 and particularly M01 could move significant distances through some soils, but often the majority of residues were retained in the top 15 cm of soil. Soil half-lives, where measurable, were biphasic in nature. In three studies, fenamiphos had a first phase half-life of 3.4–

14 days and a second phase half-life of 17.3–498 days. By contrast, M01 had a first phase half-life of 6.8–126 days and a second phase half-life of around 151–495 days. In one study, degradation followed first order kinetics with a half-life of 33 days for fenamiphos and M01, and 42 days for M02. The half-life in this study for total residues was 34 days.

6.8 Conclusions

Fenamiphos and its main M01 metabolite are hydrolytically stable within the environmentally relevant pH range. In aqueous systems and on soil, breakdown of fenamiphos through photolysis is relatively quick (half-life <1 day). However, while the parent compound itself may not persist, it is rapidly converted to its M01 metabolite that appeared much more stable to photolysis (half-life up to 96 days with a 12:12 hour light:dark day).

In soil, fenamiphos is rapidly oxidised to M01 and then further oxidised to M02. While half-lives of the parent compound in soil may be short (generally <1 week), loss of residues as the combined parent and M01 (a substance also biologically active), are much greater. Degradation often appeared biphasic. One study showed first half-lives from 6.1-17.5 days with second half-lives from 50-78 days. A second study with 16 soils at three temperatures showed degradation half-lives of combined fenamiphos and M01 residues averaging 66.3, 36.0 and 26.2 days at 16°C, 22°C and 28°C respectively.

Volatilisation from the soil was shown to be negligible based on one laboratory study. Laboratory and modelling data showed fenamiphos to be moderately mobile in soil, but unlikely to leach significantly to groundwater. M01 was shown to be a mobile metabolite capable of leaching to groundwater. These findings were supported to some degree with a field dissipation study showing no movement of fenamiphos below 0-15 cm. M01 was the most mobile metabolite and the one produced in the largest quantities. Following a second application, M01 was found at the 45-60 cm layer with some detection as low as 75-90 cm. The field dissipation study showed half-lives for fenamiphos somewhat longer than those found in the laboratory at around 16.8 days while M01 was again more persistent with field half-lives of 71-77 days. Several groundwater monitoring studies confirm these findings.

Where conditions are suitable for leaching, fenamiphos residues (particularly as the M01 metabolite) can leach to groundwater. Soil half-lives as measured in the groundwater studies were generally biphasic. M01 was more persistent than parent fenamiphos. In three studies, fenamiphos had a first phase half-life of 3.4–14 days and a second phase half-life of 17.3–498 days. By contrast, M01 had a first phase half-life of 6.8–126 days and a second phase half-life of around 151–495 days. In one study, degradation followed first order kinetics with a half-life of 33 days for fenamiphos and M01, and 42 days for M02. The half-life in this study for total residues was 34 days. Residues were more persistent in the subsoil (<15 cm) than in the top 15 cm of soil.

Where released to water, fenamiphos may move to sediments where it will degrade slowly. In an aerobic system, the half-life in water was relatively short (<8 days) while that for the whole system was much slower (up to 111 days). In an anaerobic soil/supernatant water system, most of the parent was retained in the soil while significant amounts of M01 moved from the soil to the water phase. The degradation of fenamiphos under anaerobic conditions was relatively slow with a half-life estimated to be around 90 days.

Fenamiphos may bioconcentrate in exposed aquatic organisms to a moderate degree, but data provided show it to rapidly depurate once exposure ceases. Testing with earthworms suggests the substance will not bioconcentrate in these organisms.

7 Environmental toxicity

To support the assessment, toxicity data were provided for birds, aquatic organisms and terrestrial organisms. In general, the studies (particularly for birds and aquatic organisms) were old with very little recent data (post-1990) provided. Further, the data set in certain areas was very small. For example, only one standard test was available for parent compound toxicity to aquatic invertebrates (*Daphnia magna*), and only one algal species was tested. The adequacy of the data set will be explored further in the risk assessment.

7.1 Avian toxicity

7.1.1 Acute

Several studies were provided to the APVMA for review with the following results:

Table 7. Summary of acute bird toxicity results for fenamiphos and metabolites

Species	LD_{50} (mg ac/kg bw)	NOEC (mg ac/kg bw)	Reference
Fenamiphos technical			
Japanese quail	1.28	<0.9	Barfknecht, 1998
Bobwhite quail	1.6	0.25	Lamb, 1982
Mallard duck	1.0	0.5	Nelson and Burke, 1977a
Bobwhite quail	0.7 (males)	0.46 (males)	Lamb, 1978
Mallard duck	1.1 (males)	0.68 (males/females)	Lamb, 1978
M01			
Bobwhite quail	1.8	1.0	Lamb, 1978
Mallard duck	1.5	0.68 (males)	Lamb, 1978
M02			
Bobwhite quail	1.9 (males)	1.0	Lamb, 1978
Mallard duck	1.1 (males)	0.68	Lamb, 1978

Acute oral toxicity results were available for fenamiphos (4 studies, 3 species), M01 (1 study, 2 species) and M02 (1 study, 2 species). The studies were all relatively old (1982 or earlier) except one more recent result for fenamiphos toxicity to Japanese quail (1998 study). Of the available results for technical fenamiphos, all LD_{50} values were in the range of 0.7-1.3 mg ac/kg bw, indicating fenamiphos is very highly toxic to birds. Similar results were found for the two metabolites, with LD_{50}s between 1 and 2 mg/kg bw for both metabolites tested, again indicative of very high toxicity to birds. NOECs for all three compounds ranged from 0.25-1.0 mg/kg bw.

7.1.2 Short-term

Three avian dietary studies were provided to the APVMA for technical fenamiphos. No data for metabolites were provided.

Table 8. Summary of short-term bird toxicity results for technical fenamiphos

Species	LC_{50} (mg ac/kg diet)	NOEC (mg ac/kg diet)	Reference
Fenamiphos technical			
Bobwhite quail	78	9.84	Bowers and Webster, 2002
Bobwhite quail	38	<10	Nelson and Burke, 1977b
Mallard duck	94	<46.4	Fink, 1977

Three short term toxicity tests were reviewed, all for technical fenamiphos. Two studies considered toxicity to bobwhite quail and one to mallard duck. Bobwhite quail appeared more sensitive (LC_{50}s of 38 and 78 ppm) than mallard duck (one LC_{50} result of 94 ppm). These results indicate the compound is highly to very highly toxic to birds when consumed through the diet.

7.1.3 Reproduction (chronic)

Two avian reproduction studies were provided to the APVMA for technical fenamiphos.

Table 9. Summary of Chronic Bird Toxicity Results for Technical Fenamiphos

Species	LD_{50} (mg ac/kg diet)	NOEC (mg ac/kg diet)	Reference
Fenamiphos technical			
Bobwhite quail	-	1.8	Lamb and Carsel, 1982a
Mallard duck	-	3.6	Lamb and Carsel, 1982b

Two reproduction studies were provided, one for bobwhite quail and one for mallard duck. For bobwhite quail, the main adverse effect related to chick survival (14 days), which was reduced by 31% in the 8.0 ppm group. Therefore, the NOEC from this study was the next highest level tested, 2.0 ppm (1.8 ppm corrected for purity). In the mallard duck test, there was a reduction of almost 30% in live 14 day old ducklings at 8 ppm. This was deemed not statistically significant (and resulted in a NOEC of 8 ppm), however, it is considered more appropriate by DSEWPAC to consider the reproduction NOEC as the lowest tested rate of 4 ppm (3.6 ppm corrected for purity).

7.2 Avian field data

Given the high hazard of fenamiphos to birds, several avian field studies were undertaken assessing potential adverse effects on birds in citrus groves, tobacco fields and golf courses. Application rates to citrus groves included 5 kg ac/ha (applied through chemigation; statistically, no significant effects found, however, mortality in exposed birds based on ChE levels was around 13% higher than that in non-exposed birds) and 22.4 kg/ha (granule application, soil incorporated; no significant adverse effects found on avian mortality). Application rates to tobacco fields in both tests were 6.7 kg ac/ha. Application was by broadcast spraying with soil incorporation. Different methods were used to assess impacts on avian mortality, but in both studies, no significant effects were found. Application rates to golf courses in both studies was 11.2 kg ac/ha with one study applying the substance as an EC formulation and the other as a granular formulation. Incorporation was achieved through irrigation. While no significant effects on bird survival rates were found in the granule study, in the first study there was an effect of fenamiphos treatment being a loss (either through mortality or emigration) of about 9% of the avian population at treatment sites with the 80% upper confidence limit for this loss being 13.3%. Analysis of birds found dead on treatment plots indicated that species in the family Mimidae (e.g., thrashers and mockingbirds) were more vulnerable to intoxication with heavier birds more likely to recover than lighter birds.

Abnormal behaviours were observed and for those that were followed, recovery rates were high. Although calculated mortality rates were low, there was an overall significant difference in the disappearance of colour marked birds between treatment plots and control plots. On numerous occasions, birds were seen eating 'dosed' invertebrates, and subsequently became sick. Residue monitoring indicated that concentrations of total fenamiphos were initially high in invertebrates, but decreased to relatively safe levels within a few days. Most of the treatment related deaths and behavioural impairments were found on the day of application or the next day.

In all studies, residues were found where tested in all media (soil, water and invertebrates), but these varied widely between the studies.

7.3 Aquatic toxicity

7.3.1 Fish–acute

The APVMA received several studies for acute toxicity of fenamiphos and its main metabolites to fish with the following results:

Table 10. Summary of Acute Fish Toxicity Results for Fenamiphos and Metabolites

Test species	System	LC_{50}/NOEC (µg ac/L)	Reference
Fenamiphos, technical			
Rainbow trout (*O. mykiss*)	96 hours static	58.4/50.6	Lamb and Roney, 1972
Bluegill sunfish (*L. macrochirus*)	96 hours static	14.3/10.4	Lamb and Roney, 1972
Bluegill sunfish (*L. macrochirus*)	96 hours static	9.3/3.8	Dorgerloh and Sommer, 2001
Sheepshead minnow (*C. variegatus*)	96 hours ft	17/<3.8	Suprenant, 1988a
Bluegill sunfish (*L. macrochirus*)	96 hours static	8.4/6.8	Lamb and Roney, 1977
Fenamiphos, 15% Granular Formulation			
Rainbow trout (*O. mykiss*)	96 hours static	84.4/36	Lamb and Roney, 1972
Bluegill sunfish (*L. macrochirus*)	96 hours static	22.6/7.4	Lamb and Roney, 1972
M01 (nominal)			
Bluegill sunfish (*L. macrochirus*)	96 hours static	2600/1000	Lamb and Roney, 1977
M02 (nominal)			
Bluegill sunfish (*L. macrochirus*)	96 hours static	1200/680	Lamb and Roney, 1977
M12 (nominal)			
Rainbow trout (*O. mykiss*)	96 hours static	NOEC>100000	Waggoner, 1989
Bluegill sunfish (*L. macrochirus*)	96 hours static	NOEC>100000	Waggoner, 1989
M13 (nominal)			
Rainbow trout (*O. mykiss*)	96 hours static	NOEC>100000	Waggoner, 1989
Bluegill sunfish (*L. macrochirus*)	96 hours static	NOEC>100000	Waggoner, 1989

Several older (pre-1990) fish toxicity results (including one salt-water species) were reviewed for fenamiphos and four main metabolites, M01, M02 (1 species each), M12 and M13 (two species each). In addition, a more recent study (2001) was provided for technical fenamiphos. For the parent compound, results were relatively uniform with LC_{50} values ranging from 8.4-14.3 µg/L (one LC_{50} of 58.4 µg/L was found for rainbow trout). These results suggest fenamiphos is highly to very highly toxic to fish. When tested as a granular formulation, results for two species also showed LC_{50}

values of 22.6-84.4 µg/L, based on the active, also indicative of high toxicity. Dose/response curves were steep.

The metabolites were substantially less toxic to fish than the parent compound. Based on one species and one test, M02 was the most toxic of the tested metabolites (LC_{50} 1,200 µg/L (moderately toxic) while M01 was also moderately toxic with an LC_{50} of 2,600 µg/L (1 species, 1 test). M12 and M13 were practically non-toxic with NOECs >100,000 (2 species each, 1 test).

7.3.2 Fish–subchronic/chronic

One longer term study was provided (rainbow trout, early life stage) with fenamiphos technical as the test substance. Based on significantly reduced larval growth following 60 days post-hatch exposure, the lowest observed effect concentration (LOEC) was estimated to be 7.4 µg/L with a NOEC of 3.8 µg/L, confirming fenamiphos as being highly toxic to fish.

7.3.3 Aquatic invertebrates–acute

The APVMA received a limited number of studies addressing acute toxicity of fenamiphos and its main metabolites to aquatic invertebrates with the following results:

Table 11. Summary of Acute Aquatic Invertebrate Toxicity Results for Fenamiphos and its Main Metabolites

Test species	System	LC_{50}/NOEC (µg ac/L)	Reference
Fenamiphos technical			
Daphnia magna	48 hours static	1.9/<1.0	Surprenant, 1988b
Mysid shrimp (*M. bahia*)		6.2/-	See a) below
Eastern oyster *(C. virginica*)		1,650/630	See a) below
Daphnia magna[b]	24 hours	<10/<10	Losel and Keppler, 2001
Mosquito (*A. aegypti*)[b]	24 hours	10-100/<10	Losel and Keppler, 2001
M01			
Daphnia magna	48 hours static	15/4	Hendel and Sommer, 2001a
M02			
Daphnia magna	48 hours static	3.2/1.0	Hendel and Sommer, 2001b
M12			
Daphnia magna	48 hours static	~100,000/10,000	Hendel, 2001a
M13			
Daphnia magna	48 hours static	20,200/5,600	Hendel, 2001b
M24			
Daphnia magna[b]	24 hours	>100,000/10,000	Losel and Keppler, 2001
Mosquito (*A. aegypti*)[b]	24 hours	Both >100,000	Losel and Keppler, 2001

a) Results reported in US EPA Environmental Fate and Effects Division (EFED) report, Patrick et al. (2001). Studies not provided to APVMA for review; b) Non-standard screening test.

Very few data were provided for toxicity of fenamiphos or metabolites to aquatic invertebrates. One standard study with *D. magna* for technical fenamiphos resulted in an LC_{50} of 1.9 µg/L (NOEC <1 µg/L) suggesting the substance is very highly toxic to aquatic invertebrates. M01 and M02 were also very highly toxic to aquatic invertebrates based on one study each to *D. magna* where LC_{50}s of

15 and 3.2 µg/L were found respectively. M12 and M13 were much less toxic, again based on one study each to *D. magna* with M12 resulting in an LC_{50} of around 100,000 µg/L (practically non-toxic), and M13 with an LC_{50} around 20,200 µg/L (slightly toxic). A non-standard screening study comparing toxicity of M24 to fenamiphos showed this substance to be practically non-toxic to two species, *D. magna* and a mosquito (*A. aegypti*) with LC_{50}s >100,000 µg/L for both.

7.3.4 Aquatic invertebrates–chronic

One study testing chronic toxicity of fenamiphos technical to *D. magna* was provided. Based on mortality, the EC_{50} was calculated to be 0.36 µg/L. The dose/response curve was very steep with no significant mortality found at the next lowest treatment level of 0.24 µg/L. Growth, as determined by mean body weight, was the most sensitive end-point and resulted in a NOEC of 0.12 µg/L. These results confirm fenamiphos as being highly toxic to aquatic invertebrates.

7.3.5 Algae and aquatic plants

One study each for technical fenamiphos and the main metabolites, M01 and M02, were provided to the APVMA for one algal species with the following results:

Table 12. Algae/Aquatic Plant Toxicity Results for Fenamiphos and its Main Metabolites

Test species	Test duration	Biomass (mg ac/L)	Growth rate (mg ac/L)	Reference
Fenamiphos technical		E_bC_{50}/NOEC	E_rC_{50}/NOEC	
Green algae (*S. subspicatus*)	96 hours	3.5/0.32	11.0/1.0	Heimbach, 1987a
M01				
Green algae (*S. subspicatus*)	96 hours	>100/10	>100/100	Heimbach, 1987b
M02				
Green algae (*S. subspicatus*)	96 hours	25.0/10	45.7/18	Heimbach, 1987c

Only one study each was provided testing toxicity of fenamiphos, M01 and M02 to algae/aquatic plants, and for all, only one algal species was tested (green algae, *S. subspicatus*). Fenamiphos was moderately toxic to this species (EbC_{50} 3,500 µg/L). M02 was slightly toxic (EC_{50} 25,000 µg/L) while M01 was practically non-toxic (EC_{50} >100,000 µg/L).

7.3.6 Sediment organisms

One study each was provided testing toxicity of fenamiphos and M01 to the sediment dwelling midge, *Chironomus riparius*. For fenamiphos, the EC_{50} was determined to be 20 µg/L, although it must be more realistically considered to be between 20 and 40 µg/L (very highly toxic). Due to no emergence at concentrations 40-320 µg/L, the NOEC for the development rate was also 20 µg/L. This indicates a very steep dose-response curve for these organisms under the test conditions. In the M01 study, the EC_{50} was determined to be 95 µg/L (highly to very highly toxic). A NOEC of 58 µg/L based on emergence effects was determined for the study.

7.3.7 Mesocosm studies

A mesocosm study was undertaken assessing toxicity of fenamiphos (applied as a 35.2% EC formulation). The test systems were dosed twice, with seven days between treatments. Nominal treatment levels were 1.0, 3.5 and 12.5 µg/L. Control mesocosms were maintained either with no chemical treatment, or no fish loading. The mesocosms were stocked with mature bluegill sunfish

(*Lepomis macrochirus*) with a total of 15 females and 15 males per pond. Specific effects on aquatic organisms were noted over the range of test concentrations. There were few apparent direct effects on the total numbers of zooplankton. Decreases in the number of *Rotifera* were noted at the highest dose rate. However, this effect was thought to be a result of copepod predation (due to lower predation on copepods resulting from fish mortality) on the rotifer community. Few effects were noticed on certain taxa (mayflies; caddisflies) at the highest test concentration. Direct mortality of fish was noted at the highest treatment level; however, no statistically significant effects were observed at the low and medium test levels. Based on these results, a NOEC for this study was the nominal 3.5 µg/L test concentration.

7.4 Terrestrial toxicity

7.4.1 Non-target invertebrates

7.4.1.1 Bees

Two studies were submitted to the APVMA for review with the following results:

Table 13. Summary of toxicity to bees for fenamiphos

Test species	Test duration	LD_{50} (µg ae/bee)	Reference
Fenamiphos technical			
Honey bee (*A. mellifera*)	48 hours oral	0.46	Kleiner, 1995
Honey bee (*A. mellifera*)	48 hours contact	0.28	Kleiner, 1995
Bumble bee (*B. terrestris*)	72 hours contact	1.59 (NOEC 0.7)	Kling, 2001

Fenamiphos was toxic to bees through both the oral and contact routes with LD_{50} values for honeybees of 0.46 and 0.28 µg/bee respectively. A further contact toxicity test with bumble bees resulted in an LD_{50} of 1.59 µg/bee.

7.4.1.2 Other arthropods

Several studies were provided assessing toxicity of fenamiphos and its major metabolites to various non-target arthropods with the following results:

Table 14. Summary of Toxicity to Bees for Fenamiphos

Test species	Test system	LR_{50} (g ac/ha)	Reference
Fenamiphos (CS240 Formulation)			
Aphid parasitoid (*A. rhopalosiphi*)	48 hours mortality	0.152	Vinall, 2001
Aphid parasitoid (*A. rhopalosiphi*)–extended laboratory study	Adult mortality (48 hours)	14.68	Schuld, 2000
	Reproduction	NOEC >14.2	
Predaceous mite (*T. pyri*)	Adult mortality (7 days)	1.69	van Stratum, 2002
	Reproduction	NOEC 1.0	
Predaceous mite (*T. pyri*)–extended laboratory study	Adult mortality (7 days)	14.1	Adelberger, 2002
	Reproduction	NOEC >14.2	
Green lacewing (*C. carnea*)–extended laboratory study	Adult mortality (12 days)	34.05	Kemmeter, 2000
	Reproduction	NOEC >51.6	
Carabid beetle (*P. cupreus*)–extended laboratory study	Adult mortality (22 days)	226	Neumann, 2001
	Feeding rate	NOEC 516	
Predatory bug (*M. pygmaeus)*	Adult mortality (14 days)	1.3	Jackel, 2002
Collembola (*F. candida*)–extended laboratory study	Adult mortality (28 days)	4.07 mg/kg dw	Friedrich, 2001a
	Reproduction (EC_{50})	1.14 mg/kg dw	
M01			
Collembola (*F. candida*)–extended laboratory study	Adult mortality (28 days)	8.91 mg/kg dw	Meister, 2001a
	Reproduction(EC_{50})	4.55 mg/kg dw	
M02			
Collembola (*F. candida*)–extended laboratory study	Adult mortality (28 days)	4.5 mg/kg dw	Meister, 2001b
	Reproduction(EC_{50})	5.1 mg/kg dw	
M12			
Collembola (*F. candida*)–extended laboratory study	Results not provided in report. Results for M13 below are used as a surrogate.		Friedrich, 2001b
M13			
Collembola (*F. candida*)–extended laboratory study	Adult mortality (28 days)	441 mg/kg dw	Friedrich, 2001c
	Reproduction(EC_{50})	21.6 mg/kg dw	

Several studies were provided considering toxicity to non-target arthropods when exposed through spray application. Results were variable. The aphid parasitoid (*Aphidius rhopalosiphi*) was most susceptible based on exposure to glass plates with an LR_{50} of 0.152 g ac/ha. Under more extended laboratory conditions (predominantly testing effects on both adult mortality and reproduction with exposure on tomato leaves), toxicity was less pronounced than using worst-case laboratory

exposure conditions (glass plates). Available data for the aphid parasitoid (*A. rhopalosiphi*), predaceous mite (*Typhlodromus pyri*), green lacewing (*Chrysoperla carnea*) showed LR_{50}'s (based on adult mortality) between 14.1 and 34 g ac/ha. Reproductive effects were only assessed at rates where adult mortality was not significantly affected, and resulted in NOECs of 14.2-51.6 g ac/ha. The carabid beetle (*Poecilus cupreus*) was less sensitive and resulted in a LR_{50} of 226 g ac/ha with a NOEC (based on feeding rate) of 516 g ac/ha. Collembola (*Folsomia candida*) was the only species exposed through the soil and resulted in an LC_{50} (adult mortality) of 4.07 mg/kg dw and a NOEC (reproduction) of 1.14 mg/kg dw. This species was also exposed to the metabolites M01, M02, M12 and M13. M01 and M02 had toxicity similar in magnitude to the parent compound (LC_{50}s of 8.91 and 4.5 mg/kg dw respectively). Results for M12 were not provided, however, M13 was significantly less toxic with an LC_{50} of 441 mg/kg dw.

7.4.2 Earthworms

Several studies were provided assessing toxicity of fenamiphos and its major metabolites to earthworms with the following results:

Table 15: Summary of Toxicity to Earthworms from Fenamiphos and Metabolites

Test substance	Duration	LC_{50} (mg/kg)	NOEC (mg/kg)	Reference
Acute studies				
Fenamiphos	14 days	888	0.032	Meisner, 2000
M01	14 days	>1000	0.10	Meisner, 2001a
M02	14 days	>1000	<10	Meisner, 2001b
M12	14 days	>1000	32	Meisner, 2001c
M13	14 days	>1000	315	Meisner, 2001d
Chronic studies				
Fenamiphos+M01+M02	56 days	NOEC <0.12 mg/kg fenamiphos + 0.17 mg/kg M01 + 0.02 mg/kg M02		Lechelt-Kunze, 2002
Fenamiphos EC 400	56 days	-	<6 kg ac/ha	Heimbach, 1994
Fenamiphos EC 400	Field test	-	<10 kg ac/ha	Heimbach, 1986

Toxicity of fenamiphos, M01, M02, M12 and M13 to earthworms was tested. The only definitive result for mortality obtained was for the parent fenamiphos with a 14 day LC_{50} of 888 mg/kg dw (moderately toxic). Corresponding 14 day LC_{50}s for all other compounds was >1000 mg/kg dw. Despite this apparent lack of toxicity based on mortality, when exposed to fenamiphos, significantly different weight alterations by comparison with the control (+15%) occurred in all test concentrations except the lowest concentration of 0.032 mg/kg dw soil. This resulted in a NOEC of 0.032 mg/kg dw. In the M01 study, worms in all test concentrations except the lowest test level were noted as becoming cramped. In the M02 study, worms at all test concentrations (but not the control) were noted as becoming cramped. Again, based on weight comparisons, the NOECs for M01 and M02 were 0.01 and <10 mg/kg dw (the lowest rate tested) respectively. For M12 and M13, NOECs were 100 and 315 mg/kg dw respectively.

Chronic toxicity of fenamiphos to earthworms was tested in two separate reproduction experiments (one soil incorporated and one surface applied) and one field study (as a surface spray). When exposed through the soil, the tested concentrations of fenamiphos (0.12 mg/kg dw), M01 (0.17 mg/kg dw) and M02 (0.02 mg/kg dw) had no influence on earthworm reproduction, although there was an apparent effect on weight gain of adult worms. When worms were exposed in a 56 day laboratory study to three different spray application rates (6, 10 and 40 kg/ha), no mortality of adult worms was observed but all application rates decreased the body weights of adults significantly (87-97%). The numbers and biomass of offspring were significantly reduced at all application rates (72-97%). In the field study, some earthworm species were negatively affected by fenamiphos applications at 10 and 40 kg/ha. A marked difference in comparison to control values was found for epilobous species, particularly at 40 kg/ha. Effects were noted up to 3 months after application, but by the following year, no negative effects on earthworm fauna were observed.

7.4.3 Soil microorganisms

Results from studies on effects to soil microorganisms are summarised as follows:

Table 16: Summary of toxicity of fenamiphos and metabolites to soil micro-organisms

Soil respiration/mineralisation activity		
Fenamiphos	No adverse effects up to 133 mg/kg dw (2 soil types)	Anderson, 1986a
Soil nitrogen cycle		
Fenamiphos	No adverse effects up to 133 mg/kg dw (2 soil types)	Anderson, 1989b

M01	70.19 mg/kg	No permanent adverse effects based on single application rates to a single soil. Some temporary increase in nitrate production may occur at these levels.	Anderson, 2001a
M02	73.69 mg/kg		Anderson, 2001b
M12	37.47 mg/kg		Anderson, 2001a
M13	40.93 mg/kg		Anderson, 2001b

Based one study for fenamiphos impacts on soil respiration, fenamiphos is not expected to adversely affect soil respiration rates or mineralisation activity of soil bacteria up to the maximum tested level of 133 mg/kg dw soil. In addition, 5 studies using fenamiphos technical, M01, M02, M12 and M13 were performed assessing the impact of fenamiphos treatment to soil nitrogen. Fenamiphos is not expected to adversely affect the soil nitrogen cycle up to the maximum tested level of 133 mg/kg dw soil. The single treatment rates for the four metabolites were 70.19, 73.69, 37.47 and 40.93 mg/kg dw soil for the M01, M02, M12 and M13 metabolites respectively. The results showed they are not expected to adversely affect the soil nitrogen cycle up to the maximum tested levels. However, some temporary increase in nitrate production may occur at these levels.

7.4.4 Non-target vegetation

Fenamiphos as its capsulated suspension (CS) 240 formulation (236.2 g ac/L measured) was tested on non-target plants in a screening level seedling emergence study. All plant species (11 species consisting of 6 dicots from 6 different plant families, and 5 monocots from one plant family) tested showed no phytotoxic effects up to the highest application rate of 15,000 g ac/ha.

7.5 Conclusions on environmental toxicity

Fenamiphos and its major metabolites, M01 and M02, were very highly toxic to birds based on acute oral studies. While no toxicity data were available to birds for the two main metabolites for short-term dietary exposure, or under chronic test conditions, fenamiphos was again shown to be very highly toxic to birds when consumed through the diet. Two reproduction studies (mallard duck and bobwhite quail) provided both showed the main adverse effect being related to 14 day survivors in both studies with the lowest NOEC of 1.8 ppm (bobwhite quail).

Acute testing on fish resulted in relatively consistent LC_{50} values, with results indicative of very high toxicity to fish. The metabolites tested were substantially less toxic to fish than the parent compound with the most toxic metabolite, M02 being considered moderately toxic based on one test to one species with an LC_{50} of 1200 µg/L. Only one longer term fish study was provided (rainbow trout, early life stage) with exposure to fenamiphos. The NOEC from this study was 3.8 µg/L, confirming fenamiphos as being highly toxic to fish.

Very few data were provided for aquatic invertebrates and only one standard study was provided using the parent compound. The results again show fenamiphos to be very highly toxic to *D. magna* (LC_{50} 1.9 µg/L). M01 and M02 were also very highly toxic to aquatic invertebrates based on one study each to *D. magna*. Other metabolites tested (M12, M13 and M24) were much less toxic (slightly to practically non-toxic). One study was provided for chronic toxicity to *D. magna* with a resulting NOEC of 0.12 µg/L and EC_{50} of 0.36 µg/L, again showing very high toxicity.

Only one study was provided for fenamiphos, M01 and M02 to a single algal species. Fenamiphos was moderately toxic while the metabolites were less toxic than the parent compound, with M01 being practically non-toxic and M02 being slightly toxic.

Fenamiphos and M01 were tested for toxicity to the sediment dwelling midge *C. riparius*. In the fenamiphos study, a very steep dose-response curve was observed and the NOEC for development was 20 µg/L with the EC_{50} falling between 20-40 µg/L (very highly toxic). M01 was also considered very highly toxic with a NOEC of 58 µg/L and EC_{50} of 95 µg/L.

A mesocosm study was undertaken where mesocosms were stocked with mature bluegill sunfish (15 males and 15 females per pond). The main initial effect was mortality of the fish at test concentrations >3.5 µg/L resulting in secondary effects on mesocosm structure. The NOEC was 3.5 µg/L.

Fenamiphos is very toxic to bees through both the oral and contact exposure routes. Several studies were performed on a range of non-target terrestrial arthropods with significant effects on adult mortality and reproduction at levels well below field spray rates (<1% of field spray rates). Based on soil-dwelling arthropod (Collembola) results, M01 and M02 were of a similar order of toxicity as the parent fenamiphos while M12 and M13 are less toxic. Fenamiphos demonstrated sublethal toxicity to earthworms at very low soil concentrations. In one acute study, the LC_{50} of fenamiphos was 888 mg/kg dw compared to a NOEC of 0.032 mg/kg dw based on worm weights. In a chronic 56-day study, numbers and biomass of offspring were significantly reduced at all application rates (NOEC <6 kg ac/ha). In a field study, some earthworm species were negatively affected by fenamiphos applications at 10 and 40 kg ac/ha (the only two rates trialled). Effects were noted up to 3 months after application.

Testing on soil microorganisms indicates no adverse impact on the soil nitrogen cycle up to 133 mg/kg dw soil (highest rate tested) is expected. However, some temporary increase in nitrate production may occur at these levels. A single screening level seedling emergence study at application rates up to 15 kg ac/ha showed no phytotoxic effects on all plant species tested (11 species consisting of 6 dicots and 5 monocots).

8 Environmental risk assessment

A deterministic approach will be used to try to characterise the risk from fenamiphos uses to the environment. With the deterministic risk characterisation, the primary outcome is the calculation of the risk quotient (RQ).

RQs are established for the different environmental organisms considered during the environmental effects assessment, that is, birds, terrestrial organisms and the various trophic levels in the aquatic ecosystem.

The risk quotient is interpreted through comparison with levels of concern (LOC) to analyse potential risk to non-target organisms and the need to consider further testing/refinement or regulatory action. Implicitly built into these LOCs are assessment factors to increase certainty in the risk assessment. For example, an acute LOC of 0.1 means the predicted environmental concentration (PEC)/(LC/EC_{50}) has an assessment factor of 10 built into the effects value.

8.1 Predicted environmental concentrations:

When assessing risk, not every case can be accounted for, so Australia follows an iterative process by considering:

- a 'worst case' exposure scenario, and, if needed,
- a series of refinements, which account for other factors and results in setting scenarios that are more realistic at each step.

The worst case should identify the sensitive environmental compartment(s) most at risk from exposure to the chemical. If these environmental compartments are not at risk (i.e. the RQ-value is acceptable), then no other assessment is needed.

Exposure estimates are required for food (birds and mammals), soil (soil dwelling arthropods, earthworms, soil microorganisms); water (aquatic organisms, either from spray drift or runoff); and sediment (benthic organisms). In addition, exposure to organisms such as bees, other non-target terrestrial arthropods and non-target terrestrial plants are based on the spray rate of the chemical.

For the initial exposure scenarios, a single application will initially be assumed although for several cropping situations, several applications within the season can be applied. This will be considered separately.

The exposure calculations are shown below in Tables 19, 20 and 22 below. The methodologies for calculating these values are described as follows.

8.1.1 Birds and mammals

Birds and mammals may be exposed orally through food and water ingestion as well as other sources such as granules, baits and soil ingestion. At the Tier I level it is assumed that animals obtain all their diet from the treated area and the contaminated food is not avoided. Considerations differ depending on the use pattern, e.g., sprayed formulations as opposed to granules, baits or treated seed.

Spray formulations

For spray applications, DSEWPAC estimates pesticide concentrations in animal food items with the focus on quantifying possible dietary ingestion of residues on vegetative matter and insects. Residue estimates are based on the updated Kenaga nomogram (Pfleeger et al.,1996) that relates food item

residues to pesticide application rate. Residues are compared directly with dietary toxicity data or converted to an oral dose.

Several crop uses on 400 g/L EC product labels instruct incorporation following application. It is unclear how this will affect exposure to birds. Depending on the time lag between application and incorporation (presumably by irrigation in the case of established crops), residues on foliage may be reduced for bird exposure. However, exposed insects may still have been consumed. Further, watering the product in will increase soil concentrations and possibly residue levels in soil insects that can then be consumed by birds. For this part of the exposure assessment, it is initially assumed that incorporation does not affect the residue estimates in bird diets following application.

Granular formulations

For granular formulations, the amount of pesticide per unit area for avian and mammal assessments is estimated. Consumption of granules forms the basis of the PEC_{food} in this instance. The label rate of application for the active constituent (ac) is the basis for the exposure calculation.

Exposed chemical per square metre can be calculated in several ways depending on whether the material is applied in rows or broadcast over the entire application site. In the case of fenamiphos, on the 100 g/K GR label certain cropping situations exist where no explicit instructions are made requiring incorporation. For example, no situation for bananas or ginger requires incorporation. In addition, other crops (bulbs, ornamentals) require irrigation following application but do not state this is for incorporation or provide a time following application for which to irrigate. This implies that following application, 100% of the applied dose remains on the soil surface.

For the initial risk assessment in this case, it will be assumed that incorporation is undertaken for all cropping situations. Many cropping situations include band application. The US EPA uses, as their first tier of assessment, an assumption that for banded treatments, 15% of granules remain unincorporated. In the absence of other guidance, this assumption will be used for this assessment initially for all cropping situations and rates. For those situations described above where no label instructions are provided related to incorporation, it should be confirmed by industry whether the product is in fact incorporated following application to the abovementioned crops. If this is not the case, risks will need to be re-calculated for these situations.

8.1.2 Bees and other terrestrial arthropods

8.1.2.1 Bees

Exposure to bees is determined for spray applications based on the maximum application rate. This rate is converted to a rate of chemical (ac) per square centimetre on the assumption that a honeybee is approximately 1 cm^2 in surface area (Davis and Williams 1990).

It may be argued that exposure to bees with the granular formulation is not as relevant. However, for this assessment, it will be assumed that the application rate is distributed over the soil surface given that application will usually be to moist soils or watered in following application whereby the chemical may distribute over a larger surface area than that just occupied by the granule.

8.1.2.2 Other arthropods

As with bees, the exposure to other arthropods (e.g., predators, parasites and ground dwelling organisms) is determined for spray applications based on the maximum application rate in kg/ha.

In this case, non-target terrestrial arthropods are unlikely to be exposed through application of granules unless they are soil dwelling organisms, so are not considered in the risk assessment for the granule formulation.

8.1.3 Soil organisms

The exposure calculations for soil organisms such as earthworms, soil dwelling arthropods and soil microorganisms are based on the application rate of the chemical.

With regard to these situations, the concentration in soil is predicted based on uniform mixing within the top 10 cm using a soil density of 1500 kg/m^3.

8.1.4 Aquatic organisms

Aquatic areas may be exposed through either spray drift or runoff. Neither 400 g/L EC product labels nor the 100 g/kg GR product label makes a statement precluding aerial application. However, application instructions really only relate to ground methods. Therefore, drift through aerial application will not be considered in this assessment.

8.1.4.1 Spray drift

Spray drift is only considered as an exposure route through spray application of a 400 g/L EC product. Spray drift through application of the granule formulation is not considered. In their 'Operating Principles and Proposed Registration Requirements in Relation to Spray Drift', the APVMA does not apply the requirements to granular products because they consider there is no spray involved such products (http://www.apvma.gov.au/users/spray_drift_risk.pdf).

The main models used for predicting drift are AgDRIFT and AGDISP. These are considered very reliable and well validated for aerial application, but the ground modelling components are less so. Therefore, for ground risk assessment, the APVMA also supplements modelling with available field data, for example, the 'Ganzelmeier Tables' as described in the following paragraph.

There are German studies (Rautmann et al.,2001) of drift trials carried out in field crops (including some vegetables), orchards and grapevines. Some of these were done on bare ground with others on cereals during late growth stages. In previous trials of this nature (Ganzelmeier et al.,1995), the applied amount of fluid was adjusted to be 300 L/ha at a driving speed of 6 km/hour and pressure ranging from 2.4-2.5 bar (240-250 kPa). This is assumed the case for the latest trials included in Rautmann et al. (2001).

The drift estimates used for the exposure assessment are the 90th percentile of mean values, quoted as per cent of the application rate and exposures are determined at varying distances (buffers) from the edge of the crop field. The PEC_{water} values are based on the predicted drift entering a water body of surface area 1 ha and depth 15 cm, and results in 1.5 ML of water. The refined PECwater values are therefore calculated as follows:

PECwater (mg/L) = (Rate (kg) X 106 mg X Drift (%) X Applications)/1.5 X 106 L

Initially, buffer zones of 5, 10 and 100 m have been modelled with the following basic drift values depending on cropping situation:

Table 17: Basic drift values for one application (%) of application rate (90th percentiles)

Distance (m)	**Field crops**	**Fruit crops**		**Grapevines**		**Vegetables/ornamentals**	
		Early	Late	Early	Late	Height <50 cm	Height >50 cm
5	0.57	19.89	8.41	1.18	3.62	0.57	3.62
10	0.29	5.55	1.81	0.39	1.23	0.29	1.23
100	0.03	0.06	0.06	0.009	0.03	0.03	0.03

8.1.4.2 Runoff

Australia has no defined model to use in quantifying exposure from runoff. For this assessment the model described by Birkved and Hauschild (2003) has been used. This model relies on the Koc of the chemical and calculates the fraction of applied chemical likely to runoff with consideration of soil type (based on sand content), slope of fields and excess rainfall. In running the model input parameters for Koc of 245 (this value represents the geometric mean of laboratory derived Koc values described earlier in this report); 1% organic carbon; a rainfall event sufficiently intense to result in 20 mm of excess rainfall (available for runoff); and soil with a sand content of 45-85% were chosen. The size of the watershed was 10 ha draining into a 1 ha pond. The pond was assumed to have an initial depth of 15 cm, plus the runoff generated from the watershed, resulting in a final water depth of 35 cm and volume of water of 3.5 ML.

Two scenarios with either a 1% slope or a 3% slope were run with respective water concentrations predicted for all label (whole hectare) application rates.

8.1.5 Sediment organisms

Sediment levels may be predicted through equilibrium partitioning methodology based on the predicted water concentration. However, for this assessment, the predicted water concentration will be applied to sediment organism exposure as the available test data exposed the test organisms through the water column.

8.2 Ecotoxicity estimates:

Based on the ecotoxicity data assessed for fenamiphos (both as the technical compound and in formulations), the following ecotoxicity endpoints will be used for the risk characterisation:

Table 18: Ecotoxicity data end-points for Risk Characterisation

Birds, acute, oral		Geometric mean of results[a]	LD_{50}	1.1	mg/kg bw
Birds, short term, dietary		Bobwhite quail	LC_{50}	38	ppm
Fish[b]	Acute	Bluegill sunfish	96 hours LC_{50}	9.3	µg/L
	Chronic	Rainbow trout (ELS)	NOEC	3.8	µg/L
Aquatic invertebrates[c]	Acute	*Daphnia magna*	48 hours EC_{50}	1.9	µg/L
	Chronic	*Daphnia magna*	21 days NOEC	0.12	µg/L
Algae/aquatic plants		*Scenedesmus subspicatus*	96 hours EC_{50}	3,500	µg/L
Sediment organisms		*Chironomus riparius*	28 days EC_{50}	20	µg/L
Aquatic ecosystems	Chronic	Based on mesocosm results	NOEC	3.5	µg/L
Bees (contact toxicity)			LC_{50}	0.28	ìg/bee
Non-target terrestrial arthropods (Exposure through spray)[d]			LR_{50}	14.1	g ac/ha
Non-target terrestrial arthropods (Exposure through soil)			EC_{50}	1.17	mg/kg dw
Earthworms (based on application rate)[e]			NOEC	<6	kg/ha
Earthworms (based on soil concentration)			NOEC	<0.12	mg/kg dw
Soil microorganisms				133	mg/kg dw
Non-target terrestrial plants			NOEC	>15000	g ac/ha

a) Although several studies were provided, they were all either old or used non-standard species. However, all results were similar with LD_{50} values were in the range of 0.7-1.3 mg ac/kg bw. The geometric mean of the results was chosen for this endpoint. b) Considered representative for both freshwater and saltwater. c) No seawater

invertebrate results were provided. The *D. magna* result is used as a surrogate for saltwater aquatic invertebrate toxicity. d) Not considered relevant for granular application. e) Chronic (reproductive) endpoints. Available acute toxicity data were inconclusive as to adverse effects.

8.3 Levels of concern

In order to characterise the risk, the RQ is compared to a level of concern (LOC). In Australia, the following LOC values are used (that is, the RQ needs to be below the LOC for a risk to be deemed acceptable):

Table 19: Levels of Concern for Characterising Environmental Risk.

Organisms	**Acute LOC**	**Chronic LOC**
Avian/mammals	0.1	1.0
Bees	1.0	
Terrestrial invertebrates	No set value.	
Earthworms	0.1	1.0
Soil microorganisms	In the case of non-target soil microorganism exposure, an unacceptable risk is presumed in the event that nitrogen turnover or carbon mineralisation is affected by more than 25% over the course of the study. To mitigate this risk, it must be demonstrated there is no unacceptable impact on microbial activity under field conditions, taking account of the ability of microorganisms to multiply.	
Non-target terrestrial plants	0.1	
Aquatic organisms (including sediment organisms	0.1	1.0

Note with respect to aquatic organisms, the view is taken that for LC_{50} or EC_{50} data, Q>0.5 results in a ‘presumption of unacceptable risk’ to organisms, while if 0.1<Q<0.5, there is a ‘presumption of risk that may be mitigated by restricted use’, and Q<0.1 indicates a low potential environmental risk.

8.4 Screening level exposure concentrations

8.4.1 400 g/L EC products

The majority of cropping situations provided on 400 g/L EC product labels relate to spray applications, either as overall treatments or by band application, to a wide range of crops. In addition, many of these crops allow for application through trickle irrigation systems. The following table summarises the crops and application rates. Some crops appear several times in the table as several different application rates may apply depending on crop stage or level of nematode infestation.

Uses also prescribed on the label include dip applications for aloe vera and banana planting material; and spray application to mushrooms (grown in compost enclosed in casings). These uses are considered separately (see Section 8.5.4 below).

Table 20: Summary of cropping situations/application rates on 400 g/L EC product labels

CROP	Comment	Application rate (kg/ha)
Chrysanthemums	Only crop where control is for leaf nematodes	0.4
Pineapples	Plant crop and ratoon crop foliar sprays	2.4
Sugar cane	Effective rate (that is, total rate/ha)	4
Pineapples	Ratoon crop foliar spray only	4.8
Potatoes	Effective rate	5.2
Bananas	Treatment for plant and ratoon crops (WA only)	9.6
Crucifers	Pre-plant overall treatment	9.6
Vegetables[a]	Pre-plant overall treatment or band application	9.6
Ornamentals	Pre-plant overall treatment	9.6
Bulbs	Pre-plant overall treatment or band application	9.6
Strawberries	Pre-plant overall treatment or band application	9.6
Tobacco	Overall treatment or band application	9.6
Tomatoes	Pre-plant overall treatment or band application	9.6
Pineapples	Pre-plant bed treatment (effective rate)	10
Aloe vera	Pre-planting and maintenance rate	12
Grapevines	Effective rate (intervine row application)	12
Bananas	Maintenance rate	12
Citrus	Maintenance rate	15
Bananas	Treatment of plant crop and subsequent ratoon crops	18
Ornamentals (perennial), nursery root stock	For areas of known heavy infestation	19.2
Aloe vera	Infested established crop rate	24
Bananas	Untreated/late retreatment/high nematode numbers	24
Citrus	Initial rate	30

a) includes beetroot, carrots, celery, cucurbits, endive, lettuce, onions, parsnips, sweet potatoes

Using these application rates (assuming the whole hectare is treated), and using the assumptions and methodology described above, the following exposure concentrations have been calculated.

Table 21: Predicted Environmental Concentrations for Birds (diet), Soil (surface and incorporation) and Water/Sediment (runoff).

Application rate (kg ac/ha)	0.4	2.4	4	4.8	5.2	9.6	10	12	15	18	19.2	24	30
Residue in birds diets (ppm)[a]	41.9	251.4	419	503	545	1006	1048	1257	1571	1886	2011	2514	3143
Soil surface (µg/cm^2)	4	24	40	48	52	96	100	120	150	180	192	240	300
Soil (mg/kg dw)[b]	0.33	2.00	3.33	4.00	4.33	8.00	8.33	10.00	12.50	15.00	16.00	20.00	25.00
Water, runoff, 3% slope (µg/L)[c]	1.38	8.27	13.78	16.53	17.91	33.06	34.44	41.33	51.66	61.99	66.12	82.66	103.32
Water, runoff, 1% slope (µg/L)[c]	0.46	2.75	4.59	5.50	5.96	11.01	11.47	13.76	17.20	20.64	22.01	27.52	34.40

a) Residue estimates based on Kenaga nomogram. b)Concentration estimated based on uniform mixing within the top 10 cm and assuming a soil density of 1500 kg/m3. c) Based on Birkved and Hauschild (2003) PESTLIC model. Assumes Koc 245; 1% OC; 20 mm excess rainfall; soil with a sand content of 45-85%.

Table 22: Drift Estimates and Predicted Environmental Concentrations Water/Sediment (spray drift)

CROP	Classification	Drift (%)			PEC (µg/L)		
		5 m	10 m	100 m	5 m	10 m	100 m
Chrysanthemums	Ornamentals, small	0.57	0.29	0.03	1.5	0.8	0.1
Pineapples	Fruit crop/late	8.41	3.6	0.06	134.6	57.6	1.0
Sugar cane	Field crop	0.57	0.29	0.03	15.2	7.7	0.8
Pineapples	Field crop	0.57	0.29	0.03	18.2	9.3	1.0
Potatoes	Vegetables/small	0.57	0.29	0.03	19.8	10.1	1.0
Bananas	Fruit crop/late	8.41	3.6	0.06	538.2	230.4	3.8
Crucifers	Vegetables/small	0.57	0.29	0.03	36.5	18.6	1.9
Vegetables[a]	Vegetables/small	0.57	0.29	0.03	36.5	18.6	1.9
Ornamentals	Ornamentals, small	0.57	0.29	0.03	36.5	18.6	1.9
Bulbs	Ornamentals, small	0.57	0.29	0.03	36.5	18.6	1.9
Strawberries	Small fruits	0.57	0.29	0.03	36.5	18.6	1.9
Tobacco	Field crop	0.57	0.29	0.03	36.5	18.6	1.9
Tomatoes	Vegetables/small	0.57	0.29	0.03	36.5	18.6	1.9
Pineapples	Field crop	0.57	0.29	0.03	38.0	19.3	2.0
Aloe vera	Field crop	0.57	0.29	0.03	45.6	23.2	2.4
Grapevines	Grapevine/late	3.62	1.23	0.03	289.6	98.4	2.4
Bananas	Fruit crop/late	8.41	3.6	0.06	672.8	288.0	4.8
Citrus	Fruit crop/late	8.41	3.6	0.06	841.0	360.0	6.0
Bananas	Fruit crop/late	8.41	3.6	0.06	1009.2	432.0	7.2
Ornamentals (perennial), nursery root stock	Ornamentals, small	0.57	0.29	0.03	73.0	37.1	3.8
Aloe vera	Field crop	0.57	0.29	0.03	91.2	46.4	4.8
Bananas	Fruit crop/late	8.41	3.6	0.06	1345.6	576.0	9.6
Citrus	Fruit crop/early	19.89	11.81	0.06	3978.0	2362.0	12.0

NB concentrations based on drift estimates from Ganzelmeier Tables. Calculations using ground-application from the AgDRIFT model show predicted levels to be higher than those based on the Ganzelmeier data at all buffer distances (assuming drift deposits into a downwind stream 3 m wide and 15 cm deep).

8.4.2 100 g/kg GR product

The following table summarises the crops and application rates. Some crops appear several times in the table as several different application rates may apply depending on crop stage or level of nematode infestation.

The label also prescribes a use on strawberries at a rate of 1 kg product (100 g ac)/ 1000 plants, or 1 g product (0.1 g ac)/plant. This scenario will be considered separately (Section 8.5.4 below) as it is difficult to derive an application rate/ha as per the scenarios discussed below.

Table 23: Summary of cropping situations/application rates on 100 g/kg GR product label

CROP	Comment	Application rate (kg/ha)
Sugar cane	Effective rate (band application)	4
Carrots/crucifers	Rate listed as kg/treated ha	9
Bulbs/ornamentals (annuals)	Rate listed as kg/treated ha	10
Pineapples	Effective rate (band application)	10
Potatoes	Rate listed as kg/treated ha	10
Crucifers/Duboisia/Ginger	Rate listed as kg/treated ha	11
Tomatoes	Rate listed as kg/treated ha	11
Bananas	Maintenance rate	12
Bananas	Treatment of plant crop and subsequent ratoon crops	18
Ornamentals (perennials)	Pre-plant treatment, high infestation.	20
Bananas	Untreated/late retreatment/high nematode numbers	25

Using these application rates (assuming the whole hectare is treated), and using the assumptions and methodology described above, the following exposure concentrations have been calculated.

Table 24: Predicted Environmental Concentrations for Birds (granules), Soil and Water/Sediment (runoff).

Application rate (kg ac/ha)	4	9	10	11	12	18	20	25
Bird, Acute oral (mg/m^2)	60	135	150	165	180	270	300	375
Number exposed granules(/m^2)[a]	1420	3200	3550	3900	4270	6400	7110	8890
Soil surface (µg/cm^2)	40	90	100	110	120	180	200	250
Predicted soil concentration (mg/kg)	3.33	7.50	8.33	9.17	10.00	15.00	16.67	20.83
Water, runoff, 3% slope (µg/L)	13.78	31.00	34.44	37.88	41.33	61.99	68.88	86.10
Water, runoff, 1% slope (µg/L)	4.59	10.32	11.47	12.61	13.76	20.64	22.93	28.66

a) Assuming 85% incorporation. One granule weighs 0.422 mg as advised by Bayer CropScience; Number of exposed granules calculated as ((exposed mg ac/ha)/(fraction ac in formulation X granule weight (mg)) (Patrick et al.,2001)

8.4.3 400 g/L EC turf-based product

This product is for control of nematodes in turf. Two application rates of 110 mL/100 m2 (equivalent to 4.4 kg ac/ha) or 1.5 L (0.6 kg)/bowling green are specified. The per hectare rate is within the range of rates for other 400 g/L EC products used in various crops described above.

8.4.4 50 g/kg GR home garden product

This product is for control of certain nematodes in tomatoes, crucifers and ornamentals in the home garden and is prescribed to be applied generally at rates of 25 g/m2 or 1.25 g ac/m2 (equating to a per hectare application rate of 12.5 kg ac/ha). A higher rate of 50 g/m2 (25 kg ac/ha) is prescribed for woody ornamentals with heavy infestations. These rates are within the range of rates for the 100 g/kg GR product used in various crops described above.

8.5 Risk quotients/risk characterisation

The following risk quotients have been derived for the 400 g/L EC and the 100 g/kg GR labels for crop uses and compared against the LOCs. Risk quotients have been derived as a ratio of predicted concentrations in the different environmental media (Tables 19, 20 and 22) to the environmental toxicity end-points for the various environmental compartment organisms defined in Table 16.

8.5.1 400 g/L EC formulation

Table 25: RQ's for birds, aquatic organisms (runoff), bees and other terrestrial arthropods, earthworms, microorganisms and non-target terrestrial plants.

Application rates (kg ac/ha)	0.4	2.4	4	4.8	5.2	9.6	10	12	15	18	19.2	24	30
Birds, short term, dietary	1.1	6.6	11.0	13.2	14.3	26.5	27.6	33.1	41.3	49.6	52.9	66.2	82.7
Fish, Acute, Run-off, 3% slope	0.15	0.89	1.48	1.78	1.93	3.56	3.70	4.44	5.55	6.67	7.11	8.89	11.11
Fish, Acute, Run-off, 1% slope	0.05	0.30	0.49	0.59	0.64	1.18	1.23	1.48	1.85	2.22	2.37	2.96	3.70
Aquatic invertebrates, Acute, Run-off, 3% slope	0.73	4.35	7.25	8.70	9.43	17.40	18.13	21.75	27.19	32.63	34.80	43.50	54.38
Aquatic invertebrates, Acute, Run-off, 1% slope	0.24	1.45	2.41	2.90	3.14	5.79	6.03	7.24	9.05	10.86	11.59	14.48	18.10
Algae/aquatic plants Run-off, 3% slope	0.0004	0.002	0.004	0.005	0.005	0.009	0.010	0.012	0.015	0.018	0.019	0.024	0.030
Algae/aquatic plants Run-off, 1% slope	0.0001	0.0008	0.001	0.002	0.002	0.003	0.003	0.004	0.005	0.006	0.006	0.008	0.010
Sediment organisms Run-off, 3% slope	0.07	0.41	0.69	0.83	0.90	1.65	1.72	2.07	2.58	3.10	3.31	4.13	5.17
Sediment organisms Run-off, 1% slope	0.02	0.14	0.23	0.28	0.30	0.55	0.57	0.69	0.86	1.03	1.10	1.38	1.72
Bees	14	86	143	171	186	343	357	429	536	643	686	857	1071
Non-target terrestrial arthropods (spray)	28	170	284	340	369	681	709	851	1064	1277	1362	1702	2128
Non-target terrestrial arthropods (soil)	0.28	1.71	2.85	3.42	3.70	6.84	7.12	8.55	10.68	12.82	13.68	17.09	21.37
Earthworms (Based on application rate)>	0.07	0.40	0.67	0.80	0.87	1.60	1.67	2.00	2.50	3.00	3.20	4.00	5.00
Earthworms (based on soil concentration) >	2.8	16.7	27.8	33.3	36.1	66.7	69.4	83.3	104.2	125.0	133.3	166.7	208.3
Soil microorganisms	0.003	0.02	0.03	0.03	0.03	0.06	0.06	0.08	0.09	0.11	0.12	0.15	0.19
Non-target terrestrial plants <	0.03	0.16	0.27	0.32	0.35	0.64	0.67	0.80	1.00	1.20	1.28	1.60	2.00
Aquatic systems (mesocosm NOEC of 3.5 µg/L)													
(RQ of <1 is acceptable) Run-off, 3% slope	0.39	2.36	3.94	4.72	5.12	9.45	9.84	11.81	14.76	17.71	18.89	23.62	29.52
(RQ of <1 is acceptable) Run-off, 1% slope	0.13	0.79	1.31	1.57	1.70	3.14	3.28	3.93	4.91	5.90	6.29	7.86	9.83

Dark green–Unacceptable risk; light green–risk identified, but may be mitigated; and no shading–acceptable risk.

Table 26: RQ's for aquatic organisms resulting from spray drift, ground application only

	RQ–fish			RQ–Aquatic invertebrates			RQ–algae/aquatic plants			RQ–sediment organisms		
CROP Buffer zone	5 m	10 m	100 m	5 m	10 m	100 m	5 m	10 m	100 m	5 m	10 m	100 m
Chrysanthemums	0.16	0.08	0.01	0.80	0.41	0.04	0.000	0.000	0.000	0.08	0.04	0.00
Pineapples	14.47	6.19	0.10	70.82	30.32	0.51	0.038	0.016	0.000	6.73	2.88	0.05
Sugar cane	1.63	0.83	0.09	8.00	4.07	0.42	0.004	0.002	0.000	0.76	0.39	0.04
Pineapples	1.96	1.00	0.10	9.60	4.88	0.51	0.005	0.003	0.000	0.91	0.46	0.05
Potatoes	2.12	1.08	0.11	10.40	5.29	0.55	0.006	0.003	0.000	0.99	0.50	0.05
Bananas	57.88	24.77	0.41	283.28	121.26	2.02	0.154	0.066	0.001	26.91	11.52	0.19
Crucifers	3.92	2.00	0.21	19.20	9.77	1.01	0.010	0.005	0.001	1.82	0.93	0.10
Vegetables[a]	3.92	2.00	0.21	19.20	9.77	1.01	0.010	0.005	0.001	1.82	0.93	0.10
Ornamentals	3.92	2.00	0.21	19.20	9.77	1.01	0.010	0.005	0.001	1.82	0.93	0.10
Bulbs	3.92	2.00	0.21	19.20	9.77	1.01	0.010	0.005	0.001	1.82	0.93	0.10
Strawberries	3.92	2.00	0.21	19.20	9.77	1.01	0.010	0.005	0.001	1.82	0.93	0.10
Tobacco	3.92	2.00	0.21	19.20	9.77	1.01	0.010	0.005	0.001	1.82	0.93	0.10
Tomatoes	3.92	2.00	0.21	19.20	9.77	1.01	0.010	0.005	0.001	1.82	0.93	0.10
Pineapples	4.09	2.08	0.22	20.00	10.18	1.05	0.011	0.006	0.001	1.90	0.97	0.10
Aloe vera	4.90	2.49	0.26	24.00	12.21	1.26	0.013	0.007	0.001	2.28	1.16	0.12
Grapevines	31.14	10.58	0.26	152.42	51.79	1.26	0.083	0.028	0.001	14.48	4.92	0.12
Bananas	72.34	30.97	0.52	354.11	151.58	2.53	0.192	0.082	0.001	33.64	14.40	0.24
Citrus	90.43	38.71	0.65	442.63	189.47	3.16	0.240	0.103	0.002	42.05	18.00	0.30
Bananas	108.52	46.45	0.77	531.16	227.37	3.79	0.288	0.123	0.002	50.46	21.60	0.36
Ornamentals (perennial), nursery root stock	7.85	3.99	0.41	38.40	19.54	2.02	0.021	0.011	0.001	3.65	1.86	0.19
Aloe vera	9.81	4.99	0.52	48.00	24.42	2.53	0.026	0.013	0.001	4.56	2.32	0.24
Bananas	144.69	61.94	1.03	708.21	303.16	5.05	0.384	0.165	0.003	67.28	28.80	0.48
Citrus	427.74	253.98	1.29	2093.68	1243.16	6.32	1.137	0.675	0.003	198.90	118.10	0.60

Dark green–Unacceptable risk; light green–risk identified, but may be mitigated; and no shading–acceptable risk.

8.5.2 100 g/kg GR formulation

Table 27: RQ's for birds, aquatic organisms (runoff), bees and other terrestrial arthropods, earthworms, microorganisms and non-target terrestrial plants

Application rates (kg ac/ha)	4	9	10	11	12	18	20	25	Units
Birds, acute oral (assuming 85% incorporation)									
Birds, acute oral–20 g bird	2727	6136	6818	7500	8182	12273	13636	17045	RQ/m^2
150 g bird	364	818	909	1000	1091	1636	1818	2273	RQ/m^2
1000 g bird	55	123	136	150	164	245	273	341	RQ/m^2
Area foraged to obtain lethal dose–20 g bird	7	3	3	3	2	2	1	1	cm^2
150 g bird	53	23	21	19	18	12	11	8	cm^2
1000 g bird	350	156	141	128	117	78	70	56	cm^2
Fish, Acute, Run-off, 3% slope	0.15	3.33	3.70	4.07	4.44	6.67	7.41	9.26	
Fish, Acute, Run-off, 1% slope	0.05	1.11	1.23	1.36	1.48	2.22	2.47	3.08	
Aquatic invertebrates, Acute, Run-off, 3% slope	0.73	16.31	18.13	19.94	21.75	32.63	36.25	45.32	
Aquatic invertebrates, Acute, Run-off, 1% slope	0.24	5.43	6.03	6.64	7.24	10.86	12.07	15.09	
Algae/aquatic plants Run-off, 3% slope	0.0004	0.009	0.010	0.011	0.012	0.018	0.020	0.025	
Algae/aquatic plants Run-off, 1% slope	0.0001	0.0029	0.003	0.004	0.004	0.006	0.007	0.008	
Sediment organisms Run-off, 3% slope	0.07	1.55	1.72	1.89	2.07	3.10	3.44	4.31	
Sediment organisms Run-off, 1% slope	0.02	0.52	0.57	0.63	0.69	1.03	1.15	1.43	
Bees	143	321	357	393	429	643	714	893	
Non-target terrestrial arthropods (soil)	2.85	6.41	7.12	7.83	8.55	12.82	14.25	17.81	
Earthworms (based on application rate) >	0.67	1.50	1.67	1.83	2.00	3.00	3.33	4.17	
Earthworms (based on soil concentration) >	27.8	62.5	69.4	76.4	83.3	125.0	138.9	173.6	
Soil microorganisms	0.025	0.06	0.06	0.07	0.08	0.11	0.13	0.16	
Non-target terrestrial plants <	0.27	0.60	0.67	0.73	0.80	1.20	1.33	1.67	
Aquatic systems (mesocosm NOEC of 3.5 µg/L)									
(RQ of <1 is acceptable) runoff; 3% slope	0.39	8.86	9.84	10.82	11.81	17.71	19.68	24.60	
(RQ of <1 is acceptable) runoff; 1% slope	0.13	2.95	3.28	3.60	3.93	5.90	6.55	8.19	

Dark green–Unacceptable risk; light green–risk identified, but may be mitigated; and no shading–acceptable risk.

8.5.3 50 g/kg fenamiphos GR product

As a result of the Office of Chemical Safety's toxicology assessment, the continued registration of the 50 g/kg fenamiphos GR home garden product is no longer supported. No risk characterisation for this product has been undertaken.

8.5.4 Other use patterns

8.5.4.1 Dipping solutions

The label for 400 g/L EC formulations includes dip applications for aloe vera and banana planting material. Treatment rates for aloe vera are 4 mL ac/L of dipping solution while for banana planting material, the rate is 10% of this at 0.4 mL ac/L dipping solution.

While both uses provide directions to allow dipped planting material to drain and dry prior to planting, neither use provides directions relating to disposal of spent dipping solutions. This is the area where undesirable environmental exposure could result.

The level of environmental exposure resulting from these uses will depend on the volumes of dipping solution likely to require disposal at any one site, and the method of disposal.

DSEWPAC/APVMA/RLC are currently developing a dip disposal risk assessment framework which will include specific criteria for deciding the suitability or not of land-based disposal of spent dip solutions. While specific criteria based on 10 dipping chemicals have been developed and published in Part 7 Environment of MORAG, this framework is not yet fully developed, and further information from industry and growers will allow a more considered risk assessment relating to this end-use. Such information should include:

- Likely volumes of dipping solution requiring disposal from any given site at one time;
- Current methods of disposing of dipping solution;
- Current methods of draining and drying planting material following dipping.

8.5.4.2 Mushrooms

The label for 400 g/L EC formulations includes a spray application to mushrooms grown in compost and enclosed in casings.

Several different application rates are prescribed for treating compost. A spray solution of 65 mL product (26 g ac) in 20 L water is prescribed for treatment prior to peak heating, and this amount of spray is required to treat one tonne of compost resulting in a fenamiphos concentration of 26 mg/kg compost.

An application rate of 22 mg fenamiphos/kg compost is prescribed after peak heating (55 mL product/tonne compost).

Once the mycelia have spread through the compost, a layer of peat or soil (known as the casing) is added to the compost. For casing treatment, an application rate of 4 g ac/50-60 kg bale of peat, or 26 g ac/tonne casing is prescribed. The highest application rate in this case is 80 mg ac/kg casing.

The label is explicit in its instruction that users should not treat both the casing and the compost.

The most likely environmental exposure from this use pattern will result from disposal of used compost and casing material. Information provided by the Queensland Department of Primary Industries states that spent compost can be marketed as a potting mix or garden soil additive (http://www2.dpi.qld.gov.au/horticulture/5193.html). During the growing cycle, significant degradation of fenamiphos and metabolites would be expected. Elevated temperatures would likely be found in the growing medium, and as advised on the above Queensland DPI website, at the end

of the cropping season, steam to at least 70°C for 10 hours is used on the compost to prevent the spread of pests and diseases.

Following such processes, and further diluting the compost in other soil (for example when using as a soil additive) should result in soil concentrations unlikely to result in adverse environmental effects and this use pattern is considered acceptable.

8.5.4.3 Strawberries

The label for the 100 g/kg GR formulation includes a use on strawberries at a rate of 1 kg product (100 g ac)/1000 plants, or 1 g product (0.1 g ac)/plant.

Planting density of strawberries is high. Assuming plants are spaced 35 cm apart with the same distance between rows, up to 80,000 plants per hectare can be found, which would result in an equivalent application rate of 8 kg ac/ha. This is within (but at the lower end of) the rates shown in Table 21 above for other field crops using the 100 g/kg GR product.

The label states that the granules should be applied directly into the heart of infested plants within one month of planting, and spray irrigated immediately after application to avoid possible phytotoxicity.

While bird exposure is possible, application early on in the growing cycle means flowers and fruits are unlikely to be present to attract birds. Run-off is likely to be limited due to the dense nature of the strawberry plants with application within the plant itself.

The rates prescribed may lead to unacceptable exposure to soil organisms within treated areas. The intensive nature of strawberry crops, and the likelihood that only a small fraction of the planted area is likely to be treated should mean that extensive untreated areas remain available for soil dwelling organisms. However, some further information from industry and growers in this respect would help refine this part of the risk assessment. Information should include:

- likely total area of strawberries expected to receive a treatment of fenamiphos in any given year;
- likely area as a proportion of the growing hectare likely to be treated in the season.

8.5.5 Discussion of risk quotients–field uses

8.5.5.1 Birds

The risk characterization shows an unacceptable risk to birds for all cropping situations (including turf) at all application rates. When applied as the granule formulation, risk quotients are particularly high even assuming 85% of the granules are incorporated into the soil. With this assumption, and assuming the mass of each granule is 0.422 mg, calculations show that small birds need only forage a very small surface area to potentially ingest a lethal dose (between 1 to 7 cm^2 depending on the application rate).

8.5.5.2 Aquatic organisms including sediment dwelling organisms

Risk to aquatic organisms was predicted either from exposure resulting from runoff or exposure resulting from spray drift in the case of the liquid formulation. Generally, the risk to algae/aquatic plants was deemed acceptable through both routes with the exception of an unacceptable risk to these organisms from spray drift at the highest application rate to citrus with a buffer zone of 5 or 10 m.

Conversely, the risk to fish, aquatic invertebrates and sediment dwelling organisms was generally deemed unacceptable (including for turf application).

Liquid formulation, exposure through runoff; all RQs exceeded the LOCs except for fish at the lowest application rate (0.4 kg ac/ha) with a 3% slope; fish at 0.4 and 2.4 kg ac/ha with a 1% slope; aquatic invertebrates at 0.4 kg ac/ha with a 1% slope; sediment organisms up to 2.4 kg ac/ha with a 3% slope and sediment organisms up to 5.2 kg ac/ha with a 1% slope.

Liquid formulation; exposure through runoff; chronic end-point; based on a NOEC of 3.5 µg/L obtained through a mesocosm study, runoff scenarios considered resulted in an unacceptable risk to aquatic systems at all application rates for all crops except the lowest application rate at both slopes, and the 2.4 kg ac/ha application rate on a 1% slope. This NOEC was based on mortality effects to fish and shows the potential sensitivity of aquatic systems to fenamiphos at very low concentrations.

Liquid formulation, exposure through spray drift; generally, the lowest application rate at 5 and 10 m resulted in acceptable RQs (except for aquatic invertebrates at 5 m downwind). Otherwise, all application rates for all crops resulted in an unacceptable risk to fish, aquatic invertebrates and sediment dwelling organisms at 5 and 10 m downwind, except for sediment organisms following application to sugar cane (4 kg ac/ha) and pineapples (4.8 kg ac/ha) at 10 m downwind. With the exception of application to citrus (30 kg ac/ha), a buffer zone of 100 m downwind resulted in risk either acceptable or possibly mitigable being predicted for fish and sediment dwelling invertebrates. Risk quotients for aquatic invertebrates still exceeded LOCs for all scenarios (except the lowest application rate of 0.4 kg ac/ha, and application to sugar cane at 4 kg ac/ha).

Granular formulation, exposure through runoff; an unacceptable risk to fish and sediment organisms was identified for all application rates above 4 kg ac/ha at both slopes. An unacceptable risk was identified to aquatic invertebrates at all application rates where a 3% slope was modelled, and all application rates above 4 kg ac/ha on a 1% slope.

Granular formulation; exposure through runoff; chronic end-point; based on a NOEC of 3.5 µg/L obtained through a mesocosm study, runoff scenarios considered resulted to an unacceptable risk to aquatic systems identified for all application rates above 4 kg ac/ha at both slopes.

8.5.5.3 Non-target terrestrial organisms

An unacceptable risk was identified for bees based on application from both the liquid and granule formulation for all crops (including turf) and at all application rates.

When exposed through the liquid formulation, above-ground terrestrial arthropods all showed RQs well in excess of 1 (ranging from 28–>1000 depending on application rates). While LOCs are not established for these organisms, the high RQs are of concern and indicate an unacceptable risk to these organisms. Ecotoxicity data demonstrated adverse effects on both adult mortality and reproduction for a range of arthropods at levels well under application rates prescribed for fenamiphos.

A similar concern exists for ground-dwelling terrestrial arthropods. With the exception of the two lowest application rates (0.4 and 2.4 kg ac/ha) of the liquid formulation, all RQs were at least 2, with a highest RQ around 20 for both the liquid and granule formulation uses.

RQs for earthworms were calculated using chronic toxicity data as the only available acute toxicity test showed significant effects at the lowest tested rate. RQs >1 in this case are deemed to demonstrate an unacceptable risk. Even with the reproduction tests, adverse effects were found at the lowest concentrations tested, so the RQs are not reliable. Minimum application rates of 9 kg ac/ha or more resulted in an unacceptable risk to earthworms, although application rates lower than these could also result in an unacceptable risk based on the NOECs being undefined in the ecotoxicity tests. Where the application rates were calculated as a soil concentration, all application rates for all crops on both labels resulted in an unacceptable risk to earthworms.

8.5.5.4 Soil microorganisms

Risks to soil microorganisms were acceptable up to application rates of 15 kg ac/ha (liquid formulation) and 18 kg ac/ha (granule formulation). At rates higher than this, a risk was identified, but this risk could be mitigated, and Q values for all application rates with both products never exceeded 0.2.

8.5.5.5 Non-target terrestrial plants

An unacceptable risk was identified for non-target terrestrial plants with both products at application rates of 9 kg ac/ha or higher. This risk was based on a threshold toxicity value from a single study to several plant species (seedling emergence). The result is therefore highly uncertain. No effects were observed up to the limit of exposure concentrations (15 kg ac/ha), however, only one part of a plant's life-cycle was tested. Given that the EC_{25} or EC_{50} for this study is likely to be significantly higher than the 15 kg ac/ha, the RQ approach for terrestrial plants is probably significantly overestimated. Using the NOEC as the highest rate tested, and taking an acceptable RQ to be 1, then it can be stated that risks to terrestrial plants are acceptable, at least up to an application rate of 15 kg ac/ha. This is relevant in the event the crop being treated is considered a non-target terrestrial plant. Outside the cropping area, non-target plants are unlikely to be exposed to anywhere near these levels of fenamiphos as their exposure will eventuate from spray-drift or runoff, which in both cases, will only be a fraction of the application rates.

Therefore, it can be concluded that, outside the cropping area, the risk to non-target terrestrial plants is acceptable.

8.6 Further considerations/uncertainties relating to the risk characterisation

8.6.1 Lower application rates due to banded treatments

When fenamiphos is applied as a pre-plant treatment, the whole area is treated so application rates are as described above. In many situations, when applied to established crops, the actual rate of application (when averaged over the whole hectare) is reduced compared to the rate in the treatment zone. This will therefore result in lowering predicted environmental concentrations and may lead to a more acceptable risk outcome.

The following table provides information on the crops where banded treatments may be used during application to the established crop, along with broad assumptions on the actual area treated. The average application rate is based on the whole hectare treatment rate for selected crops (see Table 18 and Table 21 above) multiplied by the expected treated percentage of the hectare.

Table 28: Application rates, averaged per hectare, where applied as banded treatments

Crop	Comments	Application rate (average/ha)
Tobacco	Assume 60 cm rows, 1 m apart (~60% ha treated)	3.8
Bananas	Band application (~40% treated)	4.8
Vegetables	Band application (~60% treated)	5.8
Bulbs	Band application (~60% treated)	5.8
Strawberries	Band application (~60% treated)	5.8
Tomatoes	Band application (~60% treated)	5.8
Bananas	Band application (~40% treated)	7.2
Pineapples	Band application (~75% treated)	7.5

Crop	Comments	Application rate (average/ha)
Grapevines	Band application (~67% treated)	8
Bananas	Band application (~40% treated)	9.6
Ornamentals (perennial)	Band application (~60% treated)	11.5

This table demonstrates that, while banded treatment results in a lower overall application rate per hectare (for example, leading to a lowering in the predicted concentrations in soil and water from runoff), the application rates are still within the range of those considered for full hectare treatment rates were unacceptable risks to birds, terrestrial organisms and aquatic organisms have already been identified. Therefore, the use of banded treatment rates will not result in sufficient lowering of the risk quotients to conclude an acceptable risk.

8.6.2 Degradation of parent compound

The above RQs have been derived for the parent compound. Often, parent substances will degrade to less toxic metabolites. In the case of fenamiphos, its main degradation products of M01 and subsequently, M02, will not reduce the RQs significantly for many environmental organisms as limited toxicity data for these metabolites suggest they are of a similar order of toxicity as fenamiphos (for example, toxicity to birds, aquatic invertebrates and soil dwelling arthropods). No standard chronic test results are available for organisms in the environment for these metabolites and insufficient test data are available to conclude on toxicity of these metabolites to other environmental organisms such as bees, earthworms and soil microorganisms. However, it is noted that in field testing of earthworms, significant effects were found on earthworm populations up to three months following application (10 and 40 kg ac/ha), and presumably a significant period of this exposure was to the M01 and M02 metabolites following degradation of fenamiphos.

Additionally, these metabolites are much more persistent than the parent compound, and the persistence of all compounds (fenamiphos, M01 and M02) is unclear once it is soil incorporated.

8.6.3 Chronic exposure and multiple applications

The above risk characterization primarily relates to acute risks to environmental organisms resulting from single applications with the result that risk is unacceptable for almost all cropping situations to all environmental organisms with exceptions of algae/aquatic plants, soil microorganisms and terrestrial plants.

Uncertainties exist with this statement, particularly for algae/aquatic plants and non-target terrestrial plants due to the limited data set in both cases.

Further, many of the cropping situations where fenamiphos is used allow for multiple applications of the substance, although several months are generally required between applications. Examples include aloe vera (apply every 4 months); bananas (up to three treatments per year with instructions including a re-application time of within 4 months); and pineapples (5 sprays over the plants at 2-3 month intervals). For pineapple ratoon crop foliar sprays, a spray following harvest with an additional spray 4-6 weeks later is prescribed. For turf applications, a repeat spray 5 weeks after the initial application is recommended. The only situation where reapplication is stated on the label being less than 1 month apart is for control of leaf nematodes to chrysanthemums where the label prescribes application at 14 day intervals.

Chronic risk to environmental organisms will depend on residues remaining in the environment at the time of subsequent applications, and the biological activity of the residues at expected levels following chronic exposure.

Fenamiphos and its main M01 metabolite are hydrolytically stable within the environmentally relevant pH range. While photolysis may provide a means of rapidly eliminating fenamiphos from soil or water (half-life <1 day), the substance is predominantly soil incorporated so this is unlikely to be a significant removal mechanism. The M01 metabolite is much more stable to photolysis (half-life up to 96 days with a 12:12 hour light:dark day).

In soil, fenamiphos is rapidly oxidised to M01 and then further oxidised to M02. While half-lives of the parent compound in soil may be fairly short (generally <1 week), loss of residues as the combined parent and M01 (a substance also biologically active), are much greater. Degradation often appeared biphasic. One study showed first half-lives from 6.1-17.5 days with second half-lives from 50-78 days. A second study with 16 soils at three temperatures showed degradation half-lives of combined fenamiphos and M01 residues averaging 66.3, 36.0 and 26.2 days at 16°C, 22°C and 28°C respectively. It is important to note that these studies were based on top soil application. Where fenamiphos is soil incorporated, there is the potential for persistence to be significantly increased.

Where released to water, fenamiphos may move to sediments where it will degrade slowly. In an aerobic system, the half-life in water was relatively short (<8 days), while that for the whole system was much slower (up to 111 days). In an anaerobic soil/supernatant water system, most of the parent was retained in the soil while significant amounts of M01 moved from the soil to the water phase. The degradation of fenamiphos under anaerobic conditions was relatively slow with a half-life estimated to be around 90 days.

8.6.3.1 Birds

Avian field studies were conducted considering impacts on bird mortality following applications of either spray or granule formulations to citrus groves, tobacco fields and golf courses in the United States. While the results of these studies generally concluded the application of the formulations did not affect survival/mortality based on certain indicator species, it must be recognized the ability to undertake such studies is difficult and large variability in results must be expected.

In actual fact there were some treatment related mortalities observed. In particular, in one study where fenamiphos was applied by chemigation in citrus groves, compared to control plots, there was significant exposure on treated plots with 13% higher mortality in these plots.

Further, in one of the studies, when applied to golf courses as a spray application at 11.2 kg ac/ha there was an effect of fenamiphos treatment being a loss (either through mortality or emigration) of about 9% of the avian population at treatment sites with the 80% upper confidence limit for this loss being 13.3%. Evidence was that heavier birds were more likely to recover than lighter birds.

Abnormal behaviours were observed and for those that were followed, recovery rates were high. Although calculated mortality rates were low, there was an overall significant difference in the disappearance of colour marked birds between treatment plots and control plots.

On numerous occasions, birds were seen eating ‘dosed’ invertebrates, and subsequently became sick. Residue monitoring indicated that concentrations of total fenamiphos were initially high in invertebrates, but decreased to relatively safe levels within a few days. Most of the treatment related deaths and behavioural impairments were found on the day of application or the next day.

In all studies, residues were found where tested in all media (soil, water and invertebrates), and often at levels higher than dietary LC_{50} values.

Concerning these studies, the US EPA notes that the studies had deficiencies, which limit or negate their use for evaluating the magnitude of impacts to terrestrial and aquatic wildlife from use of fenamiphos. Additionally, they note that no field exposure reproductive or developmental studies were performed which limits the evaluation to acute impacts (Patrick et al.,2001).

Combined with known incidents to birds from fenamiphos in the field, there appears to be support for concluding that fenamiphos poses a high risk to birds.

8.6.3.2 Terrestrial organisms

In predicting environmental concentrations (Table 19 and Table 22 above), concentrations in soil were estimated to range from 0.33 to 25 mg/kg dw depending on the application rate following a single application. Chronic NOECs for earthworms were <0.12 mg/kg dw. This shows that residues in soil may remain at levels higher than the chronic NOEC for a long time following application. For example, with a half-life in soil of 7 days, it would take around 9-10 days for residues to drop from the lowest predicted value of 0.33 mg/kg dw to the threshold level of 0.12 mg/kg dw. If the half-life were longer (for example, 36 days at an average temperature of 22°C), it would take over 1.5 months (46 days) for residues to fall to acceptable levels, and that assumes that subsurface degradation rates following incorporation mimic those of surface applied degradation rates found in the laboratory studies. This demonstrates that over all application rates of fenamiphos to crops, the potential for chronic exposure is high with residues possibly remaining at harmful levels prior to following applications.

For non-target terrestrial arthropods, effects are most likely to be acute in nature, particularly where exposed through spray. However, data show that these effects are significant on adult mortality (and reproduction for surviving adults) at levels significantly lower than crop application rates. Further, exposed insects were shown in bird field studies to contain residues at levels in excess of bird dietary LC_{50} values, and birds were observed to feed on affected insects.

8.6.3.3 Aquatic organisms

Similarly for aquatic exposure, water concentrations predicted from runoff ranged from 0.46 to 34.4 µg/L (1% slope) and 1.38 to 103.3 µg/L (3% slope) following a single application. While chronic data for metabolites are not available, there is a mesocosm study demonstrating a NOEC to aquatic systems of 3.5 µg/L, below the majority of water concentrations predicted following single application. In this study, application was to the water column, and with data indicating a half-life in water/sediment systems as high as 111 days, it can be seen the potential for residue levels to remain at levels above those known to cause adverse effects is high, particularly with the prospect of continued exposure resulting from repeat applications.

Following single applications with predicted water concentrations resulting from spray drift at 100 m downwind (see Table 22), levels are generally acceptable (that is the RQ is <1 based on the chronic mesocosm NOEC of 3.5 µg/L) except for bananas, perennial ornamentals, aloe vera and citrus (RQs of 1.1-2.7; 1.1; 1.4; and 1.7-3.4 respectively). With these crops, application rates were higher and/or drift estimates were higher. It can be seen again, that where repeat applications occur, the potential exists for residue levels to remain in the whole system at levels higher than those considered acceptable prior to subsequent applications.

8.7 Groundwater

Fenamiphos, and particularly its degradates, have demonstrated mobility in soil based on soil mobility studies, increasing the potential for leaching into groundwater. Based on laboratory and field studies conducted in the United States (see Section 5.3 above), the M01 and M02 metabolites are more mobile than the parent in the soil profile. Both these have been detected in groundwater in the United States, indicating that they are sufficiently persistent to leach in some environments. No such data exists for Australia, and in its absence, the only conclusion that can be drawn is that the potential for contamination of groundwater in fenamiphos use areas in Australia exists.

In addition, to better understand the implications of this area, further Australian data are required including:

1. Identification within fenamiphos use areas in Australia of vulnerable soils where a potential for leaching to groundwater exists;
2. Monitoring of groundwater resources within these use areas.

8.8 Risk management options

The unacceptable risk derived to birds, terrestrial organisms and aquatic organisms from both acute and chronic exposure to fenamiphos makes mitigation very difficult. The substance is applied to crops at rates of 0.4 kg/ha up to 30 kg/ha, and risk quotients from a single application result in unacceptable risks to most organisms, even at the lowest application rate.

Prior to recommending any risk management options, it is first necessary to refine to the extent possible, the risk assessment for those scenarios above where an unacceptable risk has been identified. In order to do this, further input is required from industry and/or growers to better calculate exposure concentrations and address other pertinent issues. These requirements are discussed in the 'Recommendations' section below.

9 Data requirements to refine risk assessment

The risk assessment of fenamiphos has identified an unacceptable risk to several environmental compartments through the use of fenamiphos in various field crops and turf situations. Following discussions with the APVMA, it was agreed that prior to finalising the environmental risk assessment for fenamiphos, the current preliminary report findings would be circulated to industry for input from industry and growers to enable a refinement where possible of the risk assessment findings. Responses to the following questions/data were sought.

9.1 Crop/field label uses

9.1.1 General:

Based on acute risk, unacceptable risks to several environmental compartments have been identified. It is unclear what use patterns, if any, are no longer required.

1. Industry should advise on which use patterns for both the spray and granular formulations of fenamiphos are no longer relevant.
   It is recognised that banded applications will result in significantly lower percentages of whole hectares being treated. This may reduce the overall risk. Currently, assumptions relating to this have not been able to mitigate risks (either for the spray or granule formulations) applied to field crops.
2. Industry and/or growers should provide detailed information relating to crops identified on the 400 g/L EC and 100 g/kg GR product labels on actual growing conditions (row spacings), application methods (e.g., targeted sprayers) and actual percentages of hectares within crops likely to be treated when applied as a band treatment.
3. In relation to this, views on eliminating label uses requiring whole hectare treatments are sought, for example, in pre-plant situations or where a total spray is performed on established crops.
   The risk assessment currently focuses on a single application. In many crops, repeat applications are allowed according to label directions. To account for this, modelling of field half-lives is required. However, currently all laboratory data relate to degradation following surface applied, non-incorporated test substance. A non-standard literature paper indicates degradation rates in subsurface soil may be significantly longer.

4. Information on likely degradation rates following soil incorporation is essential to allow a better estimation of risks resulting from multiple applications. Previously, the following study has been identified but not provided. It should be provided for review:
   MRID No 42216201 Carey, R. (1990) Subsurface Soil Investigation Report [Soil Field Dissipation]: Lab Project Number: ML022101: 100063. Unpublished study prepared by Kleinfelder, Inc. 52 p.
5. In the absence of available information, it is highly desirable that a study be performed addressing this issue.

9.1.2 400 g/L EC formulation

9.1.2.1 Soil incorporation

Several uses require incorporation and the impacts of this on the risk assessment have as yet not been fully explored due to limited information.

6. The registrant should comment on current methods of incorporating the liquid formulation for each cropping situation (for example, use of irrigation with a minimum amount of irrigation required to incorporate and time between application and irrigation) along with data showing the likely percentage of incorporation.

9.1.2.2 Terrestrial arthropods

Fenamiphos has proven to be very toxic to non-target terrestrial arthropods. However, all studies submitted for this end-point were performed using a micro-encapsulated formulation that is not sold in Australia.

7. The registrant should comment on this and provide any evidence as to whether the 400 g/L spray formulation used in Australia is likely to exhibit a different toxicity profile to these organisms.

9.1.2.3 Turf use patterns

8. It is desirable to have a list of turf situations where the product is most likely to be used, for example, bowling greens, golf courses, racecourses etc.
9. For identified turf situations, industry/end users should advise on practicability of using mechanical means to keep birds off exposed areas following application and watering in.

9.1.2.4 Dipping solution use pattern

The label allows for dip applications for aloe vera and banana planting material. However, neither use provides directions relating to disposal of spent dipping solutions.

DSEWPAC/APVMA are currently developing a dip disposal risk assessment framework which will include specific criteria (as published in Part 7-Environment of MORAG based on 10 chemicals) for deciding the suitability or not of land-based disposal of spent dip solutions.

While the dip disposal risk assessment framework is not yet developed, further information from industry and growers will allow a more considered risk assessment relating to this end-use. Such information should include:

10. Likely volumes of dipping solution requiring disposal from any given site at one time;
11. Current methods of disposing of dipping solution;
12. Current methods of draining and drying planting material following dipping.

9.1.3 100 g/kg GR formulation

9.1.3.1 Soil incorporation and granule characteristics

Certain cropping situations exist where no explicit instructions are made requiring incorporation. For example, no situation for bananas or ginger requires incorporation. In addition, other crops (bulbs, ornamentals) require irrigation following application but do not state this is for incorporation or indicate an amount of irrigation or a maximum time following application for which to irrigate. This implies that following application, 100% of the applied dose remains on the soil surface.

For the initial risk assessment in this case, it will be assumed that incorporation is undertaken for all cropping situations. Many cropping situations include band application. The US EPA uses as their first tier of assessment, an assumption that for banded treatments, 15% of granules remain unincorporated. In the absence of other guidance, this assumption will be used for this assessment initially for all cropping situations and rates.

The following information is required:

13. For those situations described above where no label instructions are provided related to incorporation, it should be confirmed by industry whether the product is in fact incorporated following application to the abovementioned crops. If this is not the case, risks will need to be re-calculated for these situations.
14. Confirmation of granule weight (noting the current assumption is 0.087 mg/granule as reported in the US EPA Environmental Fate and Effects Division report (Patrick et al., 2001) for a different granule formulation).
15. Comment on accuracy of assumption of 85% incorporation. Any statement indicating a rate higher than this needs to be accompanied by documentary evidence.

9.1.3.2 Strawberry use pattern

The 100 g/kg GR product label includes a use on strawberries at a rate of 1 kg product (100 g ac)/1000 plants, or 1 g product (0.1 g ac)/plant.

An equivalent application rate of 8 kg ac/ha has been calculated.

The rates prescribed may lead to unacceptable exposure to soil organisms within treated areas. However, some further information from industry and growers in this respect would help refine this part of the risk assessment.

Industry and/or strawberry growers should provide the following information:

16. Likely total area of strawberries expected to receive a treatment of fenamiphos in any given year;
17. Likely area as a proportion of the growing hectare likely to be treated in the season.

9.2 Groundwater:

Fenamiphos, and particularly its metabolites, have demonstrated mobility in soil. The M01 and M02 metabolites are more mobile than the parent in the soil profile. Both these have been detected in groundwater in the United States, indicating that they are sufficiently persistent to leach in some environments. No such data exists for Australia,

In addition, to better address implications of fenamiphos use relating to groundwater contamination, the following information is required:

18. Original United States groundwater monitoring studies identified in the US EPA reregistration assessment report, and summarized in this report are still considered important, particularly the

prospective and retrospective studies. Unfortunately, reference details are not given in the US EPA reports, but the studies required are:

- Small-scale prospective monitoring studies undertaken in Florida (Dyer et al.,1988 only details given in US EPA report); Georgia (no reference details); and California (no reference details)– see Section 5.3 of this report.
- Small scale retrospective monitoring (Lenz M, 1997 only details given in US EPA report) in Florida–see Section 5.3 of this report.

19. Identification within fenamiphos use areas in Australia of vulnerable soils where a potential for leaching to groundwater exists;
20. Any data on monitoring of groundwater resources within these use areas.

10 Refinement of risk characterisation

Additional information, received in response to the data call-in for the fenamiphos review, advised the APVMA that the only use patterns identified as no longer required are tobacco and aloe vera. These uses will not be considered further in the refinement of the risk characterisation and reference to them should be removed from current labels.

10.1 General issues

In response to provision of detailed information relating to crops on the 400 g/L EC and 100 g/kg GR formulation labels on actual growing conditions (row spacings), application methods (e.g., targeted sprayers) and actual percentages of hectares within crops likely to be treated when applied as a band treatment, a use pattern survey was undertaken during 2007.

Not all crops identified on the current labels had fenamiphos application during the period of the survey (2007), and it is noted that such crops are only occasionally treated, or at least, were not treated in 2007. The use patterns varied widely, even for the same crop and the results from the survey are presented below in Table 29. In addition, glasshouse uses for cucumbers and tomatoes were noted with the 400 g/L EC formulation, and landscape lawn market turf use was observed in 2007 with an application rate of 2.8 kg ac/ha, and with application to 100% of the area by boom spray with flat fan nozzles and irrigated immediately after spraying.

The information obtained from the survey makes it difficult to refine the Q values. It is apparent that some agricultural practices will lead to lower risk than Q-values in Tables 25-27 suggest. For example, where application is through trickle or drip irrigation systems, or as a subsurface drip, exposure to aquatic areas and non-target plants through spray drift will not occur. Further, risk to birds may be reduced as their exposure would be limited to consumption of soil insects that may contain fenamiphos residues, or from drinking irrigation water if it puddled. Given that application through drip or trickle irrigation systems results in substantially reduced treatment areas on a whole hectare basis, overall exposure would be further reduced.

Despite this, other risks cannot be discounted even when application is through drip or trickle irrigation systems. For example, the chemical and its metabolites remain available in the soil for subsurface runoff or leaching where the conditions for leaching exist. Further, avian field studies assessed showed treatment related mortalities to birds where fenamiphos was applied by chemigation in citrus groves, so exposure to birds when applied through the irrigation systems could still pose a risk.

In any event, average application rates resulting from use patterns identified in Table 29 below still fall within the range of application rates for which unacceptable Q-values were calculated in Tables 25-27.

Table 29: Fenamiphos products use pattern survey results (2007)

Crop	Rate per TREATED ha (kg ac/ha).	Treatment Band %	Application Method	Incorporation method
400 g/L EC formulation				
Potatoes	5.2	50 - 100%	Boom spray with flat fan nozzles	Irrigation immediately after spraying*
Potatoes	4.8	100%	Boom spray with flat fan nozzles	Rotary hoe to 10 cm
Potatoes	5.2	15 - 25%	Directed spray in furrow at planting	Sprayed furrow covered with soil, irrigated to 30 cm.
Carrots	9.6	30 - 100%	Boom spray with flat fan nozzles	Rotary hoe and/or irrigation immediately after spraying*.
Onion/garlic	6.4 g/10 m	15 -25%	Banded spray	Irrigation immediately after spraying*
Lettuce & Brassicas	9.6	75%	Boom spray with flat fan nozzles	Rotary hoe to 10 cm, irrigation immediately after*
Crucifers	9.6	33% - 100%	Boom spray with flat fan nozzles	Rotary hoe to 10 cm, irrigation immediately after*
Brassicas	9.6	33% - 75%	Trickle irrigation	Trickle irrigation*
Cut Flowers & bulbs	9.6	50 - 100%	Boom spray with flat fan nozzles	Rotary hoe to 15 cm or Irrigation immediately after spraying*
Ornamentals	9.6	25%	T Tape drippers	T Tape Drippers*
Ornamentals	9.6	25%	Directed boom spray	Foliar spray then washed off plant with irrigation
Grapevines	9.6-12	25%	Drip irrigation	Drip irrigation*
Strawberries	9.6	25%	Trickle irrigation	Trickle irrigation*
Tomatoes (Field Grown)	9.6	25 - 100%	Boom spray with flat fan nozzles	Rotary hoe to 10 cm, irrigation immediately after*
Tomatoes (Field Grown)	9.6	33 - 50%	Subsurface drip or band spray	Incorporated by bedforming/mulch laying equipment
Cucurbits	9.6	33 - 50%	Subsurface drip	Applied below surface
Bananas	9.6-24	18 -20%	Butt spray using handgun	Incorporated by irrigation or rainfall
Bananas	9.6-24	40 - 50%	Banded boom spray on tree row	Incorporated by irrigation or rainfall
Bananas	9.6-24	15 - 60%	Through trickle irrigation	Incorporation by trickle irrigation
Bananas	9.6	25%	Through trickle irrigation	Incorporation by trickle irrigation
100 g/kg GR formulation				
Carrots	9	100%	Broadcast	Rotary hoe to 25 cm
Carrots	1.8	20%	Granule band placed above seed row	Irrigation sufficient to wet seed row to depth of 20 cm
Ornamentals	10	50-100%	Broadcast	Rotary hoe to depth of 15 cm or incorporated with planter

*sufficient irrigation is applied to wet the soil to the extent of the crop roots within one hour of application.

On the question of eliminating label uses requiring whole hectare treatments, the response to this was that whole area treatments are widely used for some of the major crop uses (carrots, potatoes, ornamentals), and needs to be retained. Again, this does not allow any refinement of previously calculated risk quotients.

DSEWPaC has undertaken a more detailed re-calculation of risk quotients for field crops identified on both the 400 g/L EC and 100 g/kg GR labels based on the use survey data. These calculations are described below in Attachment 2 (p 82).

10.2 Soil degradation rates

In some crops, repeat applications are allowed according to label directions. In the 2007 use survey, there was one crop per year with one treatment per crop with the following exceptions. Lettuce/brassicas and cut flowers/bulbs had two crops per year (1 treatment per crop). For bananas with the application rate of 9.6 kg ac/ha in the treated area, 2 treatments per crop were noted.

To allow for more realistic exposure concentrations resulting from multiple applications, modelling of field half-lives is required. However, currently all laboratory data relate to degradation following surface applied, non-incorporated test substance. A non-standard literature paper indicates degradation rates in subsurface soil may be significantly longer.

One study that may have been useful in this regard was identified as cited in the US EPA reregistration assessment document. However, this was not able to be provided.

One of the groundwater studies provided as additional data provides some further insight into the degradation rate of subsurface residues (Dyer et al., 1998). In this study, fenamiphos, M01 and M02 were measured in soil down to 106 cm in 15 cm increments. The majority of the residues were found in the 0-15 cm layer, particularly early in the sampling regime. In this soil layer, the first half-life was in the order of 30 days. However, when residues from 30-106 cm were considered, the half-life was in the order of 130 days.

The main issue is that, while soil incorporation is needed for the product to be efficacious and aids in reducing environmental exposure, for example to birds or aquatic systems by reducing runoff, the build-up of residues following multiple applications is undesirable and this cannot be determined without adequate half-life data. Industry could not identify any relevant information at this time relating to this issue.

DSEWPaC considers this issue to be unresolved and recommends further data be generated to address this. Specifically, studies should be conducted for at least fenamiphos and M01 using both top-soil (0-15 cm horizon) and subsoil (>30 cm deep) from the same soil series. At least two soil series should be tested.

10.3 400 g/L EC formulation specific issues

10.3.1 Soil incorporation

Methods of incorporation used during the 2007 use survey are noted above in Table 29. This information was sought along with data showing the likely percentage of incorporation. Unfortunately, no data were available to enable a refinement of exposure calculations based on the degree of incorporation so no further refinement of the risk characterisation can be made from this perspective.

10.3.2 Non-target arthropods

While fenamiphos was shown to be toxic to non-target terrestrial arthropods, all data related to a formulation not currently sold in Australia. Industry could not provide any data to determine the

relativity between the emulsifiable concentrate formulation currently used in Australia and the micro-encapsulated formulations used to generate the toxicity data. Consequently, it must be assumed that the current formulation is at least as toxic to non-target terrestrial invertebrates as the formulation used to generate the data, and no further refinement of the risk characterisation can be made to non-target arthropods.

10.3.3 Turf use patterns

A list of turf situations where fenamiphos was most likely to be used was sought. Industry has advised that fenamiphos is not routinely used in turf situations, but most likely used where soil tests indicate that nematodes are causing damage to turf. Any turf areas (except home garden lawns) may be treated with fenamiphos, with high value areas, for example, bowling greens, golf greens and sports fields being the most likely to be treated.

It is noted from the response that industrial turf growers and areas that interface with wetlands that are likely to attract ducks (being a sensitive species) are known to use portable gas-fired bird scarers to keep birds away until watering-in is complete.

It is difficult to mitigate the risk from turf use patterns. There may be some instances where use is acceptable provided adequate measures are taken to scare away birds, for example, use on bowling greens where runoff would be minimal due to their flat nature and location in highly urbanised areas. However, other uses, for example on golf courses or turf farms, may well result in unacceptable risks to a range of environmental organisms.

The current label rate, equivalent to 4.4 kg ac/ha, will result in unacceptable risk to birds, bees, aquatic organisms in the event of runoff and soil dwelling organisms including earthworms and based on current information, further mitigation of these risk quotients is not possible.

10.3.4 Dipping solution use patterns

In response to questions for this use pattern, the advice received is that dipping of banana planting pieces still takes place on a routine basis.

Banana planting pieces are dipped using a wire mesh cage mechanically lowered into a dipping vat. Following dipping, the cage is raised above the vat for several hours to allow it to fully drain. It is then transported to a covered area where it is air dried for up to a week before planting.

There is no disposal of dipping solution in the traditional sense. Unwanted dipping solution is strained to remove extraneous materials and used in the adult banana plantations as per label instructions. Rubbish that accumulates in the bottom of dipping vats is placed within the banana row (in the sprayed area) after removal of the product.

This process is sound in terms of controlling environmental exposure of dipping solutions in that exposure is limited to areas where spraying would otherwise occur. However, actual spraying of fenamiphos in banana plantations has been shown to potentially have unacceptable risk to birds, aquatic organisms and terrestrial organisms at all registered label use rates.

10.4 100 g/kg GR formulation specific issues

10.4.1 Soil incorporation and granule characteristics

Explicit label instructions should appear on the label requiring users to incorporate the granule formulation following application.

Initial exposure calculations were based on an incorporation rate of 85% and a granule weight of 0.087 mg/granule (relevant for bird exposure). Industry notes that 85% primary incorporation is acceptable such as where a rotary hoe or planter is used to achieve primary incorporation. While

they point out that secondary incorporation (by irrigation) would ensure an incorporation level higher than 85%, no data were available to support the assumption. Therefore no refinement to exposure calculations can be made with respect to incorporation efficiency.

The granule weight was determined for the 100 g/kg GR product by weighing a random sample of 100 granules and resulted in an average weight of 0.422 mg/granule (almost 5 times as heavy as assumed in the exposure calculations). Calculations have been based on this new information.

10.4.2 Strawberry use pattern

Further information on use in strawberries was sought as calculations indicated an unacceptable risk to soil organisms within the treated area. In response, industry has advised that very little fenamiphos is used in strawberries in Australia, and the likely area as a proportion of the total growing area likely to be treated in the season is less than 5%.

Given this, the use of the 100 g/kg GR product in strawberries should result in an acceptable risk as the small treatment area (as a proportion of the total growing area) would allow for significant areas of untreated soil where soil organisms would remain unexposed. Risk to other environmental organisms has been discussed above in Section 8.5.4 from this use pattern.

10.5 Groundwater

Fenamiphos, and particularly its metabolites, have demonstrated mobility in soil. The M01 and M02 metabolites are more mobile than the parent in the soil profile is. Both these have been detected in groundwater in the United States, indicating that they are sufficiently persistent to leach in some environments.

The groundwater monitoring studies identified in the US EPA reregistration report have been provided and confirm the mobility of fenamiphos metabolites through the soil profile, and their ability to reach groundwater where conditions conducive to leaching exist.

Industry has been unable to address the question of use areas in Australia of vulnerable soils where potential for leaching to groundwater exists. They have responded that they are aware that growers who use fenamiphos are very aware of the importance of placing the product in the desired treatment band and not washing the product through the soil beyond the treatment zone – particularly in soils that may be prone to leaching. Industry submits that the product is broken down quite rapidly by microbial action in soil. However, as shown in this assessment, while parent fenamiphos may transform to M01, then to M02, the main M01 metabolite is biologically active and persistent in soils. The evidence available suggests the persistence of the residues is greater in subsurface than the top soil thereby increasing their potential to migrate to groundwater.

Industry has no data available on monitoring of groundwater in Australia for fenamiphos.

This issue is inadequately addressed. DSEWPaC recommends:

1 Industry undertake a survey to identify vulnerable soils in fenamiphos use areas (for example, sandy soils and/or shallow groundwater);
2 Fenamiphos is prohibited from use in the identified vulnerable areas.

11 Conclusions

Based on information provided for this risk assessment, DSEWPaC advises the APVMA they cannot be satisfied that the use of fenamiphos in accordance with label instructions would not be likely to have an unintended effect that is harmful to animals, plants or things or to the environment. Despite additional information provided, the potential risks from the majority of currently registered use patterns have not been able to be mitigated to levels where such a risk is considered acceptable.

With current information, mitigation of the risks associated with fenamiphos use are very difficult because:

- fenamiphos has been shown to be highly toxic to organisms in the environment
- while fenamiphos converts relatively rapidly to a major metabolite, this metabolite has been shown to be biologically active and toxicity is not remarkably less than the parent compound to a number of environmental organisms
- overall removal of fenamiphos and its metabolites from environmental media does not occur quickly. Therefore, the use of time-weighted average exposure concentrations does little to mitigate exposure and potential risk, particularly where repeat applications to crops occur.

12 Recommendations

For the majority of use patterns with fenamiphos, the risk assessment has shown an unacceptable risk to birds, aquatic organisms and terrestrial organisms including non-target arthropods and earthworms. Additionally, no data exist on likely fenamiphos use areas than could be vulnerable to leaching. Consequently, DSEWPaC recommends that the following uses be cancelled:

Recommendation 1: The APVMA should not be satisfied that the use of fenamiphos in accordance with label instructions would not be likely to have an unintended effect that is harmful to animals, plants or things or to the environment. The following uses should be cancelled.

1. 400 g/L EC product (and labels imaged from this product, not part of this review):

   Aloe vera–all uses (as advised by industry), Bananas–all uses, Citrus, Crucifers, Vegetables, Grapevines, Ornamentals–all uses, Bulbs, Chrysanthemums, Pineapples, Potatoes, Strawberries, Sugar cane, Tobacco (as advised by industry), Tomatoes, and Turf.

   The only label use remaining acceptable from this product is application to mushrooms.

2. 100 g/kg GR product (and labels imaged from this product, not part of this review)

   Bananas–all uses; Bulbs; Carrots and parsnips; Crucifers–all uses, Duboisia, Ginger, Ornamentals–all uses, Pineapples, Potatoes, Sugar cane, Tomatoes–all uses, and Woody ornamentals.

   The only label use remaining acceptable from this product is application to strawberries.

3. 400 g/L EC turf-based product (and labels imaged from this product, not part of this review):

   All uses.

4. 50 g/kg GR product for the home garden (and labels imaged from this product, not part of this review):

   All uses.

12.1 Data required to refine exposure assessment

Based on current information, exposure remains unacceptable in most situations for birds, aquatic organisms (primarily resulting from exposure through runoff), non-target terrestrial arthropods exposed through spray application and soil dwelling organisms, including earthworms, exposed through soil residues. With current information, it is difficult to mitigate the risks associated with the modelled exposures. However, additional data can be generated to assist in refining exposure assessments. Any data generated should follow currently accepted test guidelines, or test protocols should be agreed between industry and the APVMA/DSEWPaC prior to commencing any research.

Recommendation 2: The following data should be provided to allow refinement of the environmental exposure assessment of fenamiphos.

1. Additional scientific information on bird exposure. Industry should comment on the validity or otherwise of modelling of expected residues in bird's diets performed in this assessment and provide any additional scientific data related to this to justify any further refinement of this end-point.
2. Undertake studies to demonstrate the effectiveness of buffer strips (vegetative or otherwise) in reducing runoff of fenamiphos.
3. The degradation of fenamiphos and its metabolites in subsoil remains unresolved and will impact on exposure of soil dwelling organisms (and leaching potential). The main issue is that, while soil incorporation is needed for the product to be efficacious and aids in reducing environmental exposure, for example to birds or aquatic systems by reducing runoff, the build-up of residues following multiple applications is undesirable and this cannot be determined without adequate half-life data. Industry could not identify any relevant information at this time relating to this issue.
4. DSEWPaC considers this issue to be unresolved and requires further data be generated to address this. Specifically, studies should be conducted for at least fenamiphos and fenamiphos sulfoxide (M01) using both top-soil (0-15 cm horizon) and subsoil (>30 cm deep) from the same soil series. At least two soil series should be tested.
5. Fenamiphos and its main metabolites have the potential to move through soil and contaminate ground water and the issue of potential exposure to groundwater through fenamiphos use in Australia has not been adequately addressed. Further information must be provided with respect to this including the identification of soils vulnerable to leaching in fenamiphos use areas. The actual characteristics of a 'vulnerable soil' should be developed between industry, the APVMA and DSEWPaC, but should include relevant soil characteristics and depth of underlying groundwater.

12.2 Data required to refine ecotoxicity assessment

Q-values can be further refined by addressing the ecotoxicity component of the risk characterization equations. Currently, the majority of ecotoxicity data relate to fenamiphos as the parent compound. However, available data show that the main metabolite, M01, is biologically active. Consequently, risk calculations have been made based on total residues (fenamiphos and metabolites), but based on the toxicity of fenamiphos alone.

It is apparent that exposures to organisms in the environment would occur primarily to the M01 metabolite following relatively fast conversion of fenamiphos to this metabolite as expected in both water and soil. Consequently, to refine Q-values further, a full suite of ecotoxicity data for M01 should be provided in line with the following recommendation. Additionally, further data relating to fenamiphos are prescribed in the following recommendation. Data should be provided based on tests following acceptable Organisation for Economic Co-operation and Development or US EPA guidelines:

Recommendation 3: The following ecotoxicity data should be provided to allow refinement of the environmental effects assessment of fenamiphos.

1. Short term (dietary) avian toxicity tests for the M01 metabolite to bobwhite quail and mallard duck
2. Reproduction (chronic) avian toxicity tests for the M01 metabolite bobwhite quail and mallard duck
3. Oral and contact toxicity for the M01 metabolite to bees
4. Dose/response tests for M01 and the 400 g/L EC formulation to the aphid parasitoid A. rhopalosiphi and the predaceous mite T. pyri. with tests sufficient to define NOECs and EC50s
5. Long-term (56-day) dose/response studies with fenamiphos and M01 separately to earthworms with tests sufficient to define NOECs and EC50s. Separate tests should be performed to assess for exposure through surface spray or through soil incorporation.

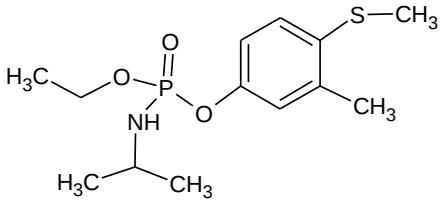
For aquatic organisms, the overall impact of revised results based on individual species testing will be limited given the use of mesocosm data in determining aquatic Q-values. The mesocosm results account for exposure to fenamiphos and its metabolites over the course of the test. The mesocosm data used were based on two applications of fenamiphos with a week between applications, then monitoring effects up to 14 weeks following the first application. Three dose levels were used (1, 3.5 and 12.5 µg fenamiphos/L). While no effects were dose related at 1.0 and 3.5 µg/L, a statistically significant effect on fish weights after 14 weeks was found at 12.5 µg/L thereby resulting in a NOEC of 3.5 µg/L. To refine this NOEC, the mesocosm study could be repeated and include dose levels in between the 3.5 and 12.5 µg/L treatments.

6. To refine the aquatic chronic NOEC (currently 3.5 µg/L), the mesocosm study used in this assessment report should be repeated and include at least 2 additional dose levels between 3.5 and 12.5 µg/L.

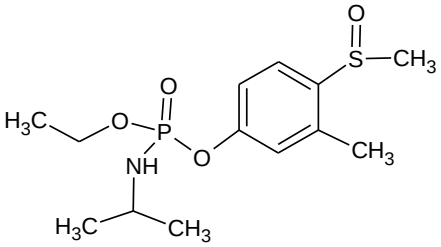
In the absence of such data, the current aquatic NOEC of 3.5 µg/L will remain valid.

Appendix 1 Metabolite Chemical Structures

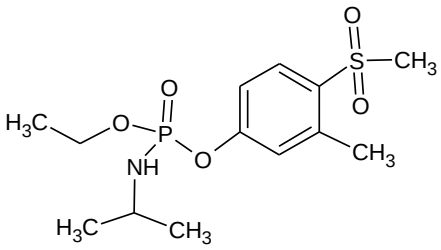
Fenamiphos



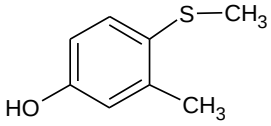
M01: Fenamiphos sulfoxide



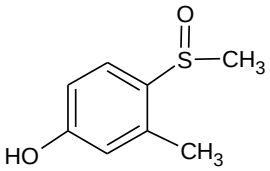
M02: Fenamiphos sulfone



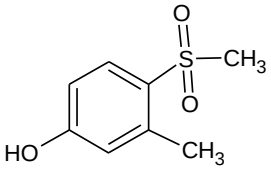
M11: Fenamiphos phenol



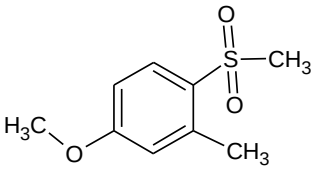
M12: Fenamiphos sulfoxide phenol



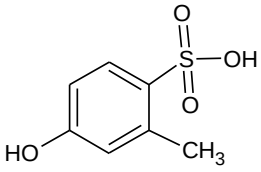
M13: Fenamiphos sulfone phenol



M14: Fenamiphos sulfone anisole



M24: Fenamiphos phenol sulfonic acid



Appendix 2 Refined Risk Quotients–Field Crop Uses

All calculations have been performed using ecotoxicity end-points and exposure calculation methodology described earlier in this report. For aquatic organisms, the mesocosm NOEC of 3.5 µg/L has been used thereby allowing a Q-value of 1 to be acceptable. One aquatic exposure for runoff (3% slope) and one for spray drift (100 m downwind) have been modelled. Q-values for full hectare treatments have already been calculated in Table 25.

Risk to soil microorganisms and non-target terrestrial plants (NTTPs) have not been considered as they have been shown to be generally acceptable in earlier calculations.

Often when considering risk to non-target terrestrial arthropods, a potential risk may be identified in-field, but when out of field exposures are considered (mainly resulting from spray drift), the risk is acceptable. In this case however, exposure to terrestrial arthropods is a concern, not just for the arthropods themselves, but for potential secondary poisoning to birds as well. This has been shown to be a valid exposure route for fenamiphos that can result in adverse effects. Consequently, the risk assessment for non-target terrestrial arthropods has remained an 'in-field' one only.

In the tables below, the following colour coding is used to describe the risk based on comparison of the risk quotient with DSEWPaC levels of concern:

Acceptable risk	Risk identified, but may be mitigated	Unacceptable risk identified

Field Crop Uses–400 g/L EC formulations

Bananas

Application rate of 9.6 kg/ha (in the treated area)

Area treated (% ha)	Risk quotients							
	Birds	Aquatic (runoff, 3% slope)	Aquatic (spray drift, 100 m)	Bees	Terrestrial arthropods (spray)	Terrestrial arthropods (soil)	Earthworms (spray)	Earthworms (soil)
100	26.5	9.45	1.1	343	681	6.84	>1.6	>66.7
50[a]	13.2	4.7	0.55	171	340	3.42	>0.8	>33.4
25[b]	6.6	2.4	0.27	86	170	1.71	>0.4	>16.7

1) Identified in 2007 Nemacur Use Survey for banded boom spray on tree rows, or application through trickle irrigation.

2) Identified in 2007 Nemacur Use Survey, possibly for application through trickle irrigation or butt spray using handgun.

Birds continue to show an unacceptable risk even with smaller portions of the hectare being treated. Where application is through irrigation equipment, it could be argued the Q-values are too high as there will not be drift exposure to insects and plants contributing to the birds diets. However, soil insects could still be exposed and consumed, and birds may drink irrigation water.

The risk to aquatic areas is marginal even when the whole hectare is treated where exposure results from spray drift with a 100 m downwind buffer zone. While the risk where exposure occurs through runoff is calculated to be higher, it is well recognised that runoff can be reduced significantly through the use of buffer zones (USDA, 2000). The problem is that where aquatic areas are not downwind, buffer zones may not necessarily be used. Therefore, it is difficult to mitigate risk from

runoff unless prescribed buffer zones are placed on the label addressing this specific issue. Currently, there is insufficient information to assess this.

While DSEWPaC does not have prescribed LOCs for non-target terrestrial arthropods, it is apparent that these are at high risk, even when only a quarter of the hectare is treated. While it may be argued that unsprayed areas provide sufficient refuge for such organisms, the Q-values for exposure through spray of 170 with 25% hectare treated have effectively taken this issue into account (compared with Q ~680 for whole hectare treatment). Bees also show unacceptable Q-values even with only 25% of the hectare being treated. Where application occurs through trickle irrigation systems, the risk to bees is probably acceptable through the contact route, although fenamiphos is also toxic to bees through oral ingestion, which may eventuate through drinking irrigation water.

Similarly for earthworms, the greatest risk is identified when exposed through the soil. Again, while partial hectare treatments can leave untreated soil areas to provide refuges for soil organisms including earthworms, in this case, the Q values for 25% treatment of >16.7 show a risk may still be present. This is of increased concern given the expected persistence of fenamiphos and M01 in subsurface soils and the toxicity results for earthworms where a lower end NOEC could not be defined.

This is the lowest application rate registered for use on bananas and unacceptable risks remain to birds, aquatic organisms, bees, terrestrial arthropods and earthworms, so it can be seen that higher application rates will result in greater risk quotients. Refined risk quotients have not been calculated for the higher application rates.

On this basis, and in the absence of other information, 400 g/L EC formulations should not be used on bananas.

Bulbs

Application rate of 9.6 kg/ha (in the treated area)

Area treated (% ha)	Risk quotients							
	Birds	Aquatic (runoff, 3% slope)	Aquatic (spray drift, 100 m)	Bees	Terrestrial arthropods (spray)	Terrestrial arthropods (soil)	Earthworms (spray)	Earthworms (soil)
100	26.5	9.45	1.1	343	681	6.84	1.6	66.7

The Nemacur use survey in 2007 notes that cut flowers and bulbs had 2 crops per year with 1 application per crop. Application was to 50-100% of the cropped area with application by boom spray with flat fan nozzles. Incorporation was by rotary hoe to 15 cm or irrigation immediately after spraying.

No refinement on the original Q-values can be made based on this, and an unacceptable risk remains to birds, aquatic organisms through runoff (marginal risk only through spray drift), bees, terrestrial arthropods and earthworms.

On this basis and in the absence of other information, 400 g/L EC formulations should not be used on bulbs.

Chrysanthemums

Application rate of 0.4 kg/ha (in the treated area)

Area treated (% ha)	Risk quotients							
	Birds	Aquatic (runoff, 3% slope)	Aquatic (spray drift, 100 m)	Bees	Terrestrial arthropods (spray)	Terrestrial arthropods (soil)	Earthworms (spray)	Earthworms (soil)
100	1.1	0.39	0.03	14	28	0.28	>0.07	>2.8

This use pattern represents the best case for field crops using 400 g/L EC formulations in that is has the lowest application rate. This is the only crop where control is for leaf nematode and the label instructions include applying at 14 days intervals from the first sign of infestation using hollow cone nozzles.

Given that application would be primarily to foliage, significant interception would be expected. However, it can be seen from the above that even if 90% interception occurred, Q-values for earthworms would still indicate a potential risk. Similarly, there would remain an unacceptable risk to bees and terrestrial arthropods exposed through spray. While the risk to aquatic organisms is acceptable from this use pattern, that to birds remains unacceptable.

Of further concern with this use pattern is the potential for repeat application.

On this basis and in the absence of other information, Nemacur® 400 Liquid Nematicide should not be used on Chrysanthemums.

Citrus

Application rate of 15 kg/ha (in the treated area)

Area treated (% ha)	Risk quotients							
	Birds	Aquatic (runoff, 3% slope)	Aquatic (spray drift, 100 m)	Bees	Terrestrial arthropods (spray)	Terrestrial arthropods (soil)	Earthworms (spray)	Earthworms (soil)
100	41.3	14.8	1.7	536	1064	10.8	>2.5	>104.2

The rate of 15 kg ac/ha is a maintenance rate while the initial label rate is double this at 30 kg ac/ha.

The Nemacur use survey did not identify use in citrus in 2007. No further information was provided relating to reduction of treated areas through band application. It can be seen however, that even if 25% of the cropped area were treated, Q-values would remain at values indicative of an unacceptable risk with the exception of aquatic organisms when exposed through spray drift.

Further, when the initial rate of 30 kg ac/ha is considered, the Q-values are doubled.

On this basis and in the absence of other information, 400 g/L EC formulations should not be used on citrus orchards.

Crucifers

Application rate of 9.6 kg/ha (in the treated area)

Area treated (% ha)	Risk quotients							
	Birds	Aquatic (runoff, 3% slope)	Aquatic (spray drift, 100 m)	Bees	Terrestrial arthropods (spray)	Terrestrial arthropods (soil)	Earthworms (spray)	Earthworms (soil)
100	26.5	9.45	1.1	343	681	6.84	>1.6	>66.7

The Nemacur use survey in 2007 did not identify any use on crucifers and no further information has been received for this use pattern.

No refinement on the original Q-values can be made based on this, and an unacceptable risk remains to birds, aquatic organisms through runoff (marginal risk only through spray drift), bees, terrestrial arthropods and earthworms.

On this basis and in the absence of other information, 400 g/L EC formulations should not be used on crucifers.

Grapevines

Application rate of 12 kg/ha (in the treated area)

Area treated (% ha)	Risk quotients							
	Birds	Aquatic (runoff, 3% slope)	Aquatic (spray drift, 100 m)	Bees	Terrestrial arthropods (spray)	Terrestrial arthropods (soil)	Earthworms (spray)	Earthworms (soil)
100	33.1	11.8	0.7	429	851	8.6	>2.0	>83.3
25[a]	8.3	2.9	0.18	107	213	2.2	>0.5	>20.8

a) Identified in 2007 Nemacur Use Survey for banded application through trickle irrigation.

The Nemacur use survey in 2007 notes that use in grapevines in 2007 was at rates of 9.6-12 kg ac/ha with application through trickle irrigation where 25% of the cropped area was treated.

Birds continue to show an unacceptable risk even with smaller portions of the hectare being treated. Where application is through irrigation equipment, it could be argued the Q-values are too high as there will not be drift exposure to insects and plants contributing to the birds diets. However, soil insects could still be exposed and consumed, and birds may drink irrigation water.

The risk to aquatic areas is acceptable even when the whole hectare is treated where exposure results from spray drift with a 100 m downwind buffer zone. While the risk where exposure occurs through runoff is calculated to be higher, it is well recognised that runoff can be reduced significantly with buffer zones (USDA, 2000). The problem is that where aquatic areas are not downwind, buffer zones may not necessarily be used. Therefore, it is difficult to mitigate risk from runoff unless prescribed buffer zones are placed on the label addressing this specific issue. Currently, there is insufficient information to assess this.

While DSEWPaC does not have prescribed LOCs for non-target terrestrial arthropods, it is apparent that these are at high risk, even when only a quarter of the hectare is treated. While it may be argued that unsprayed areas provide sufficient refuge for such organisms, the Q-values for exposure through spray of 213 with 25% hectare treated have effectively taken this issue into account (compared with Q ~850 for whole hectare treatment). Bees also show unacceptable Q-values even with only 25% of the hectare being treated. Where application occurs through trickle irrigation systems, the risk to bees is probably acceptable through the contact route, although fenamiphos is also toxic to bees through oral ingestion, which may eventuate through drinking irrigation water.

Similarly for earthworms, the greatest risk is identified when exposed through the soil. While partial hectare treatments can leave untreated soil areas to provide refuges for soil organisms including earthworms, in this case, the Q values for 25% treatment of >20.8 show a risk may still be present. This is of increased concern given the expected persistence of fenamiphos and M01 in subsurface soils and the toxicity results for earthworms where a lower end NOEC could not be defined.

On this basis, and in the absence of other information, 400 g/L EC formulations should not be used on grapevines.

Ornamentals

Application rate of 9.6 kg/ha (in the treated area)

Area treated (% ha)	Risk quotients							
	Birds	Aquatic (runoff, 3% slope)	Aquatic (spray drift, 100 m)	Bees	Terrestrial arthropods (spray)	Terrestrial arthropods (soil)	Earthworms (spray)	Earthworms (soil)
100	26.5	9.45	1.1	343	681	6.84	>1.6	>66.7
25a	6.6	2.4	0.27	86	170	1.71	>0.4	>16.7

a) Identified in 2007 Nemacur Use Survey with application either through T Tape drippers or by directed boom spray.

Birds continue to show an unacceptable risk even with smaller portions of the hectare being treated. Where application is through irrigation equipment, it could be argued the Q-values are too high as there will not be drift exposure to insects and plants contributing to the birds diets. However, soil insects could still be exposed and consumed, and birds may drink irrigation water.

The risk to aquatic areas is marginal even when the whole hectare is treated where exposure results from spray drift with a 100 m downwind buffer zone. While the risk where exposure occurs through runoff is calculated to be higher, it is well recognised that runoff can be reduced significantly with buffer zones (USDA, 2000). The problem is that where aquatic areas are not downwind, buffer zones may not necessarily be used. Therefore, it is difficult to mitigate risk from runoff unless prescribed buffer zones are placed on the label addressing this specific issue. Currently, there is insufficient information to assess this.

While DSEWPaC does not have prescribed LOCs for non-target terrestrial arthropods, it is apparent that these are at high risk, even when only a quarter of the hectare is treated. While it may be argued that unsprayed areas provide sufficient refuge for such organisms, the Q-values for exposure through spray of 170 with 25% hectare treated have effectively taken this issue into account (compared with Q ~680 for whole hectare treatment). Bees also show unacceptable Q-values even with only 25% of the hectare being treated. Where application occurs through trickle irrigation systems, the risk to bees is probably acceptable through the contact route, although fenamiphos is also toxic to bees through oral ingestion, which may eventuate through drinking irrigation water.

Similarly for earthworms, the greatest risk is identified when exposed through the soil. Again, while partial hectare treatments can leave untreated soil areas to provide refuges for soil organisms including earthworms, in this case, the Q values for 25% treatment of >16.7 show a risk may still be present. This is of increased concern given the expected persistence of fenamiphos and M01 in subsurface soils and the toxicity results for earthworms where a lower end NOEC could not be defined.

This is the lowest application rate registered for use on ornamentals and unacceptable risks remain to birds, aquatic organisms, bees, terrestrial arthropods and earthworms, so it can be seen that higher application rates will result in greater risk quotients. Refined risk quotients have not been calculated for the higher application rates.

On this basis, and in the absence of other information, 400 g/L EC formulations should not be used on ornamentals.

Pineapples

Application rate of 2.4 kg/ha (in the treated area)

Area treated (% ha)	Risk quotients							
	Birds	Aquatic (runoff, 3% slope)	Aquatic (spray drift, 100 m)	Bees	Terrestrial arthropods (spray)	Terrestrial arthropods (soil)	Earthworms (spray)	Earthworms (soil)
100	6.6	2.36	0.3	86	170	1.71	>0.4	>16.7

Several rates for pineapple treatment are prescribed, namely, 2.4 kg ac/ha for plant crop and ratoon crop foliar spray; 4.8 kg ac/ha for ratoon crop foliar spray only and 10 kg ac/ha for pre-plant bed treatment.

The use survey in 2007 did not identify any use on pineapples and no further information has been received for this use pattern.

No refinement on the original Q-values can be made based on this, and an unacceptable risk remains to birds, aquatic organisms through runoff (acceptable risk through spray drift exposure), bees, terrestrial arthropods and earthworms for the lowest registered application rate in pineapples.

On this basis and in the absence of other information, 400 g/L EC formulations should not be used on pineapples.

Potatoes

Application rate of 5.2 kg/ha (in the treated area)

Area treated (% ha)	Risk quotients							
	Birds	Aquatic (runoff, 3% slope)	Aquatic (spray drift, 100 m)	Bees	Terrestrial arthropods (spray)	Terrestrial arthropods (soil)	Earthworms (spray)	Earthworms (soil)
100	14.3	5.1	0.3	186	369	3.7	>0.87	>36.1
25[a]	3.6	1.3	0.07	46.5	92	0.92	>0.2	>9

a) Identified in 2007 Use Survey for directed spray in furrow at planting.

The use survey in 2007 identified use in potatoes with 50 to 100% of the cropped area being treated with application by boom spray with flat fan nozzle and incorporation either by rotary hoe to 10 cm or by irrigation immediately after application. A further use in potatoes identified treatment to 15-25% of the cropped area by directed spray in the furrow at planting.

In the case of treatment up to 100% of the cropped area by boom spray, no further refinement of Q-values can be made with current information and an unacceptable risk remains to birds, aquatic organisms, bees, terrestrial arthropods and earthworms.

Application to 25% of the cropped area as an in furrow spray at planting reduces the Q-values and the risk to aquatic organisms is only marginal from runoff at these rates and acceptable through spray drift. However, a risk to birds is still identified (noting the Q-values for birds have already accounted for incorporation). While there is an identified risk to bees, at planting bees should be absent from the field so this risk is unlikely to eventuate. This would also be the case for terrestrial arthropods likely to be exposed by spray. However, soil arthropods and earthworms would still face a potential risk.

On this basis and in the absence of other information, 400 g/L EC formulations should not be used on potatoes.

Strawberries

Application rate of 9.6 kg/ha (in the treated area)

Area treated (% ha)	Risk quotients							
	Birds	Aquatic (runoff, 3% slope)	Aquatic (spray drift, 100 m)	Bees	Terrestrial arthropods (spray)	Terrestrial arthropods (soil)	Earthworms (spray)	Earthworms (soil)
100	26.5	9.45	1.1	343	681	6.84	>1.6	>66.7
25[a]	6.6	2.4	0.27	86	170	1.71	>0.4	>16.7

a) Identified in the use survey in 2007 with application by trickle irrigation.

Birds continue to show an unacceptable risk even with smaller portions of the hectare being treated. Where application is through irrigation equipment, it could be argued the Q-values are too high as there will not be drift exposure to insects and plants contributing to the birds' diets. However, soil insects could still be exposed and consumed, and birds may drink irrigation water.

The risk to aquatic areas is marginal even when the whole hectare is treated where exposure results from spray drift with a 100 m downwind buffer zone. While the risk where exposure occurs through runoff is calculated to be higher, it is well recognised that runoff can be reduced significantly with buffer zones (USDA, 2000). The problem is that where aquatic areas are not downwind, buffer zones may not necessarily be used. Therefore, it is difficult to mitigate risk from runoff unless prescribed buffer zones are placed on the label addressing this specific issue. Currently, there is insufficient information to assess this.

While DSEWPaC does not have prescribed LOCs for non-target terrestrial arthropods, it is apparent that these are at high risk, even when only a quarter of the hectare is treated. While it may be argued that unsprayed areas provide sufficient refuge for such organisms, the Q-values for exposure through spray of 170 with 25% hectare treated have effectively taken this issue into account (compared with Q ~680 for whole hectare treatment). Bees also show unacceptable Q-values even with only 25% of the hectare being treated. Where application occurs through trickle irrigation systems, the risk to bees is probably acceptable through the contact route, although fenamiphos is also toxic to bees through oral ingestion, which may eventuate through drinking irrigation water.

Similarly for earthworms, the greatest risk is identified when exposed through the soil. Again, while partial hectare treatments can leave untreated soil areas to provide refuges for soil organisms including earthworms, in this case, the Q values for 25% treatment of >16.7 show a risk may still be present. This is of increased concern given the expected persistence of fenamiphos and M01 in subsurface soils and the toxicity results for earthworms where a lower end NOEC could not be defined.

On this basis, and in the absence of other information, 400 g/L EC formulations should not be used on strawberries.

Sugar cane

Application rate of 4 kg/ha (in the treated area)

Area treated (% ha)	Risk quotients							
	Birds	Aquatic (runoff, 3% slope)	Aquatic (spray drift, 100 m)	Bees	Terrestrial arthropods (spray)	Terrestrial arthropods (soil)	Earthworms (spray)	Earthworms (soil)
100	11	3.94	0.23	143	284	2.85	>0.67	>27.8

The use survey did not identify use in sugarcane in 2007. No further information was provided relating to reduction of treated areas through band application. However, it can be seen that even a

reduction to 50% of the cropped area being treated would still result in an unacceptable risk for birds, aquatic organisms from runoff, bees, terrestrial arthropods and earthworms.

On this basis and in the absence of other information, 400 g/L EC formulations should not be used on sugar cane.

Tomatoes

Application rate of 9.6 kg/ha (in the treated area)

Area treated (% ha)	Risk quotients							
	Birds	Aquatic (runoff, 3% slope)	Aquatic (spray drift, 100 m)	Bees	Terrestrial arthropods (spray)	Terrestrial arthropods (soil)	Earthworms (spray)	Earthworms (soil)
100	26.5	9.45	1.1	343	681	6.84	>1.6	>66.7
50[a]	13.2	4.8	0.55	172	340	3.42	>0.8	>33.4

a) Identified in the Nemacur use survey in 2007 with application by subsurface drip or band spray.

The fenamiphos product use survey in 2007 identified field grown tomatoes with application to 25 to 100% of the cropped area when applied by boom spray, or 33 to 50% of the cropped area when application was by subsurface drip or band spray.

Birds continue to show an unacceptable risk even with smaller portions of the hectare being treated. Where application is by subsurface drip, there is likely to be minimal exposure to birds and the risk quotient in this case probably overly conservative. However, subsurface drip would still expose organisms residing in the soil and an unacceptable risk remains to terrestrial arthropods and earthworms. The risk to birds where 50% of the cropped area is treated by band spray remains unacceptable.

The risk to aquatic areas is marginal even when the whole hectare is treated where exposure results from spray drift with a 100 m downwind buffer zone. While the risk where exposure occurs through runoff is calculated to be higher, it is well recognised that runoff can be reduced significantly with buffer zones (USDA, 2000). The problem is that where aquatic areas are not downwind, buffer zones may not necessarily be used. Therefore, it is difficult to mitigate risk from runoff unless prescribed buffer zones are placed on the label addressing this specific issue. Currently, there is insufficient information to assess this.

While DSEWPaC does not have prescribed LOCs for non-target terrestrial arthropods, it is apparent that these are at high risk, even when only a quarter of the hectare is treated. While it may be argued that unsprayed areas provide sufficient refuge for such organisms, the Q-values for exposure through spray of 170 with 25% hectare treated have effectively taken this issue into account (compared with Q ~680 for whole hectare treatment). Bees also show unacceptable Q-values even with only 25% of the hectare being treated. Where application occurs through subsurface drip, exposure to bees is not likely to occur.

Similarly for earthworms, the greatest risk is identified when exposed through the soil. Again, while partial hectare treatments can leave untreated soil areas to provide refuges for soil organisms including earthworms, in this case, the Q values for 25% treatment of >16.7 show a risk may still be present. This is of increased concern given the expected persistence of fenamiphos and M01 in subsurface soils and the toxicity results for earthworms where a lower end NOEC could not be defined.

On this basis, and in the absence of other information, 400 g/L EC formulations should not be used on tomatoes.

Vegetables

Application rate of 9.6 kg/ha (in the treated area)

Area treated (% ha)	Risk quotients							
	Birds	Aquatic (runoff, 3% slope)	Aquatic (spray drift, 100 m)	Bees	Terrestrial arthropods (spray)	Terrestrial arthropods (soil)	Earthworms (spray)	Earthworms (soil)
100	26.5	9.45	1.1	343	681	6.84	>1.6	>66.7
25	6.6	2.4	0.27	86	170	1.71	>0.4	>16.7

The use survey in 2007 identified use on carrots (up to 100% of the cropped area being treated), onion/garlic (25% of the cropped area being treated as a banded spray), brassicas (up to 75% of the cropped area being treated by trickle irrigation) and lettuce/brassicas (75% of the cropped area being treated by boom spray with flat fan nozzles).

As with other cropping situations at this rate of application, it can be seen that a reduction of the area of the cropped area being treated to 25% still results in an unacceptable risk to birds, aquatic areas through runoff, bees, terrestrial arthropods and earthworms.

On this basis, and in the absence of other information, 400 g/L EC formulations should not be used on vegetable crops.

Field Crop Uses–100 g/kg GR formulation

Table 27 provides Q-values for the use rates of the 100 g/kg GR formulation to field crops. Q-values for birds are already based on the assumption that 85% of the application is incorporated into the soil and therefore, not available to birds. Even at the lowest rate (4 kg ac/ha for use in sugar cane) an unacceptable risk is identified to birds, non-target terrestrial arthropods (soil exposed) and earthworms (soil exposed). An unacceptable risk is identified to bees, however, the granular formulation is unlikely to expose bees through the contact route. Where granules are incorporated through irrigation, puddling may result in potential bee exposure through drinking. At the lowest application rate of 4 kg/ha, the risk to aquatic areas based on runoff (3% slope; chronic NOEC = 3.5 µg/L; Q = 1 or less being acceptable) is considered acceptable. However, at all other application rates (9 to 25 kg ac/ha), this is not the case and an unacceptable risk to aquatic areas is identified.

In the use survey in 2007, only three uses of the 100 g/kg GR formulation were identified. Two of these were to carrots where application was at 9 kg ac/ha to 100% of the cropped area by broadcast application, and one was to 20% of the treated area where the granules were applied in a band above the seed row. The other use of this formulation was in ornamentals where application was at 10 kg ac/ha to 50–100% of the cropped area by broadcast application.

The only risk quotients that can be refined following this information are those for carrots with a banded treatment. With an application rate of 9 kg/ha (in the treated area), the refined risk quotients become:

Area treated (% ha)	Risk quotients							
	Birds	Aquatic (runoff, 3% slope)	Aquatic (spray drift, 100 m)	Bees	Terrestrial arthropods (spray)	Terrestrial arthropods (soil)	Earthworms (rate)	Earthworms (soil)
100	Up to 6136	0.39	NA	321	NA	6.41	>1.5	>62.5
20	Up to 1227	0.08	NA	64	NA	1.3	>0.3	12.5

It can be seen that even at 20% of the cropped area being treated, an unacceptable risk remains to birds, bees (although this is likely to be a significant overestimation) and soil dwelling organisms including earthworms.

No refinements can be made for other cropping situations as no further information is available to refine the Q-values.

On this basis, all use patterns of the 100 g/kg GR formulation should be cancelled with the exception of use in strawberries (assessed above).

Appendix 3 Technical report for environmental fate of fenamiphos

Contents

The following environmental fate data provided by the registrant or sourced from the literature are available for the fenamiphos review.

Hydrolysis

Two studies are available, the first a conventional study at pH 5, 7 and 9, and the second a study of the stability of fenamiphos, fenamiphos sulfoxide and fenamiphos sulfone at pH 4.

Report: Mulford, 1987a.
Guidelines: US-EPA Subdivision N; 161-1, Hydrolysis Studies
GLP: No

Test System

The hydrolysis of fenamiphos, ^{14}C-radio-labelled in the 1-position of the phenyl ring, was studied at a concentration of about 35 ppm in sterilised aqueous solutions buffered at pH 5, 7 and 9. The test solutions were incubated in the dark for a minimum of 31 days at 25^{o}C. Samples of the test solutions were taken immediately after treatment and at various sampling intervals during the study. These were analysed by LSC for total radioactivity (material balance) and by HPLC for identification of parent and hydrolysis products. TLC and GC/MS were used as confirmatory analytical methods.

Findings

The amount of initially applied radioactivity (AR) recovered during the study ranged from 93.0-98.9% (pH 5), 94.3-96.5% (pH 7) and 98.3-100.1% (pH 9). The lower recovery at lower pH was attributed to some binding to the nylon filters. Total losses to adsorption or volatility were estimated as no greater than 7.0% (pH 5).

HPLC analysis of the test solutions showed that after 31 days the amount of fenamiphos remaining was 89.6% AR at pH 5, 91.9% AR at pH 7 and 90.1% AR at pH 9. The major hydrolysis product at all pH levels was fenamiphos sulfoxide (M01), which accounted for 9.9% (pH 5), 8.1% (pH 7) and 4.1% (pH 9) AR after 31 days. At pH 9, fenamiphos phenol (M11) accounted for 5.2% of AR after this time.

The data from all pH levels yielded straight-line plots indicating that hydrolysis was consistent with a first-order reaction. Fenamiphos is relatively stable to hydrolysis at all three pHs, and estimated half-lives were 245 days at pH 5, 301 days at pH 7 and 235 days at pH 9. These half-lives and the apparent greater stability at pH 7 should be treated with caution, as they are much greater than the duration of the study.

These results are said to be consistent at pH 7 and 9 with a previous study (McNamara and Wilson, 1979). However, the earlier study is said to have found fenamiphos to be unstable at pH 3, with a half-life of 10 days at 30^{o}C.

Conclusion

Fenamiphos is relatively stable to hydrolysis at environmentally relevant pH and temperature conditions.

Report: Arthur, Parker and Shepherd (1999).
Guidelines: US-EPA Subdivision N 161-1, Hydrolysis (supplemental); and
N 166-1, Small Scale Prospective Ground-Water Monitoring (supplemental)
GLP: No

Test System

The hydrolysis of fenamiphos, M01 and M02, all ^{14}C-radio-labelled in the 1-position of the phenyl ring, was studied at concentrations of 0.5 ppm in sterile pH 4 aqueous buffer solution. The test solutions were incubated for 30 days in the dark at a constant temperature of 24.5^{o}C. Samples of the test solutions were taken immediately after treatment and at various sampling intervals during the study. Samples were analysed by LSC for radioactivity in each vial (for material balance) and chemical analyses were performed by HPLC via direct injection.

Findings

As noted above, an earlier study is said to have found fenamiphos to be unstable at pH 3, with a half-life of 10 days at 30^{o}C. A Prospective Ground-Water Monitoring Study conducted in Georgia (not provided for this assessment) had a pH of about 4.5 and consequently, the US EPA requested an evaluation of the stability of fenamiphos and its degradates at this pH.

The amount of initially applied radioactivity recovered during the study ranged from 99.9-104.5% (fenamiphos), 91.8-100.0% (M01) and 95.6-99.5% (M02). Sterility was maintained (except for one vial, which may have been contaminated during handling) and pH (4.1) remained within range throughout.

HPLC analysis of the test solutions showed that after 30 days, the amount of fenamiphos remaining was 82.9%, with M01 increasing to 14.9% after this time, and a further 2.1% as the sum of all unidentified degradates. A first–order kinetics calculation indicated the half-life of fenamiphos was 192 days.

After 30 days the amount of M01 remaining was 86.9%, with 11.1% as the sum of all unidentified degradates, including an individual maximum of 5.3% of applied. The half-life of M01 was 151 days, again by a first–order kinetics calculation.

After 30 days the amount of M02 remaining was 85.3%, with 10.8% as the sum of all unidentified degradates. This was primarily one degradate, which may have been the deaminated M02, similar to the fenamiphos degradate found in the 1979 study at pH 3. A first–order kinetics calculation indicated the half-life of M02 was 136 days.

Again the above half-lives should be treated with caution as they are much greater than the duration of the study.

Conclusion

The outcomes of this study confirm those of Mulford (1987a), and further demonstrate that M01 and M02 are also relatively hydrolytically stable within environmentally relevant pH and temperature conditions.

Photodegradation in Water and Soil

Four studies are available on the photolytic stability of fenamiphos and some of its metabolites in water and on soil.

Report: Dime, Leslie and Puhl (1983)
Guidelines: Not stated
GLP: No

Test System

The photodegradation of fenamiphos, ^{14}C-radio-labelled in the 1-position of the phenyl ring, was studied in a merry-go-round reactor with a medium pressure light source suspended in a borosilicate

glass immersion well through which cool water was circulated. The samples were irradiated with a mercury vapour lamp with light intensity of the source at the sample surface being 5200 μW/cm^2, which was said to be nearly twice that of a July day in Kansas City.

For the aqueous photolysis a 12 ppm solution of fenamiphos in sterile pH 7 buffered water was placed into borosilicate glass tubes sealed with parafilm. For the soil photolysis 10 μg portions of fenamiphos were added to 40 X 25 mm thin layers of soil (weight approx. 0.5 g) on glass slides. The samples were held about 12 cm from the light source and rotated at 17 rpm during the 24 h (aqueous) or 48 h (soil) constant irradiation, with the temperature held "in the vicinity of 27-28^{o}C."

Samples of the test solution were taken immediately after treatment and at various sampling intervals during the study. Triplicate aliquots of the test samples were extracted with solvent and water and analysed by TLC, with appropriate precautions (room lights turned off, use of a gentle stream of nitrogen, the plate put into the tank immediately after application and developed in a darkened cabinet) to minimise oxidation to the sulfoxide, which was said to have occurred rapidly in an earlier soil photolysis study (Houseworth and Tweedy, 1974 – not reviewed for this assessment). Radioactive zones were located by autoradiography, scraped off the plates and quantitated through measurement of their ^{14}C-content, and the Rf values compared with known substances.

Findings

Fenamiphos was rapidly and extensively degraded when photolysed in aqueous buffer solution, with an experimental half-life of 3.6 hours, estimated as equivalent to 6.8 h on a mid-west USA July day. However, it was stable under similar conditions in the absence of light. Recovery of radioactivity averaged 94.4% (range 90.6-100.0%) from photolysis solutions, somewhat lower than those left in the dark (average 99.0%, range 94.6-102.1%).

The main component in the organosoluble fraction was M01, which peaked at 17.3% AR after 24 h, with 4.3% of parent remaining after this time. All other components of this fraction comprised <5%. The major component of the aqueous fraction, the phenol sulfonic acid (M24), reached a maximum of 18.6% after 24 hours. Another band, which reached a level of 6.1% after 24 h, was tentatively identified as fenamiphos sulfonic acid. Again all other components comprised <5%. The amount of ^{14}C that stayed at the origin of the plates after 24 hours was 20.8% AR. A small amount (<2%) of this fraction was the phenol sulfoxide.

A reaction scheme was proposed for the photolytic breakdown of fenamiphos going through two parallel pathways, involving the initial oxidation to the M01 or the formation of fenamiphos sulfonic acid, possibly through cleavage of the S-C bond, with the resulting radical then being oxidised. The two pathways were proposed as M01 had previously been shown to be resistant to photolysis, with a half-life of 188 days (Houseworth and Tweedy, 1974), though this experiment was conducted under different conditions.

In contrast the only reaction following photolysis on soil was the rapid photo-oxidation of fenamiphos to M01 (63.7% of applied after 6 h, with 22.0% of unchanged starting material remaining). This slowly further oxidised to the M02 (6.6% after 24 h). The presence of fenamiphos sulfonic acid was also demonstrated at the TLC origin, but could not be quantitated. The overall recovery of radioactivity from soil after 48 h was 89.3%, with 5.2% remaining in the soil residue, indicating an acceptable total recovery of 94.5% of applied.

A plot of the fenamiphos concentration with time indicated a slowing in rate over time. The authors calculated a half-life for the early part of the experiment of 1.6 h. This appears to be based on the dissipation up to 2 h (r^2 = 0.91, k = 0.41).

Using the equation t1/2 = ln(2)/k, DSEWPAC has calculated a first phase half-life of 2.3 hours based on degradation over 0-4 h (r^2 = 0.93, k = 0.3027). Fenamiphos was stable under similar conditions in the dark. The M01 metabolite was stable under the experimental conditions. Following its peak concentration at 6 hours, the estimated half-life until the end of the experiment (where 54.9% AR was still found as M01) was calculated by DSEWPAC to be in the order of 187 hours (r^2 = 0.86, k = 0.0036).

While radioactive CO_2 or any organic volatiles produced were not collected in either experiment, the mass balances achieved indicate these fractions are likely to have been minor.

Conclusion

Photodegradation in water is likely to be a key factor in the removal of fenamiphos in the environment. The estimated half-life of 6.8 h indicates this chemical would not persist in clear aqueous solution where it will be oxidised to the sulfoxide and more polar components. Likewise fenamiphos will not be persistence on soil when exposed to sunlight, though in this case it will oxidise mainly to the sulfoxide, which is more stable under these conditions.

Report: Hellpointner (1994)
Guidelines: Phototransformation of Chemicals in Water, Part A: Direct Phototransformation; Umweltbundesamt, Berlin (Dec. 1992)
GLP: Yes

Test System

This photodegradation experiment was conducted in a merry-go-round irradiation apparatus fitted with a mercury immersion lamp where the higher energy UV rays (λ <295 nm) had been almost quantitatively absorbed. Fenamiphos, at a concentration of about 5 ppm, was placed into 10 cuvettes on the merry-go-round and at intervals of 3 minutes one sample from each duplicate was removed over the total of 30 minutes irradiation period at 25^{o}C.

The fenamiphos concentrations in the samples over time were determined by reverse-phase HPLC. In addition its UV absorption spectrum was determined and the intensity of the light acting on the test solution was measured by means of the chemical actinometer uranyl oxalate in the cuvettes. The quantum yield was calculated by means of the computer program QUANT.

Findings

The UV absorption spectrum of fenamiphos showed typical maxima at 201 and 248 nm, with a broad shoulder at about 280 nm, which extends out to about 306 nm, that is, just in the environmentally relevant range of wavelengths.

Concentrations of fenamiphos dropped from 5 to <2 ppm over the 30 minutes irradiation period, indicating a half-life of about 20 minutes under the conditions of the experiment (r^2 = 0.99). It is stated that several more polar product peaks were detected in the HPLC chromatograms, but these were not identified or quantitated.

A mean quantum yield of Φ = 0.232 was determined, and through inserting this and the molar extinction coefficients from 297.5 to 305 nm into the GC-SOLAR computer program, the half-lives (integrated over the whole day) in Table A1.1 were determined. These assume pure water close to the surface (0-5 cm), a clear sky and typical ozone concentrations in the atmosphere.

Table A1.1 – Estimated Environmental Aqueous Photolysis Half-lives (days) of Fenamiphos

Season	30° latitude	40° latitude	50° latitude	60° latitude
Spring	4.1	8.4	22	76
Summer	2.6	3.7	6.2	12
Autumn	6.8	18	80	>1 year
Winter	20	119	>1 year	>1 year

Use of the model developed by Frank and Klöpffer allowed the conditions for cloudiness in, and latitude of, Central Europe to be taken into account and resulted in mean half-lives ranging from about 7.5 days in summer to >1 year in winter, consistent with the above results at 50° latitude.

Conclusion

The results of the modelling indicate that during the summer period direct photodegradation in water is likely to be a significant removal process of fenamiphos in the environment. When considering the latitudes more relevant to Australia, this is also likely to be a contributor in both spring and autumn, as well as in winter for latitudes above 30°S. Note that this conclusion does not consider any indirect photodegradation mechanisms, which could increase degradation in natural waters.

Metabolites

Test Material: M01
Report: Stupp (2001)
Guidelines: US EPA Pesticide Assessment Guideline, Subdivision N, Section 161-2, and EC- and SETAC guidelines
GLP: Yes

Test System

The photodegradation of M01, ^{14}C-radio-labelled in the 1-position of the phenyl ring, was studied in sterile pH 7 buffered aqueous solution in quartz glass vessels at a concentration of 3 ppm. The test solutions were continuously irradiated with artificial light in a Suntest unit equipped with a xenon lamp for up to 168 hours at 25±1°C. A special UV-glass filter removed light below 290 nm.

An UV absorption spectrum was run for M01, and the intensity of the filtered xenon light determined using a radiometer at the beginning and end of the period, and additionally with uranyl oxalate actinometry. A dark control was run concurrently. The septum of each test vessel was penetrated using an injection needle fitted with a trap attachment to absorb volatiles.

Samples of the test solution were taken immediately after treatment and at various sampling intervals during the study. LSC (also used for $^{14}CO_2$), TLC and HPLC were used to determine M01 and its degradation products.

Findings

The mass balance for both irradiated and control samples was in the range of 98.4-102.6%. The UV spectrum had an absorption maximum at about 195 nm, with only low absorption at 290 nm (ε = 70).

Over the 168 hours the content of M01 declined to 86.6% of applied. Under the continuous irradiation experimental conditions the photolytic half-life of M01 was calculated as 1155 hours (48

days, $r^2 = 0.87$), assuming a first order rate of transformation. Based on this, the half-lives under environmental conditions were calculated for a range of cities. The results for Phoenix, Arizona (USA – June), Athens, Greece (EU – June), Edmonton, Alberta (Canada – June) and Tokyo (Japan – April) were 248, 385, 350 and 513 days respectively. There was no degradation in the dark controls.

Eight radioactive zones indicative of degradation products were detected by TLC, but all were <10% of applied (maximum of 6.3%), so these were not further identified. Evolution of $^{14}CO_2$ accounted for a maximum of 0.3% at the end of the irradiation.

Conclusion

It may be concluded from the study that under environmental conditions solar radiation would not significantly contribute to the degradation of M01. This is in line with its UV absorption spectrum and previous conclusions (see Dime, Leslie and Puhl (1983) above].

Test Material M24
Report: Stupp (2002a)
Guidelines: US EPA Pesticide Assessment Guideline, Subdivision N, Section 161-2, and EC- and SETAC guidelines
GLP: Yes

Test System

The photodegradation of fenamiphos phenol sulfonic acid (M24), ^{14}C-radio-labelled in the 1-position of the phenyl ring, was studied in sterile pH 7 buffered aqueous solution in quartz glass vessels at a concentration of 3 ppm. The test solutions were continuously irradiated with artificial light in a Suntest unit equipped with a xenon lamp for up to 192 hours at $25 \pm 1^{o}C$. A special UV-glass filter removed light below 290 nm.

An UV absorption spectrum was run for M24, and the intensity of the filtered xenon light determined using a radiometer at the beginning and end of the period, and additionally with uranyl oxalate actinometry. A dark control was run concurrently. The septum of each test vessel was penetrated using an injection needle fitted with a trap attachment to absorb volatiles.

Samples of the test solution were taken immediately after treatment and at various sampling intervals during the study. LSC and HPLC were used to determine M24 and its degradation products.

Findings

The mass balance for both irradiated and control samples was in the range of 94.0-100.0%. The UV spectrum had an absorption maximum at about 200 nm, with very low absorption at 290 nm (ε = 19).

Over the 192 hours the content of M24 declined to 83.5% of applied. Under the continuous irradiation experimental conditions the photolytic half-life of M24 was calculated as 768 hours (32 days, $r^2 = 0.94$), assuming a first order rate of transformation. Based on this, the half-lives under environmental conditions were calculated for a range of cities. The results for Phoenix, Arizona (USA – June), Athens, Greece (EU – June), Edmonton, Alberta (Canada – June) and Tokyo (Japan – April) were 161, 249, 226 and 332 days respectively. There was no degradation in the dark controls.

Five radioactive zones indicative of degradation products were detected by TLC, but all were <10% of applied (maximum of 4.2%), so these were not further identified. Evolution of $^{14}CO_2$ accounted for a mean maximum of 1.7% at the end of irradiation.

Conclusion

It may be concluded from the study that under environmental conditions solar radiation would not significantly contribute to the degradation of M24. This is in line with its UV absorption spectrum.

Degradation in Soil and Water

Soils – Aerobic

Three aerobic soil metabolism studies were provided and a further study described in the literature was obtained.

Report: Brumhard (2002)
Guidelines: OECD TG 307: Aerobic and Anaerobic Transformation in Soil and EC- and SETAC guidelines
GLP: Yes

Test System

An aerobic soil metabolism study of fenamiphos, ^{14}C-radio-labelled in the 1 position of the phenyl ring, was studied in 4 different German soils at an application rate of 0.67 ppm (equivalent to a maximum single use rate of 10 kg/ha for 10 cm depth of soil) for up to 120 days under aerobic conditions in the dark at around 20^{o}C. This study was undertaken as a new product of fenamiphos was a slow release capsule. Due to the lower concentration of the available active constituent (due to the slower release and claimed rapid degradation of the released portion), the "study was performed at one tenth of the annual use rate."

The soil characteristics were as summarised in Table A1.2:

Table A1.2: Soil characteristics of 4 German soils.

Type	Textural class	% Sand	% Silt	% Clay	OC (%)	CEC (meq/100 g)	pH	Max WHC[1]
Laacher Hof AXXa	Sandy Loam	72.4	22.6	5.0	1.02	8	7.2	34.4
Laacher Hof AIII	Silt loam	36.9	51.1	12.0	0.83	8	7.4	36.4
Hoefchen am Hohenseh 4a	Silt	8.5	81.3	10.2	2.11	15	7.6	63.1
Standard soil BBA 2.1	Sand	89.6	8.1	2.3	0.38	5	5.9	27.6

1) g water to 100 g dry soil.

The test systems were prepared by adding the equivalent of 100 g of soil (for which the moisture contents were then adjusted to correspond to 40% of the maximum water holding capacity) to Erlenmeyer flasks, into which the test substance solutions were pipetted. The flasks were attached with traps for collection of volatile material, with a polyurethane foam plug used to trap organic volatiles and soda lime used for capturing CO_2, respectively. Sampling was conducted at days 0 (approx. 2 hours after application), 0.25, 1, 2, 4, 7, 14, 30, 60 and 120.

Microbial biomass measurements were carried out at the beginning, middle and end of the experiment. At the start these ranged from 950 (Hoefchen) to 85 (BBA 2.1) mg microbial C/kg dry soil. These are said to be within the usual range expected for agricultural field soils. With the exception of the Laacher Hof AIII soil, all dropped by between 30 to >50% after 120 days, though levels were similar to control soils after this period.

Soil was extracted three times at room temperature with 1:1 aqueous acetonitrile and then once with acetonitrile alone followed by centrifugation. During clean-up and concentration extracted soil was extracted once more with aqueous acetonitrile under reflux for one hour. Fenamiphos residues were analysed by reverse phase HPLC and normal phase TLC. Transformation products were identified using co-chromatography and spectroscopic methods (LC/MS and LC/MS/MS, nuclear magnetic resonance - NMR). Liberated $^{14}CO_2$ and non-extracted radioactivity in soil were assayed by LSC.

Samples were assayed within a few days of processing. All samples and reference standards were stored frozen at <-10^{o}C when not in use. A sample extract analysed after 46 days under these storage conditions showed no further degradation.

Findings

Mass Balance

The mean total recovery of radioactivity for all four soils ranged from 98.5-101.1%, with the individual range from 94.3-103.4%, indicating there was no significant losses of radioactivity from the vessels or from processing.

Parent Decline and Metabolite Formation

Fenamiphos disappeared rapidly in all four soils, with a mean calculated DT50 of 0.9 days, and a range of DT90s of 1.4 to 4.6 days. Individual DT50s, as calculated in the test report, were 0.6 (Laacher Hof AXXa), 1.0 (Laacher Hof AIII), 0.4 (Hoefchen am Hohenseh) and 1.4 days (BBA 2.1). Note that the last-named had the lowest microbial mass but still the degradation of parent was very rapid.

Three major degradation products were found at levels >10% applied radioactivity (AR) during the study. Fenamiphos sulfoxide (M01) reached maximum amounts between days 1 to 4 in all soils, with the highest level of 77.2% AR after 4 days in the BBA 2.1 soil. Levels declined towards the end of the study, to 2.1–19.3% on day 120 (highest again for the BAA 2.1 soil). Fenamiphos sulfone (M02) reached its maximum between days 3 to 7, except for the lower active BBA 2.1 soil where again it peaked the highest at 29.3% AR, and was still 25.0% of applied after 120 days (cf 0.4-6.7%). Likewise, fenamiphos phenol sulfone (M13) reached its maximum between 7 to 14 days (20.0-25.1% AR, dropping to 2.0-10.4% AR by day 120) after treatment, except for the BBA 2.1 soil where it highest concentration of 5.4% of applied was found on day 120.

Two minor metabolites were also detected in all soils with fenamiphos phenol sulfoxide (M12) accounting for between 2.7-6.5% of AR between days 7 to 14, and declining to 0.4-1.3% by 120 days. Fenamiphos sulfone anisole (M14) started to appear from day 14 onwards and reached a maximum level of 8.2% AR on day 120 for Laacher Hof AIII soil. Diffuse radioactivity and TLC origin material was a maximum of 5.3% of AR.

In all soils $^{14}CO_2$ steadily increased to yield 23.0 (BBA 2.1 soil) to 52.1% AR (Hoefchen soil) by day 120. No other volatile organics were detected.

A significant formation of bound residues also occurred, increasing in all soils towards the end of the study, with a range of 17.5% (BBA 2.1 soil) to 34.8% of AR (Hoefchen soil) on day 120. Since there was a concomitant similar, strong increase in CO_2 release, the study authors concluded that mineralization of fenamiphos and metabolites from bound residues can occur.

Table A1.3: Breakdown and Mass Balance

Day	Soil	Fen	M01	M02	M12	M13	M14	Ext.	Bound	CO_2	Total
	Laacher Hof AXXa	63.2	35.3	0.7	nd	nd	nd	99.2	4.2	0	103.4
0	Laacher Hof AIII	85	13.7	0.2	nd	nd	nd	98.9	4.1	0	103.2
	Hoefchen	64.5	31.2	0.5	nd	nd	nd	96.2	4.2	0	100.4
	BBA 2.1	76.9	20.6	0.2	nd	nd	nd	97.8	3	0	100.8
	Laacher Hof AXXa	36.8	55.5	4.2	0.6	0.4	nd	97.5	2	0	99.5
0.25	Laacher Hof AIII	68.2	27.8	0.8	0.2	nd	nd	97	3.9	0	100.9
	Hoefchen	44.3	49.4	2.5	1.1	nd	nd	97.3	4.3	0	101.6
	BBA 2.1	55.4	40.5	0.7	nd	nd	nd	96.8	1.5	0	98.1
	Laacher Hof AXXa	24	65.4	7.4	0.9	0.7	nd	98.4	3.2	0.2	101.8
1	Laacher Hof AIII	40.2	52.2	3.7	0.8	0.5	nd	96.4	4.4	0.1	100.1
	Hoefchen	11.1	66.9	11.1	3.3	2.9	nd	95.3	5.5	0.4	101.3
	BBA 2.1	43.6	52.3	1.3	nd	nd	nd	97.2	1.8	0.1	99
	Laacher Hof AXXa	5.6	63	21.3	2	4.2	nd	96.2	6.2	0.6	102.9
2	Laacher Hof AIII	19.7	65.4	9.1	1.3	1.5	nd	97	5.6	0.2	102.9
	Hoefchen	5.8	57.6	15.3	4.2	8.1	nd	91	8.2	1.6	100.7
	BBA 2.1	25.8	65.5	3.5	0.7	nd	nd	95.4	3.5	0.1	99
	Laacher Hof AXXa	2.2	51.2	24.9	2.6	10.8	nd	91.6	6.8	1.9	100.4
4	Laacher Hof AIII	6.6	64.2	15	2.6	6.7	nd	95.2	5	0.5	100.7
	Hoefchen	3.1	46.9	14.1	5.2	17	nd	86.4	10.7	4.5	101.6
	BBA 2.1	10.3	77.2	7.7	1.3	0.4	nd	96.8	3.7	0.3	100.8
	Laacher Hof AXXa	2.6	43.1	24	3.7	20	nd	93.4	3.1	4.5	101
7	Laacher Hof AIII	3.2	58.1	17.7	4	15.1	nd	98	1.8	1.4	101.2
	Hoefchen	1.9	37.1	9.3	6.5	25.1	nd	80.4	9.2	10.5	100.1

Day	Soil	Fen	M01	M02	M12	M13	M14	Ext.	Bound	CO_2	Total
	BBA 2.1	6	72.1	14.1	1.8	1.6	nd	95.6	2.9	0.6	99.1
	Laacher Hof AXXa	2	27.7	19.2	3.2	19.8	1.8	77	13.4	10.2	100.6
14	Laacher Hof AIII	2.7	37.8	12.9	2.6	23.7	1.2	83.7	11.6	4.6	99.9
	Hoefchen	2.3	13.1	3.5	3.2	20.5	3.5	48.1	25.1	24.1	97.2
	BBA 2.1	4	51.6	25.2	2.7	4.8	nd	91.5	5.3	2.1	98.9
	Laacher Hof AXXa	1.4	19.9	13.4	2.5	12	2.8	55.9	19.4	19	94.4
30	Laacher Hof AIII	2.2	29.2	6.3	1.9	21.1	3.2	66.5	20.8	12.4	99.7
	Hoefchen	1.6	5.1	1.2	1.6	7.1	3.2	22	36.2	39.9	98.1
	BBA 2.1	2.2	37.5	26.2	2.3	5.2	0.3	76.9	9.6	5.8	92.3
	Laacher Hof AXXa	1.1	14.2	10.6	1.8	8.8	5.1	45.7	22.9	30	98.6
60	Laacher Hof AIII	1.1	18.8	3.2	1.2	13.8	6.3	48.5	27.6	23.9	99.9
	Hoefchen	0.7	2.3	0.5	0.6	2.5	1.5	11.1	35.9	47.3	94.3
	BBA 2.1	1.1	30.3	29.3	1.6	5.1	0.6	72.8	12.2	12.7	97.7
	Laacher Hof AXXa	0.6	7.4	6.7	1.2	5.7	4.5	30	28.5	38.4	96.8
120	Laacher Hof AIII	1.3	11.7	1.9	0.7	10.4	8.2	40.1	33.6	27.8	101.4
	Hoefchen	1	2.1	0.4	0.4	2	0.8	10.4	34.8	52.1	97.4
	BBA 2.1	0.9	19.3	25	1	5.4	1.4	58.6	17.5	23	99.1

The above table describes the decline of the parent compound and corresponding metabolite formation.

Discussion

Oxidation of fenamiphos to its M01 metabolite is rapid with significant transformation occurring even at day 0. Given that M01 is biologically active and is by far the major metabolite produced at least initially, a half-life for the combined radioactivity levels of fenamiphos and M01 has been determined.

The following figure demonstrates the degradation behaviour of these combined residues:

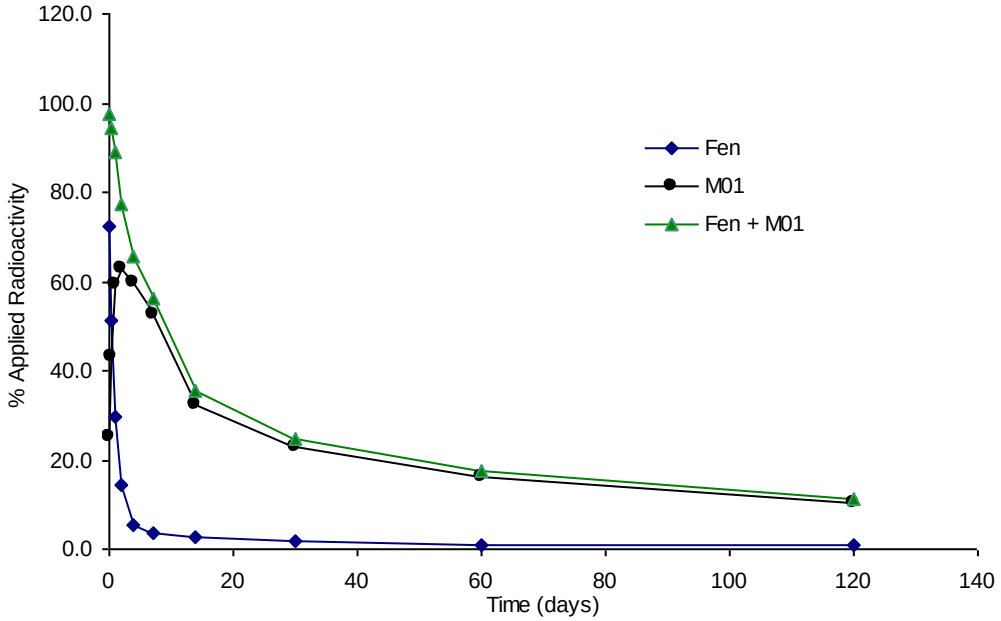


Figure A1.1 –Decline of Average Residues of Fenamiphos, M01 and Combined.

Based on this simple analysis, it can be seen that based on mean values from Table A1.3 above, the soil half-life appears to be bi-phasic with fast initial degradation followed by a significant slowing in the degradation rate. Degradation from days 0-14 show good linear correlation ($r^2 = 0.93$) with an average initial half-life of around 10.4 days. The average second phase half-life from days 14-120 ($r^2 = 0.85$) is calculated to be around 82 days.

The first step in the degradation is the extensive and rapid oxidation to M01, which can then either oxidise further to M02 or split the phosphate group to M12, which can further oxidise to M13 (which may also be formed from the cleavage of M02). Further degradation takes place through M14 leading to CO_2 (see Attachment 1).

Conclusion

Results indicate that fenamiphos and its soil degradates should dissipate from the soil environment, with mineralisation and incorporation, partly unchanged, into the soil organic matter as the principal pathways of carbon disposition.

Report: Simon, 1990.
Guidelines: Partially based on US EPA 162-1
GLP: No

Test System

The metabolism studies were carried out with 16 soils originating from different geographic areas

The soil characteristics were as summarised in Table A1.4:

Table A1.4: Soil characteristics of the 16 test soils.

Soil origin	Textural class[a]	% Sand	% Silt	% Clay	OC (%)	CEC[b]	pH	WHC[c]
Canada	Loam	29.7	47.6	22.7	6.52	47.7	7.27	43.5
Sweden	Loamy sand	82.5	9.0	8.5	1.23	7.4	6.33	11.7

Soil origin	Textural class[a]	% Sand	% Silt	% Clay	OC (%)	CEC[b]	pH	WHC[c]
Germany/Puch	Silty loam	11.0	74.9	14.1	1.21	13.6	6.98	25.7
Germany/Speyer	Loamy sand	81.4	14.1	4.5	2.22	12.0	6.45	18.3
The Netherlands	Silty loam	22.7	58.0	19.3	1.60	15.2	6.60	23.3
France	Clay loam	32.0	39.9	28.1	1.58	19.1	7.96	22.8
USA/Indiana	Sandy loam	62.4	25.6	12.0	0.95	10.8	6.42	12.1
USA/Nebraska	Silty clay loam	3.2	69.8	27.0	1.51	22.5	6.68	30.8
Japan/Toyoda	Loam	42.1	48.1	9.8	3.53	31.0	5.97	58.3
USA/Florida	Sand	95.4	3.3	1.3	0.77	4.4	6.58	5.2
Costa Rica	Clay loam	28.8	41.6	29.6	4.76	39.5	6.03	51.8
Brazil/P. Fundo	Clay	31.2	24.4	44.4	1.63	13.6	5.79	23.1
Brazil/Parana	Clay	15.6	30.9	53.5	2.28	23.2	6.52	31.3
Thailand	Silty clay	1.7	43.0	55.3	1.63	23.8	5.72	37.0
The Philippines	Loam	42.5	42.3	15.2	0.73	16.9	5.83	24.9
Japan/Tsurug.	Loam	42.2	47.2	10.6	3.58	38.3	7.10	59.8

(a) Classification according to USDA; (b) mval/100 g soil; and (c) g water to 100 g dry soil.

The soil samples were taken in naturally moist conditions from the top soil level at 5 spots of a homogeneous plot, combined to a total sample of about 50 kg and immediately airfreighted to Germany where they were stored under vegetation in the greenhouse during winter and in the field during summer. The microbial biomass and the catalase activity of the soils were investigated before and during the experiment.

The air-dried soils were sieved (2 mm). The entire amount of soil needed for each temperature batch was weighed and an aliquot of this (2%) completely dried and ground. Radioactive and inactive fenamiphos dissolved in acetone (0.5 mL/100 g soil) was added to the sub-sample. The rate of active ingredient amounted to 0.77 mg/100 g soil corresponding to a maximum rate of 10 kg/ha with the ratio of radioactive/inactive fenamiphos being about 1:10. The sub-sample was then mixed into the total amount of soil and homogenised. After this, 100 g soil each was incubated in a closed system and the water content adjusted to 75% WHC.

Half the flasks incubated with one soil type were stored in a climatic cabinet in the dark at around 22^{o}C. The remaining part of the flasks were placed in incubators at a second temperature level being around 16^{o}C for soils from zones with moderate climate or around 28^{o}C for soils from sub-tropical and tropical climates. The water content was checked every 2 weeks and corrected if needed with deionised water. Sterile soil samples were maintained to distinguish between microbial and abiotic degradation. In the sterile samples, fenamiphos was applied to the soil surface in the flask. After evaporation of the acetone the soil was thoroughly mixed.

At all sampling dates (on days 0, 15, 30, 50, 70 and 90), 2-3 batches were processed. One sterile control each was extracted on days 15, 50 and 90. Briefly, the extraction procedure is described as follows: The initial extraction in centrifuge beakers included two extractions with 150 mL acetone:methanol (1:1) and 1 extraction with 150 mL chloroform:methanol (1:1). Centrifugation was for 15 minutes after which the supernatant was decanted through a filter. The combined organic extract was concentrated and radioactivity measured by LSC. Compounds were characterised by

TLC and possibly GC/MS. The remaining soil was air dried and pulverised. In the case of three soils that showed particularly high proportions of unextractable residues at the last extraction date, humic substance fractionations were carried out with sub-samples. Carbon dioxide was captured in a soda lime trap.

Findings:

The range of microbial biomass measurements (mg C_{mic}/kg soil) for soils at 22°C without test substance was found as follows:

Table A1.5: Soil Microbial Biomass Findings at 22°C

Days after treatment	Soils (n=9) from moderate climate zones	Soils (n=7) from (sub) tropical climate zones
0	240-900	61-749
15	175-905	58-722
50	159-849	95-674
90	190-919	62-609

Application of fenamiphos generally had a positive influence on microbial biomass with treated soils averaging 22.9 mg C_{mic}/kg soil more than untreated soil samples. There was also an influence of temperature. While the biomass values were on an average 35.9 mg C_{mic}/kg soil higher at 16°C than at the standard temperature of 22°C, the values in case of the variant with 28°C incubation temperature were considerably below the comparative values at 22°C (the range in these soils at 28°C was 85-478 mg C_{mic}/kg soil at day 90 compared to the 22°C soils in the above table from the sub-tropical and tropical climates).

Mass balance and breakdown of parent compound

Total recovery in the three different temperature soils ranged from 96.3-97.1% mean applied radioactivity (AR) compared to 102.5% AR in the sterile soils. The breakdown pattern is shown in tables A1.6 to A1.9 below.

Generally, at 22°C, the rate of decline of fenamiphos was fast over the first 15 days while the increase in formation of the oxidation product, M01 was correspondingly fast and had reached its peak in most soils by 15 days. For soils incubated at 16°C also, peak concentrations of M01 appear to have been reached between 15 and 30 days in some instances, while for soils incubated at 28°C, the peak concentrations of M01 were found by day 15. The general pattern of parent decline was similar in soils at all incubation temperatures with the exception of the Japan/Toyoda soil at 16°C where degradation of the parent compound seemed much slower.

The general pattern of parent decline and corresponding formation of M01 can be demonstrated by considering the mean levels of radioactivity found for each sampling day. Doing this for all soils at the 22°C incubation temperature (Figure A1.2), it can be seen that by the first sampling day (day 15), mean residue levels of fenamiphos had reduced to about 12% AR with the maximum residues of M01 being detected at this time (around 51% AR based on mean values). A steady decline in both compounds was seen from day 15 onwards.

Table A1.6: Breakdown and Mass Balance of Moderate Climate Soils at 22^0C

	Soil	Fen	M01	M02	M12	M13	M14	Ext.	Bound	CO_2	Total
	Canada	79.8	3.9	-	-	-	-	83.7	10.7	-	94.4
	Sweden	84.3	13.2	-	-	-	-	97.5	0.7	-	98.2
Day 0	France	83.4	10.6	-	-	-	-	94	3	-	97
	USA/Indiana	75	21.6	-	-	-	-	96.6	2.5	-	99.1
	USA/Nebraska	60.5	25.2	-	-	-	-	85.7	3.1	-	88.8
	Canada	14.6	45	6.2	3.9	4.8	-	74.5	18.5	1.3	94.3
	Sweden	7.8	65.3	9	1.3	2.3	-	87.5	6.3	1.7	93.7
	Germany/Puch	2.6	56.6	5.3	2.6	10.3	-	77.4	19.8	4	101.2
Day 15	Germany/Speyer	15.7	52.3	4.3	7.6	4.1	-	84.5	10.1	2	96.6
	Netherlands	2.6	68.1	9.6	1.1	7.9	-	89.3	12.7	3.4	105.4
	France	5.5	36.8	1.8	5.4	14.2	0.8	65.3	29.8	2.5	97.6
	USA/Indiana	7.3	47.3	6.4	3.7	14.5	-	79.2	18.4	1.5	99.1
	USA/Nebraska	6.1	58.1	5.5	1	-	-	70.7	13.1	1	84.8
	Japan/Toyoda	48.5	34.4	-	-	-	-	82.9	17.5	0.1	100.5
	Canada	8.4	35.4	8.7	4.6	12.9	0.8	70.8	28.6	3.9	103.3
	Sweden	2.5	48.5	17.9	1.2	8.1	1	79.2	10.1	5.6	94.9
	Netherlands	1.1	41.9	9.3	1	14.3	1.5	69.6	21.1	10	100.7
Day 30	France	2	11.4	0.7	1.8	20	2.6	39.3	62.6	7.9	109.8
	USA/Indiana	3.5	49.2	6.8	3	12.2	0.8	75.5	22.3	3.5	101.3
	USA/Nebraska	3.3	49	18.2	1.3	2.1	-	73.9	16.3	3	93.2
	Japan/Toyoda	24.7	45.8	2.1	1.3	-	-	73.9	18.3	0.2	92.4
	Canada	2.9	24.3	6.3	3.7	14.9	1.4	53.5	36.2	8.3	97.7
	Sweden	1.5	35.6	19	1.1	11.9	1.7	70.8	12.2	8.1	91.1
	Germany/Puch	0.1	24.1	2.1	0.8	12.3	2.4	41.8	40.3	21.2	103.2
Day 50	Germany/Speyer	2.3	34.9	5.9	11.1	12.3	1.2	68.4	19.8	8.7	96.9
	Netherlands	0.3	24.3	5.7	0.7	14.9	3.1	49.4	29.5	21.8	100.7
	France	1.1	4.8	0.3	0.8	12.2	3.3	23.1	69.1	16.8	109
	USA/Indiana	1.3	25.5	6.6	2.1	19.5	1.6	56.6	29.1	7.7	93.4
	USA/Nebraska	2.1	33.8	22.6	1.6	7.1	0.7	67.9	23.5	6.6	98
	Japan/Toyoda	17.6	48.9	7.1	2	1.1	-	76.7	25.6	0.3	102.6
	Canada	2.8	19.2	5.4	2.7	15.7	2.1	47.9	40.4	12.6	100.9
	Sweden	0.5	35.2	14.2	0.9	9.9	1.9	62.6	18.7	12.7	94
	Netherlands	1.1	15.3	3.6	0.4	8.7	3.5	32.6	38	31.9	102.5
Day 70	France	1	2.8	0.2	0.4	7.6	3.4	15.9	59.7	22.2	97.8
	USA/Indiana	1	19.4	4.4	1.9	21.9	2.9	51.5	37.3	9.3	98.1
	USA/Nebraska	0.7	31.2	21.9	1	7.3	0.9	63	26.9	9.4	99.2
	Japan/Toyoda	11.2	47.4	10.6	2.3	2.4	-	73.9	26.7	0.7	101.3
	Canada	2.2	16.7	4.3	2.7	16.7	2.7	45.3	34.8	17	97.1
	Sweden	0.8	21	14.1	0.9	14.8	3.9	55.7	18.5	16.2	90.4
	Germany/Puch	0.4	7.1	0.5	0.4	7	3.3	19.2	48.2	32.9	100.3
Day 90	Germany/Speyer	0.8	23.4	5.2	10.1	16.2	2	57.7	25.4	13.2	96.3
	Netherlands	0.5	10.8	2.2	0.4	5.2	2.9	22	33.8	39	94.8
	France	0.6	1.5	0.2	0.2	3.9	3.7	10.5	61.8	23.2	95.5
	USA/Indiana	1.1	12.5	2.5	1.8	24.7	3.3	45.9	33.8	14	93.7
	USA/Nebraska	0.8	23.4	19.2	1.4	11.5	1.7	58	26.3	12.8	97.1
	Japan/Toyoda	7.3	45.3	13.9	2.8	4.1	-	73.4	35.5	1.1	110

Table A1.7: Breakdown and Mass Balance of Moderate Climate Soils at 16^0C

		Fen	M01	M02	M12	M13	M14	Ext.	Bound	CO_2	Total
	Canada	76.2	4.4	-	-	-	-	80.6	14.8	-	95.4
	Sweden	63.4	34.8	-	-	-	-	98.2	0.8	-	99.6
Day 0	France	86.2	11	-	-	-	-	97.2	2.1	-	99.3
	USA/Indiana	94.8	10.2	-	-	-	-	105	2.7	-	107.7
	USA/Nebraska	70.1	15.1	-	-	-	-	85.2	1.7	-	86.9
	Canada	33.5	41.4	2.1	2.1	1	-	79.9	14.8	0.6	95.3
	Sweden	18	65.7	3.6	0.5	-	-	87.8	3.7	0.6	92.1
	Germany/Puch	3.9	66.8	3	2.4	3.7	-	79.8	12.7	1.2	93.7
Day 15	Germany/Speyer	24	54.2	2.5	4.2	0.9	-	86.5	8.5	0.1	95.1
	Netherlands	5.1	79.1	3.9		2	-	90.1	9	1.1	100.2
	France	6.8	52.9	0.9	4.4	14.4	-	79.4	23.3	1.6	104.3
	USA/Indiana	24.7	58.6	2.6	2.3	2.6	-	90.8	11.7	0.8	103.3
	USA/Nebraska	12.3	65.5	1.6	-	-	-	79.4	13	0.4	92.8
	Japan/Toyoda	69.1	17.8	-	-	-	-	86.9	10.4		97.3
	Canada	18.8	45.2	5.6	4.2	4.6	-	78.4	21.5	1.5	101.4
	Sweden	9.9	61.4	10.5	1.6	3.6	-	87	5.3	2.2	94.5
	Netherlands	3	57.8	11.5	1.1	11.4	0.4	85.2	12.6	3.2	101
Day 30	France	6.8	32.9	1.2	4.4	15.4	1	62.5	37.1	3.7	103.3
	USA/Indiana	11.9	53.9	5.7	3.1	6.1	-	80.7	16.8	1.7	99.2
	USA/Nebraska	6.1	63.5	7.8	0.9	-	-	78.3	10.7	1	90
	Japan/Toyoda	40.2	37.1	-	0.7	-	-	78	12.8	0.1	90
	Canada	10	37.8	7.2	4.8	10.3	-	70.1	21.5	3.4	95
	Sweden	8.6	53.9	11.7	2.1	5.2	-	81.5	8.1	3.1	92.7
	Germany/Puch	0.2	29.6	3.1	1.1	17.3	1.3	52.6	23.7	11.3	87.6
Day 50	Germany/Speyer	4.4	44	7.4	9.1	8.9	0.5	74.9	13.6	4.1	92.6
	Netherlands	1.7	37.8	11.6	1.2	19	1.2	72.5	18.3	7.8	98.6
	France	3.8	27.7	0.8	2.8	16	1.1	52.2	42.5	7.2	101.9
	USA/Indiana	13.1	48.7	4.8	3.2	8	-	77.8	19.6	2.8	100.2
	USA/Nebraska	3.8	54.3	11.4	0.8	0.6	-	70.9	14.9	1.7	87.5
	Japan/Toyoda	34.7	48.8	0.6	1.1	-	-	85.2	19	0.1	104.3
	Canada	7.9	29.1	5.7	3.7	13.5	1.1	61	29.8	5.4	96.2
	Sweden	6	54.2	12.4	2.4	6.3	-	81.3	8.5	3.2	93
	Netherlands	0.7	27.8	7.5	0.7	17.9	2	56.6	27.1	14.6	98.3
Day 70	France	4.4	23	1	3.7	16.7	1.5	50.9	40.5	8.3	99.7
	USA/Indiana	13.1	46.9	5.4	3.7	7.3	-	76.4	18.4	2.2	97
	USA/Nebraska	3	49.1	18.2	1.5	2.5	-	74.3	15.1	2.6	92
	Japan/Toyoda	29	47	2.5	1.9	-	-	80.4	18.4	0.2	99
	Canada	5.3	25.4	4.5	3.4	14.4	1.3	54.3	31.6	10.4	96..3
	Sweden	4.9	49.8	14.3	2	6	0.7	77.7	9.1	4.8	91.6
	Germany/Puch	0.5	12.6	1.2	0.4	17	1.7	33.9	35.1	21	90
Day 90	Germany/Speyer	1.7	28.7	7.3	8.1	18.4	1.7	66.6	20.6	9	96.2
	Netherlands		18.7	4.7		15.8	3.5	42.7	28.6	23.4	94.7
	France	3.9	22.4	0.6	2.8	15.2	1.5	47.3	46.4	9.8	104
	USA/Indiana	4.4	45.5	5.4	4.3	12.3	0.7	72.6	25.9	4.1	102.6
	USA/Nebraska	2.2	37.8	22.8	1.8	6.4	-	71	18.9	4.8	94.7

		Fen	M01	M02	M12	M13	M14	Ext.	Bound	CO_2	Total
	Japan/Toyoda	24.8	49.3	3.1	2.5	0.6	-	80.3	23.9	0.4	104.6

Table A1.8: Breakdown and Mass Balance of (Sub) Tropical Climate Soils at 22^0C

		Fen	M01	M02	M12	M13	M14	Ext.	Bound	CO_2	Total
	USA/Florida	81.4	13.4	-	-	-	-	94.8	2	-	96.8
Day 0	Costa Rica	79	9.9	-	-	-	-	88.9	6.6	-	95.5
	Japan/Tsurugashimi	63.3	24.1	-	-	-	-	87.4	4.5	-	91.9
	USA/Florida	30.7	34.4	8.1	1.3	-	-	74.5	10	0.6	85.1
	Costa Rica	15.5	45.4	5.9	3.7	2.5	-	73	21.6	2	96.6
	Brazil/Passo Fundo	11.2	53.5	6.7	5.4	4.3	-	81.1	18.1	2.7	101.9
Day 15	Brazil/Parana	16.9	40.6	5.2	4.5	4.4	-	71.6	28.2	1.1	99.9
	Thailand	24.6	60.9	0.3	1.1	-	-	86.9	13.8	0.4	101.1
	The Philippines	6.4	61.7	4.4	1.6	1.3	-	75.4	11.5	1.8	88.6
	Japan/Tsurugashimi	14.8	56.6	1.1	0.9	-	-	73.4	20	0.3	93.7
	USA/Florida	12.1	33.3	13.6	1.9	2.9	-	63.8	20.9	1.8	86.5
	Costa Rica	10.4	32.5	7.9	4.3	5.1	-	60.2	36.3	4	100.5
	Brazil/Passo Fundo	5.3	32	11	5.4	13.6	1.3	68.6	22.8	7.2	98.6
Day 30	Brazil/Parana	6.1	22.1	5.3	5.3	20	1.2	60	33	5.4	98.4
	Thailand	8.1	62.4	4.1	2.8	-	-	77.4	20.6	1	99
	The Philippines	2.4	50.5	9	2.4	5.1	0.7	70.1	18.9	5.8	94.8
	Japan/Tsurugashimi	4.5	50.3	5.4	2.2	1.4	-	63.8	34.5	0.7	99
	USA/Florida	7.6	30.7	15.5	2	4.4	-	60.2	22.7	2.7	85.6
	Costa Rica	5.9	28.9	7	5.2	8.2	0.6	55.8	37.1	7.5	100.4
	Brazil/Passo Fundo	2	26.2	9.7	5.5	13.5	1.9	58.8	33.4	13.3	105.5
Day 50	Brazil/Parana	5.1	17.6	5.2	3.8	16.6	0.9	49.2	39.4	9.4	98
	Thailand	5	52.5	7.7	5.2	3.9	-	74.3	20.6	3	97.9
	The Philippines	1.2	31.7	10.6	1.7	9.6	1.4	56.8	27	11.2	95
	Japan/Tsurugashimi	4.8	45.1	9.3	3.1	3.9	-	66.2	25.4	1.2	92.8
	USA/Florida	7.9	23.4	17.3	1.8	5.7	0.5	56.6	20	3.8	80.4
	Costa Rica	5.2	23.8	5.6	5.4	9.1	0.7	49.8	32.4	8.7	90.9
	Brazil/Passo Fundo	1.7	18.9	6	4.8	17.4	2.9	51.6	29.7	17.8	99.2
Day 70	Brazil/Parana	2.7	11	2.7	3	17.2	1.4	38	47	14.4	99.4
	Thailand	2.5	51.5	10.3	6.6	6	-	76.9	29.5	4.4	110.8
	The Philippines	0.4	23.4	8.7	1	8.8	2.1	44.8	31.9	18.2	94.9
	Japan/Tsurugashimi	3	34.7	11.1	2.9	6	-	57.7	34.6	2.4	94.7
	USA/Florida	6.7	20.2	16.3	1.8	6.9	0.5	52.7	24.8	4.8	82.3
	Costa Rica	3.5	21.3	5.5	5.4	10.5	1.3	47.5	39.6	12	99.1
	Brazil/Passo Fundo	1.2	13	3.5	4.2	18.9	3.5	44.3	32.1	20.8	97.2
Day 90	Brazil/Parana	2.2	7.8	2	2.7	15.6	2.1	32.4	48.5	18.1	99
	Thailand	2.9	39.6	8.5	6.2	4	-	61.2	24.6	4.3	90.1

		Fen	M01	M02	M12	M13	M14	Ext.	Bound	CO_2	Total
	The Philippines	0.3	18	6.7	0.9	9.3	2.1	37.7	35.7	24.2	97.6
	Japan/Tsurugashimi	1.9	33.7	11.3	3.2	8	0.6	58.7	33.2	3.5	95.4

Table A1.9: Breakdown and Mass Balance of (Sub) Tropical Climate Soils at 28^{0}C

		Fen	M01	M02	M12	M13	M14	Ext.	Bound	CO_2	Total
	USA/Florida	86.3	10.1	-	-	-	-	93.7	1.8	-	95.3
Day 0	Costa Rica	85.2	5.6	-	-	-	-	90.8	5.9	-	96.7
	Japan/Tsurugashimi	61.1	17.7	-	-	-	-	88.8	3.5	-	92.3
	USA/Florida	16.5	38.1	11.4	1.7	1.9	-	69.6	14.3	1.2	85.1
	Costa Rica	14	37.1	5.2	6.5	4.1	-	66.9	28.9	4.4	100.2
	Brazil/Passo Fundo	4	49.6	9.2	5.9	5.8	-	74.5	21.4	5	100.9
Day 15	Brazil/Parana	11	32.3	6.9	5.1	8.4	-	63.7	35.7	3.8	103.2
	Thailand	25	64.2	2.5	2.5		-	94.2	16.1	0.6	110.9
	The Philippines	3.5	57.2	7.5	2.2	3	-	73.4	18.3	4.6	96.3
	Japan/Tsurugashimi	5.6	51	4	2.3	1.1	-	64	31.4	0.5	95.9
	USA/Florida	6.5	29.2	15.2	2.3	4.4	-	58.1	27.6	3.5	89.2
	Costa Rica	6	30	4.3	6.5	5.9	0.5	53.2	37.7	8	98.9
	Brazil/Passo Fundo	3.4	25.3	8.6	5.2	14.6	1.9	59	30.1	12.4	101.5
Day 30	Brazil/Parana	4.1	18.3	3.9	4	15.8	1.4	47.5	50.6	11.2	109.3
	Thailand	7.9	59	9.7	4.6	-	-	81.2	19.6	2.1	102.9
	The Philippines	1.2	36.8	8.2	1.7	5.8	1.6	55.3	24.7	13.6	93.6
	Japan/Tsurugashimi	2.7	32.9	8.8	2.7	3.8	-	50.9	41.3	2	94.2
	USA/Florida	5.3	21	16.2	1.8	6.2	0.5	51.3	24.3	5.2	80.8
	Costa Rica	4.6	20.9	3.6	6.3	6.8	1	43.2	47.3	12.4	102.9
	Brazil/Passo Fundo	1.7	15.2	3.7	3.9	14.6	3.5	42.6	33.3	24.4	98.3
Day 50	Brazil/Parana	2.7	10.6	2.1	2.9	13.3	2.1	33.7	50.5	19	103.2
	Thailand	3.7	45.6	11.5	4.9	4.6	-	70.3	27.1	4.4	101.8
	The Philippines	0.4	22.5	6.4	0.9	5.6	2.5	38.8	30.8	23.3	92.9
	Japan/Tsurugashimi	2.3	29.3	9.5	2.7	6.7	0.8	51.3	32.8	4.4	88.5
	USA/Florida	3.9	19.3	15.9	2	6.4	0.8	48.5	35.6	7.4	91.5
	Costa Rica	3.7	2.1	4	5.6	6.5	1.2	41.1	38.6	15.5	95.2
	Brazil/Passo Fundo	0.9	11.2	2.3	3.9	11.8	5.2	35.3	35.2	29.4	99.8
Day 70	Brazil/Parana	1.7	6.2	1.4	1.9	11.2	2	24.4	49.3	25.6	99.3
	Thailand	2.8	36.4	12.1	4.3	4.8	-	60.4	28.7	7.2	96.3
	The Philippines	0.1	14.9	4.3	0.7	4	2.5	26.9	35.6	32.3	94.8
	Japan/Tsurugashimi	1.3	23.4	7.5	3	8.3	1.4	44.9	37.4	7.3	89.6
	USA/Florida	2.9	16.4	13.4	2	7.6	1	43.7	36.3	8.6	88.6
	Costa Rica	2.6	17.6	3.9	5	6.2	1.5	36.8	39.3	16.1	92.2
	Brazil/Passo Fundo	0.7	5.8	1	2.4	8.4	5	23.3	46.4	36.5	106.2
Day 90	Brazil/Parana	1.1	4.3	0.9	1.3	8	2.6	18.2	52.3	33.7	104.2
	Thailand	1.9	28	9.7	4.2	6.3	-	50.1	30.7	9.9	90.7
	The Philippines	0.2	11.1	2.8	0.6	1.8	3	19.9	39.7	40	99.6
	Japan/Tsurugashimi	1.2	22	6.6	3.3	8.5	2.1	43.7	44.8	9.9	98.4

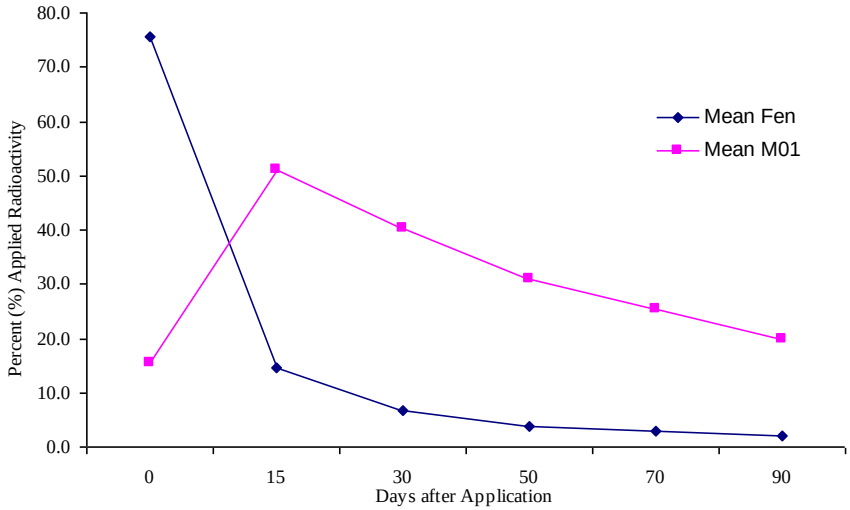


Figure A1.2: Mean levels of decline of Fenamiphos and corresponding formation of MO1 (% AR) from 16 soils at 22°C.

The study authors point out that because more than 50% degradation through oxidation of fenamiphos had occurred prior to the first sampling event at day 15 with evidence that oxidation to M01 had already occurred on day 0, it was justified to take the sum of fenamiphos and M01 as the basis for kinetic considerations and to describe the decline of these two compounds together. Based on decline rates of the combined values of fenamiphos and the M01 metabolite (k_{fox}), half-lives have been calculated using the equations $T_{1/2} = \ln(2)/k_{fox}$. The following results were obtained:

Table A1.10: Half-lives by soil type and temperature

	Half-Life (days)		
	16°C	22°C	28°C
Canada	48.7	27.1	
Sweden	85.3	37.5	
Germany/Puch	29.6	22.5	
Germany/Speyer	50.2	36.2	
Netherlands	39.5	26.5	
France	29.1	11.7	
USA/Indiana	80.8	27.9	
USA/Nebraska	67.7	36.0	
Japan/Toyoda	166.1	86.4	
MEAN	66.3	34.4	
USA/Florida		34.7	24.7
Costa Rica		32.1	23.8
Brazil/Passo Fundo		25.7	18.0
Brazil/Parana		21.0	14.0
Thailand		69.8	52.4
The Philippines		32.9	23.1
Japan/Tsurugashimi		48.3	27.5
MEAN		37.8	26.2

Other metabolite formation

In the soils incubated at 16°C, M01 and M13 were found at levels >10% AR, though not in all soils. M12 approached 10% in one soil on the Day 50 sampling event, but otherwise, was <5% AR. M14 was mainly found later in the experiment and was detected in 7 of the 9 soils at day 90. All levels were <5% AR.

In the soils incubated at 22°C, M01 and M13 were found at levels >10% AR, though not in all soils. M12 was detected consistently through the study, generally at <5% AR, although some samples had levels higher than this at 5-7% AR. This metabolite was found at >10% (up to 11.1%) in one soil at two sampling events. M14 was consistently in most soils from day 30. All levels were <5% AR.

In the soils incubated at 28°C, M01 and M13 were found at levels >10% AR, though not in all soils. M12 was detected consistently through the study at <5% AR, although some samples had levels higher than this at 5-7% AR. M14 was mainly found later in the experiment and was detected in 6 of the 7 soils at day 90. All levels were <5% AR with one exception in 1 soil on day 70.

Mineralisation was evident. In the 22°C soils, CO_2 levels up to 33% were detected. However, rates of CO_2 formation were highly variable and ranged from 1.1-32.9% in soils from moderate climates and 3.5-20.8% in the soils from (sub) tropical climates at the end of the incubation period.

Sterile soils

Significant conversion of the active ingredient to M01 occurred in the sterile controls after 90 days. However, generally this process took place considerably more slowly in the sterile soils than the biologically active soils.

Conclusion:

Fenamiphos seems to in part rapidly degrade abiotically through oxidation to form the M01 metabolite. The parent compound and this metabolite degrade through biological means with rates of degradation generally increasing as temperature increases. At 22°C, the half-life range from 16 different soils was 11.7 to 86.4 days for the combined levels of fenamiphos and the M01 metabolite.

Report: Spiteller, 1989a.
Guidelines: US EPA Guideline 162-1
GLP: Yes

Test System

The biotransformation of fenamiphos was studied in a North American soil under aerobic conditions using ^{14}C-fenamiphos labelled in the phenyl ring. The soil, originating from Howe, Indiana, had the following characteristics:

Table A1.11: Study Soil Characteristics

Texture	% Sand	% Silt	% Clay	OM %	CEC[1]	pH	WHC[2]
Sandy loam	65.5	26.3	8.2	1.29	10.0	6.8	12.4

1) CEC – mEq/100 g dry soil. 2) Water Holding Capacity = mL H_2O/100 g dry soil

At the beginning of the experiments, microbial biomass was 227 mg C_{mic}/kg soil. Based on an application rate of 10 kg ac/ha, the rate used in the study was 1.37 mg fenamiphos/100 g air-dried soil. Both labelled and unlabelled active ingredient were dissolved in acetone and mixed together. Before and immediately after application the test solution was examined for identity and purity.

The soil was air-dried and sieved (2 mm). Each total soil sample (2.8 kg dw) was treated with active constituent and mixed with the active constituent introduced via a 40 g sub-sample of soil. 100 g of the total treated soil was weighed into each incubation vessel and the soil moisture adjusted to 75% of 0.33 bar WHC with distilled water. Test vessels were incubated in the dark at around 20^{o}C with a relative humidity of 80-90%.

The test was run for a total of 365 days. The incubation flasks were closed with a trap attachment for volatiles (including CO_2). Two samples were processed on each sampling day, namely, 0, 1, 3, 7, 14, 31, 63, 100, 123, 184, 274 and 365 days after application.

Soil batches were processed by extracting twice with acetone/methanol (1:1 v/v) and once with chloroform/methanol (1:1 v/v) in an ultrasonic bath. After each treatment the soil was centrifuged and the supernatant decanted through a filter. The combined extracts were examined using TLC and HPLC. The radioactivity remaining after solvent extraction was fractionated into fulvic acids, humic acids and humin. This appears to have been done for samples on days 100 and 365.

Findings:

Active substance did not appear to adversely affect microbial biomass in the soil. Over the course of the study, there was a steady decrease in microbial activity in soils both with and without active substance, and by the end of the study microbial biomass was 74-96 mg C_{mic}/kg soil.

Mass balance

The mass balance was 101.4% AR on day 0, mostly as extractable residues although around 3.4% AR was in the form of bound residues. Over the different sampling days, total recoveries ranged from 101.4% AR to 96.1% AR. The breakdown pattern and products of fenamiphos are shown in more detail below.

Quantitation

Extractable residues are quantified in Table A1.12. Values are the average of the two replicates.

Table A1.12: Recovery of radioactivity (%AR) and distribution of major metabolites after application of [^{14}C]-fenamiphos based on HPLC characterisation.

DAT	Parent	M01	M02	M11	M12	M13	M14	Extracted	CO_2	Bound
0	90.0	7.6	<0.1	<0.1	<0.1	<0.1	<0.1	98.0	nd	3.4
1	75.8	18.1	<0.1	<0.1	<0.1	<0.1	<0.1	94.1	<0.1	4.9
3	53.8	34.4	0.6	<0.1	1.0	<0.1	<0.1	90.1	0.1	9.1
7	28.5	48.1	2.4	<0.1	2.5	2.1	<0.1	84.1	0.4	11.6
14	13.3	51.4	3.5	<0.1	4.6	6.8	<0.1	80.3	1.1	16.2
31	4.0	36.9	2.3	<0.1	5.4	17.5	0.7	66.8	4.2	23.8
63	1.7	17.7	1.2	<0.1	3.0	24.3	1.9	49.8	10.5	38.2
100	1.1	9.3	0.6	<0.1	2.0	21.3	2.7	37.0	16.6	44.3
123	1.0	7.5	0.2	<0.1	1.5	19.7	3.0	32.9	19.2	48.4
184	0.7	4.0	<0.1	<0.1	1.1	13.9	4.3	24.0	23.8	49.4
274	0.5	1.5	<0.1	<0.1	1.0	7.7	4.3	15.0	31.8	51.1
365	0.4	1.0	<0.1	<0.1	1.1	6.6	4.4	13.5	34.2	50.5

Apart from CO_2, no other volatile substance was found at any level of 0.1% AR or higher. The data show that oxidation to M01 was initially the dominant reaction, followed by conversion to M13. No

other metabolite (apart from CO_2) was found in concentrations exceeding 5% AR with the exception of 5.4% AR being attributed to M12 on day 31.

The bound residue fractionation for sampling days 100 and 365 were given. Overall, 53.8% and 60.5% of the bound radioactivity at days 100 and 365 respectively remained in the stable humin and humic acid fraction. Fulvic acid fraction accounted for 40.3% and 34.6% of the bound radioactivity at days 100 and 365 respectively. From the latter, M12 and M13 could be determined by TLC in significant amounts. Neither parent, M02 nor M11 could be detected in the fulvic acid fractions.

Using a first order plot of the sampling intervals from day 0 to 100, a first order rate constant for fenamiphos degradation under the aerobic conditions of this study was 0.044/d with a corresponding half-life of 15.7 days ($r^2 = 0.85$).

In fact, the degradation appeared to be biphasic. DSEWPAC has plotted the results and the first phase half-life (to day 31) has a rate constant of 0.0995/d ($r^2 = 0.96$) with a half-life of around 7 days. The second half-life (calculated from day 63-365 degradation data) had a rate constant of 0.0045 ($r^2 = 0.94$) and a half-life of 154 days.

When the residue values for fenamiphos and M01 are combined, the degradation over the course of the study is largely first order with a rate constant of 0.012 ($r^2 = 0.93$) and a total half-life of 55.9 days.

Conclusion:

Fenamiphos was identified in all samples at all sampling intervals. Primary metabolism results in formation of the oxidation product M01. The half-life of fenamiphos seemed biphasic with a first phase half-life in the order of 7 days and a second phase half-life around 154 days. Mineralisation occurred with up to 34% AR found as CO_2 at the end of the study. Bound residues increased gradually throughout the study, stabilising at around 50% after 184 days.

Report: Kookana *et al*., 1997
Guidelines: Not stated
GLP: No

Test System

The study was performed to examine the transformation and degradation behaviour of fenamiphos, M01 and M02 in a surface and subsurface soil. The laboratory study was conducted on a sandy soil from the Swan Coastal Plain of Western Australia. The surface soil (0-25 cm) and subsurface soil (25-50 cm) had the following characteristics:

Table A1.13: Study Site Soil Characteristics

Layer	% sand	% silt/clay	pH	% OC	Microbial biomass[1]	Moisture content[2]
Surface	99	1	5.3	0.53	196.0	0.051
Subsurface	99	1	5.5	0.02	60.9	0.024

1) mg/kg; 2) cm^3 (mL)/cm^3 at –10 kPa.

A solution of fenamiphos (Nemacur) was added to 1 kg of the freshly collected soil to produce a concentration of 10 mg ac/kg at the moisture level corresponding to –10 kPa metric potential. This concentration was based on the recommended application rate of 24 L/ha (9.6 L ac/ha) for some Western Australian crops. Although the concentration is likely to be lower than this in subsurface soil, the same concentration was tested for comparison purposes. The test substance was mixed into the test soil and incubated in the dark at 25°C. A 50 g sample was removed in duplicate from each

bag at 0, 4, 18, 30, 74 and 139 days for the surface soil and 0, 3, 10, 31, 66 and 131 days for the subsurface soil. Test soils were frequently mixed to ensure uniform conditions.

Soils were extracted with acetonitrile/water (9:1 v/v) and centrifuged. The soils were subjected to a second extraction with the same solvent system and a longer extraction period. Aliquots from the 2 extraction steps were combined and analysed for parent, M01 and M02 using HPLC.

Findings:

Mass balance data are not available. The degradation of fenamiphos and subsequent formation and decline of M01 and M02 are only presented graphically in the report. Reading from these graphs, the following data are estimated:

Table A1.14: Approximate levels of fenamiphos, M01 and M02 over time in surface and subsurface soil (mg/kg)

	Surface soil				Subsurface soil			
Sampling period[1]	Fen	M01	M02	Total	Fen	M01	M02	Total
1	1.4	6.0	0.3	7.5	7.0	2.6	0.1	10.0
2	1.1	5.7	0.2	4.9	7.3	2.5	<0.1	9.9
3	0.5	5.3	0.4	4.2	6.0	3.6	0.1	9.5
4	0.3	4.0	0.4	4.7	5.2	3.9	0.1	9.2
5	0.2	0.4	<0.1	0.7	2.6	5.0	1.0	8.5
6	<0.1	0.1	0.5	1.7	2.6	1.8	0.5	4.6

1) Sampling periods 1-6 correspond to 0, 4, 18, 30, 74 and 139 days after application in the surface soil and 0, 3, 10, 31, 66 and 131 days after application in the subsurface soil

The rate of degradation in the subsurface soil was much slower than found in the surface soil with total residues in the subsurface soil still being about 85% after 66 days, and almost 50% after 131 days. The main differences in soil characteristics were the amount of organic carbon and the microbial biomass. In the surface soil, microbial biomass was some 3 times higher than in the subsurface soil indicating microbial activity may influence the level of oxidation of fenamiphos.

Degradation kinetics and half-life values were determined using the LEACHM model. The model described the observed behaviour of the 3 compounds reasonably well for the surface soil, however, there was considerable deviation between observed and simulated values for the subsurface soil. While first-order degradation was assumed, this may not be valid, particularly for the subsurface soil, given the deviations observed. Rate coefficients fitted to the observed data show that transformation from fenamiphos to M01 (k_1) is up to two orders of magnitude faster than from M01 to M02 (k_2). Further, there was a 25-fold difference in k_1 values between the surface and subsurface soils.

It was not possible to determine half-lives for fenamiphos (taken as total residues of fenamiphos, M01 and M02) because first order kinetics were not followed, particularly in the subsurface soil. However, the time taken for a 50% loss of total residues in the surface soil was about 50 days compared to about 140 days in the subsurface soil.

DSEWPAC has calculated rough half-life estimates using the approximate total residue values provided above, based on the equation $t1/2 = \ln(2)/k$. In the surface soil, half-lives were predicted to range between 23 and 77 days. If the day 139 value is ignored as an outlier, $k = 0.0296$, $r^2 = 0.91$ and the half-life is calculated to be 23 days. If however, the day 74 value is ignored as an outlier, $k = 0.009$, $r^2 = 0.90$ and the half-life is calculated to be 77 days. The dissipation of total residues in

the subsurface soil was well-defined using natural log transformation of the residues. A half-life of 124 days was calculated (k = 0.0056, r^2 = 0.91).

Conclusion:

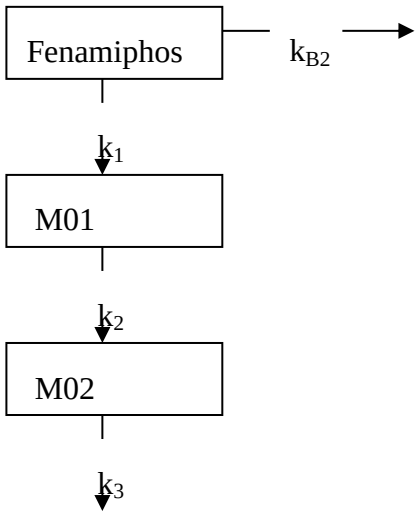
Degradation/transformation behaviour of fenamiphos in subsurface soil can be markedly different to that observed in the surface soil with greater persistence (possibly due to lower microbial activity) in the subsurface soil.

Metabolites

Test Material: M01, M02
Report: Schäfer, 2001a.
Guidelines: Based on recommendations of the FOCUS Groundwater Scenarios Workgroup, EC EU document SANCO/321/2000 rev. 2.
GLP: NA. Modelling report

Test System

Data from Brumhard (2002) described above were considered to quantify the degradation behaviour of the fenamiphos metabolites M01 and M02. The mathematical evaluation of the experimental data was done with the ACSL Optimize Software package. All reaction steps were assumed first order following the pathway:



The DT50 values of both metabolites were obtained using the standard formula DT50 = ln2/k_x where k_x was either k_2 (rate constant for M01) or k_3 (rate constant for M02). The DT50 values were then normalised to 100% field capacity (FC) in accordance with FOCUS recommendations.

Findings:

The following values were obtained:

Table A1.15: Calculated DT50 Values (Days) for M01 and M02

	M01			M02		
Soil	DT50	DT50 (100% FC)	r^2	DT50	DT50 (100% FC)	r^2
Laacher Hof AXXa	30.1	20.3	0.94	51.1	34.4	0.98
Laacher Hof AIII	36.1	22.1	0.96	26.1	15.9	0.93
Höfchen	5.5	3.2	0.99	13.6	7.9	0.80
BBA 2.1	47.8	40.9	0.97	-	-	-

In the BBA 2.1 soil, no half-lives could be calculated for M02 as residues of this metabolite did not peak until day 60 and consequently, the descending part of the observed concentration-time curve only consisted of two data points.

Conclusion:

Based on an analysis of residue data from laboratory aerobic soil degradation studies in four soils at 20^{o}C, half-lives for the two major metabolites, M01 and M02, have been modelled to range between 5.5-47.8 days and 13.6-51.1 days respectively. When calculations were adjusted to 100% field capacity, half-lives were calculated to range from 3.2-40.9 days (M01) and 7.9-34.4 days (M02).

Test Material M12, M13
Report: Simon, 1990.
Guidelines: Partially based on US EPA 162-1
GLP: No

Test System

In addition to the metabolism study in 16 soils described above, to assess the importance of the phenolic hydrolysis metabolites M12 and M13, the German/Puch soil was incubated with these compounds using the test system described above.

The application rate was reduced to 1.3 mg/kg soil corresponding to a maximum amount of a phenolic compound which was formed out of fenamiphos in the above study.

Extraction procedures are described above. In addition, a water extraction at three different pH values (2, 7 and 12) was conducted where 30 g each of the dried soil solids were extracted 3 times with 20 mL water in an ultrasonic bath. The supernatants were centrifuged, measured and extracted with ethylacetate in the acid medium, if necessary, dried and analysed by TLC. Humic substance fractionation was performed using extracted soil samples on sampling dates day 60 and 90 because in these cases, particularly high proportions of unextracted residues had been measured.

Findings:

Based on graphical representation of the findings, M13 was subject to the best mineralisation with around 51% CO2 produced after 90 days. This compared to around 38% CO2 produced after 90 days in the soil incubated with M12. The majority of CO2 found had occurred by day 60 and from then until the end of the incubation period for these metabolites of 180 days, only a small additional amount was produced. The authors suggest this may indicate that the remaining portion of the applied radioactivity was present in the soil in a form that can be mineralised only slowly.

Conclusion:

The phenyl hydrolysis metabolites M12 and M13 can be expected to mineralise in microbially active soils. Actual degradation half-lives for these compounds were not determined.

Test Material: M12, M13
Report: Schäfer, 1994.
Guidelines: NA – Modelling Study
GLP: No – Modelling Study

Test System

The half-life values for the two fenamiphos metabolites M12 and M13, were calculated based on kinetic data obtained from Simon (1990) described above. With the assumption of first order kinetics for each reaction step in the degradation pathway, rate constants were estimated for each step. Briefly, the degradation pathways and associated rate constants were:

Fenamiphos to M01 (k_1); Fenamiphos to bound residues/CO_2 (kB_1);

M01 to M02 (k_2); M01 to M12 (k_3); M01 to bound residues/CO_2 (kB_2);

M02 to M13 (k_4);

M12 to M13 (k_5); M12 to CO_2 (kC_1);

M13 to M14 (k_6); M13 to CO_2 (kC_2).

Considering all reaction steps contributing to the dissipation of each metabolite, the DT50 values for each were determined by the following equations:

$DT50_{M12} = \ln(2)/(k_5+kC_1)$ $DT50_{M13} = \ln(2)/(k_6 + kC_2)$

The criteria used to select results from Simon (1990) for use in the modelling included soil originating in a moderate climate, sufficient number of data points (>3), sufficiently high concentrations of the metabolites under investigation, and measurements at day 0. These criteria lead to the choice of the studies conducted with soils from Canada and France. The results from the Dutch soil were chosen as the third study with the omission of the fourth criterion.

Findings:

Mathematical evaluation of the metabolism data yielded the following results:

Table A1.16 – Calculated half-lives for M12 and M13

	DT50 (days) - M12	DT50 (days) - M13
Canada	10.5	18.5
France	1.6	12.3
Netherlands	12.0	8.6
Average	8.0	13.1

Conclusion:

The calculated values are shorter than the time period over which the metabolites were observed in the metabolism study. This is explained by the fact that the metabolites are built continuously from other metabolites as long as significant amount s of these compounds exist.

Soils – Anaerobic

Report: Spiteller, 1989b.
Guidelines: US EPA Guideline 162-2
GLP: Yes

Test System

The biotransformation of fenamiphos was studied in a North American soil under anaerobic conditions using ^{14}C-fenamiphos labelled in the phenyl ring. Prior to establishing anaerobicity, the soil was kept under aerobic conditions with fenamiphos for around one half-life. The soil, originating from Howe, Indiana, had the following characteristics:

Table A1.17: Study Soil Characteristics

Texture	% Sand	% Silt	% Clay	OM %	CEC[1]	pH	WHC[2]
Sandy loam	65.5	26.3	8.2	1.29	10.0	6.8	12.4

1) CEC – mEq/100 g dry soil. 2) Water Holding Capacity = mL H_2O/100 g dry soil

At the beginning of the experiments, microbial biomass was 291 mg C_{mic}/kg soil. Based on an application rate of 10 kg ac/ha, the rate used in the study was 1.33 mg fenamiphos/100 g air-dried soil. Both labelled and unlabelled active ingredient were dissolved in acetone and mixed together. Before and immediately after application the test solution was examined for identity and purity.

The soil was air-dried and sieved (2 mm). Each total soil sample (1.5 kg dw) was treated with active ingredient and mixed with the active ingredient introduced via a 40 g sub-sample of soil. 100 g of the total treated soil was weighed into each incubation vessel and the soil moisture adjusted to 75% of 0.33 bar WHC with distilled water. Test vessels were incubated in the dark at around 20^{o}C with a relative humidity of 80-90%.

The test was run for a total of 66 days (first 6 days being under aerobic conditions). The incubation flasks were closed with a trap attachment for volatiles (including CO_2). Two samples were processed on day 0 and two more after day 6. The remaining flasks were changed to anaerobic conditions after day 6 by purging with nitrogen. Then each soil sample was flooded with distilled water and two batches were processed each on days 20, 36, 62 and 66.

Aerobic soil batches were processed by extracting twice with acetone/methanol (1:1 v/v) and once with chloroform/methanol (1:1 v/v) in an ultrasonic bath. After each treatment the soil was centrifuged and the supernatant decanted through a filter. The combined extracts were examined using TLC and HPLC.

For the anaerobic soil batches, the surface water was decanted and the wet soil centrifuged. Soil samples were extracted in the same manner as described for aerobic soil batches. In the surface water, $^{14}CO_2$ was determined using LSC. In the supernatant water, total radiocarbon content was determined by LSC, and examined by HPLC.

Findings:

To prove anaerobicity, the redox potential was measured in the supernatant water with redox potential of 20, -25, -10 and -15 mV at days 20, 36, 52 and 66 respectively. These conditions may be regarded as anaerobic, with anaerobic reactions expected to occur below oxidation-reduction values of +50 mV (Tebbutt, 1992).

Mass balance

The mass balance was 99.7% AR on day 0, mostly as extractable residues although around 3% AR was in the form of bound residues. By day 66, around 95.9% AR was recoverable. Around 27% of this was as bound residues, with 50.4% AR in the form of extractable residues and 17.4% AR in the supernatant water phase. The breakdown products of fenamiphos are shown in more detail below.

Quantitation

Extractable residues are quantified in Table A1.18. Values are the average of the two replicates.

Table A1.18: Recovery of radioactivity (%AR) and distribution of major metabolites after application of [^{14}C]-fenamiphos based on HPLC characterisation.

DAT	Parent	M01	M02	M11	M12	M13	Extracted	Bound
Extracted soil								
0	93.3	3.5	<0.1	<0.1	<0.1	<0.1	96.9	2.8
6 (0)*	36.3	46.5	<0.1	<0.1	2.5	<0.1	85.8	13.3
20 (14)*	26.0	20.5	0.5	0.4	3.1	2.1	52.9	14.3
36 (30)*	25.4	20.4	<0.1	<0.1	3.2	4.6	53.9	18.3
52 (46)*	22.9	15.4	0.5	4.2	2.1	6.8	52.1	24.5
66 (60)*	21.8	14.3	0.5	3.2	1.6	8.7	50.4	27.0
Supernatant water phase								
20 (14)*	2.6	24.4	0.6	<0.1	2.7	1.4	31.7	-
36 (30)*	1.7	19.3	0.5	<0.1	2.6	2.5	26.6	-
52 (46)*	1.0	13.4	0.3	<0.1	1.1	3.3	19.1	-
66 (60)*	0.4	11.5	0.4	<0.1	1.0	4.1	17.4	-

( )* = days after establishing anaerobic conditions

The only volatile substance detected at levels of 0.1% AR or more was CO_2. This accounted for up to 0.3% AR in the volatile traps and up to 0.8% AR (day 66) in the surface water.

During the course of ageing fenamiphos under aerobic conditions for 6 days, the parent compound was rapidly transformed, mainly to M01. This was the only metabolite in the anaerobic phase of the experiment that accounted for >10% AR in either water or soil. M13 was found at >10% based on combined levels in water and soil, and at the end of the experiment, was found at 12.8% AR (8.7% AR in soil extracts and 4.1% AR in supernatant water).

Once anaerobic conditions were established, degradation of the parent compound slowed considerably with the majority of this remaining in the soil and <3% AR in the supernatant water.

Unknown degradation products did not account for more than 1% AR at any time.

The half-life of fenamiphos was calculated following the formula t1/2 = ln(2)/k and was determined to be 87.9 days with a rate constant of 0.0079/d and r^2 = 0.92. Half-life data were based on combined fenamiphos residues in soil and supernatant water. DSEWPAC has re-plotted the data and derive slightly different, but comparable, results with an estimated half-life of 91.2 days (r^2 = 0.93 and rate constant of 0.0076/d).

The authors do not calculate a half-life for the main metabolite M01. Combined levels of this substance peaked at day 6 (day 0 for anaerobic conditions) then degraded following first order kinetics. Using the combined soil/supernatant water data, the half-life has been estimated by DSEWPAC to be around 64.8 days (r^2 = 0.93, rate constant = 0.0107/d).

Conclusion

Degradation of fenamiphos in the aerobic/anaerobic study described here resulted primarily from oxidation to M01, and by hydrolysis of the phosphorous group. The half-life of fenamiphos in the test system was in the order of 90 days following establishment of anaerobic conditions with a half-life of the main metabolite, M01, being around 65 days.

Metabolites

Test Material: **M01**
Report: Schäfer, 2001b
Guidelines: NA – modelling study
GLP: NA

Test System

Using the results of Spiteller (1989b) above for degradation of fenamiphos in an anaerobic soil, a DT50 value for M01 under anaerobic conditions was modelled using ACSL Optimize Software package. Modelling assumed that fenamiphos transformed to M01 with rate constant $k_{1,}$ then degradation of M01 was characterised with rate constant k_2. First-order kinetics for both reaction steps were assumed. Calculated concentrations were fitted to experimental data by adjusting the parameters k_1 and k_2. Only the data measured under anaerobic conditions were taken into account.

Findings:

Predicted concentrations differed significantly from experimental results based on absolute concentrations in terms of %AR. Based on the predicted values, the r^2 of the fit to fenamiphos sulfoxide was 0.96. Utilising the equation $t1/2 = \ln(2)/k_2$, the half-life for M01 was calculated to be 19.9 days.

Conclusion:

Modelling predicts a half-life of M01 in anaerobic soils to be in the order of 19.9 days. DSEWPAC is uncertain as to the relevance of this approach. M01 was found in significant quantities in the supernatant water of the experiment used for the data in this modelling exercise. This supernatant water was also anaerobic, and the concentrations of M01 in the water were around an order of magnitude higher than those of fenamiphos found in the water indicating that they were being generated from oxidation of fenamiphos found in the soil compartment, and migrating to the water. Disregarding these concentrations is likely to effect the calculation of rate constants (particularly k_1).

The degradation half-life of M01 using the combined soil and supernatant water concentrations is well characterised using the measured data and described in Spiteller (1989b) above where a half-life for M01 was calculated by DSEWPAC to be around 65 days for the whole anaerobic system.

Water – Aerobic

Report: Stupp, 2002b
Guidelines: EC Directive 91/414/EEC Annex I Part 7; Annex II part 9 and SETAC Procedures for Assessing the Environmental Fate and Ecotoxicity of Pesticides.
GLP: yes

Test System

The aerobic aquatic metabolism of ring-labelled ^{14}C-fenamiphos was studied at a concentration of 1 ppm in two non-sterilised sediment/water systems. The sediment characteristics were as follows:

Table A1.19: Chemical and physical properties of sediment.

Parameters	Angler Weiher	Hoenniger Weiher
Textural Class	Sand	Loam
Sand [%]	93.3	42.9
Silt [%]	1.3	40.2
Clay [%]	5.4	16.9
pH	6.7	6.0
Water content (%)	29.7	56.1
Organic Carbon (%)	1.04	4.41
Cation Exchange Capacity [meqBa/100 g dry sediment]	5	11
Redox Potential (mV)	-166 to -74	-150 to -134
Microbial activity (mg CO_2/hr kg sediment):		
Day 0 - without as	8	40
Day 100 – without/with as	4 / 6	16 / 20

Sediment characteristics were determined in sub-samples of freshly sampled test sediment. The redox potential of the sediment was determined at the end of the pre-equilibration period of the test systems and shows the sediments were anaerobic. The water for both systems was aerobic with redox potentials determined at the end of the pre-equilibration period ranging from 132-194 mV. The Angler Weiher (AW) water had a pH of 8.2, dissolved oxygen of 77-82% saturation and hardness (grad DH[1]) of 9.6. The Honniger Weiher (HW) water had pH of 7.2, dissolved oxygen of 73-84% saturation and hardness (grad DH) of 3.3.

Untreated sediment/water mixture (consisting of 164.8 g (AW) and 82.8 g (HW) dry weight sediment and 390 mL water) was pre-incubated under aerobic aquatic conditions in darkness at 20^{o}C for an equilibration period. The actual water depth in the test vessels was not reported. However, based on the test vessels having an inner diameter of 10.5 cm, and an application of 390 mL water, the water depth would be around 4.5 cm. Following the activation period, ^{14}C-fenamiphos in acetonitrile was added to the sediment/water mixture as small droplets pipetted in the supernatant water. The test vessels were closed with a solid trap attachment for collecting volatile radioactivity. The test system was then aerobically incubated in darkness at around 20^{o}C for 100 days. The application rate of 1 ppm (that is, around 390 µg ac in 390 mL water per test flask) to the overlying water was chosen to simulate direct overspray at a field rate of 10 kg/ha to a 1 m deep-water body. No evaporation procedures were used to flush volatile compounds.

Samples of the test system were taken after treatment (2 h) and at 2, 8, 20, 58 and 100 days after treatment. Supernatant was decanted then centrifuged. Aliquots of the aqueous layer were taken for LSC and determination of $^{14}CO_2$. The sediment was extracted twice with acetonitrile/water (80:20 v/v) and additionally with acetonitrile. The radioactivity of the combined extracts was determined

1. [1] DH = degrees hardness. One German degree hardness (dH) is 10 mg of calcium oxide (CaO)/L

and HPLC analyses performed to characterise metabolites. An additional hot extraction was performed with the day 8 and 100 samples.

Findings

During the study, total recovery in the AW system ranged from 92.3-100.8% AR while in the HW system, it ranged from 97.3-104.1% AR (mean of duplicates). The following tables provide information on the partitioning and breakdown pattern of fenamiphos in the two systems.

Table A1.20: Proportion of radioactive components (% AR) in water and sediment – AW system.

DAT	Fen	M01	M02	M12	Bound	TOTAL
Water						
0	94.1	2.0	nd	nd	-	96.2
2	60.9	10.7	nd	nd	-	71.6
8	22.2	5.4	7.5	4.7	-	39.9
20	1.8	9.2	0.6	10.8	-	23.0
58	nd	5.4	1.3	2.4	-	11.6
100	0.5	7.4	2.2	2.0	-	14.9
Sediment						
0	3.9	0.4	nd	nd	0.3	4.6
2	22.9	1.2	nd	nd	2.2	26.4
8	31.2	2.4	2.2	nd	17.8	54.5
20	17.7	5.4	0.6	nd	41.8	68.9
58	15.9	3.5	0.5	nd	48.8	69.5
100	18.8	4.3	1.7	nd	40.9	66.2

CO_2 levels in the AW water phase were <2% AR. However, CO_2 gas was found in steadily increasing levels and accounted for 13.6% AR at the end of the study.

M01 was the predominant metabolite in both systems. Levels in water and sediment were comparable. The maximum level of this metabolite was found in the HW system at 100 days, accounting for around 30% AR in water and sediment combined. M02 was never found at more than 5% in either water or sediment with the exception of 7.5% AR in water in the AW system at day 8. The only other metabolite found at more than 10% AR was M14, found at 10.8% AR in the AW water layer at day 20.

Mineralisation was much higher in the AW system with around 14% AR attributed to $^{14}CO_2$ at the end of the test compared with 2.4% AR in the HW system.

Table A1.21: Proportion of radioactive components (% AR) in water and sediment – HW system.

DAT	Fen	M01	M02	M12	Bound	TOTAL
Water						
0	90.5	2.4	nd	nd	-	92.8
2	56.8	6.0	nd	nd	-	62.8
8	42.4	2.7	nd	nd	-	45.1
20	17.0	9.7	0.2	nd	-	26.9
58	6.9	10.5	1.0	nd	-	18.4
100	2.0	13.7	2.8	0.1	-	19.5
Sediment						
0	5.2	0.3	nd	nd	0.4	6.0
2	33.7	1.3	nd	nd	3.1	38.1
8	45.8	5.2	0.2	nd	5.2	56.8
20	59.2	6.0	nd	nd	4.5	70.1
58	62.2	7.8	0.6	nd	8.6	79.3
100	45.7	16.8	2.3	nd	17.4	82.2

CO_2 levels in the HW water phase were <1% AR. CO_2 gas production was low and accounted for 2.4% AR at the end of the study.

Fenamiphos disappeared from the water layer of both systems by adsorption to the sediment and through degradation. Despite lower microbial activity in the AW system, degradation of fenamiphos and its metabolites was faster in this system. The DT50 (first order kinetics) was 3.6 days in water and 9.3 days in the entire system. Nonetheless, in the sediment, fenamiphos proved somewhat more persistent. The peak concentration in sediment was 32.8% AR at 8 days and remained at almost 20% AR after 100 days.

In the HW system, the DT50 (first order kinetics) was 7.9 days in water and 111 days in the whole system. Again, fenamiphos was persistent in the sediment peaking at 62.2% AR at day 58 and still found at 45.7% AR after 100 days.

Conclusion:

In two water/sediment systems, fenamiphos moved from the water to sediment (combined with some degradation) with a half-life in water of 3.6-7.9 days. However, it appeared to persist in the sediment with appreciable amounts approaching 46% AR in one system at the end of the study. Transformation to M01 was still the predominant degradation pathway, but this was much less significant than observed in aerobic soil studies.

Water – Anaerobic

No data were available for this end-point.

Mobility

Volatilisation from Soil

Report: Detra, 1988
Guidelines: EPA 163:2
GLP: yes

Test System

The volatility of ^{14}C-labeled fenamiphos from the surface of a sandy loam was tested. The soil had particle size distribution of 56, 40 and 14% sand, silt and clay respectively, pH 6.6, CEC of 10 meq/100 g and 1.1% organic matter. Two experiments were conducted, the first to determine the profile of volatilisation and the second to provide some indication of the identity of volatilised products. The efficiency of the volatility trapping system was verified with a determination of the mass balance.

Soil was sieved (2 mm) then amended to be 75% of 0.33 bar moisture content. The test substance in aqueous solution was sprayed onto the surface of the soil (100 cm^2) at a rate of 13.5 kg ac/ha. A constant air stream of 100 mL/min was maintained in the test system and the volatilised material was absorbed on Chromosorb at 0, 0.5, 1, 1.5, 2, 3, 6, 24, 48, 96 and 168 h after application. The volatility apparatus was maintained at a temperature of 22-23^oC. For the second part of the test, the air stream was 300 mL/min and sampling occurred after 4 hours.

Radioactivity from the Chromosorb samples was determined by LSC. Soil samples were air-dried and extracted twice with acetone/methanol (1:1 v/v). The extracts were combined and radioactivity determined by LSC. Bound radioactivity was determined by combustion analysis and LSC. HPLC and GC methods were used for characterising the volatilised material.

Findings:

There was no significant volatility from the soil surface with accumulated radioactivity over the entire 7 days of testing for two replicates being <0.1% AR. The material balance of the soil was 98.9% AR indicating no significant loss of radioactivity due to poor retention of volatile organics in the traps.

HPLC analysis of the trap in the second study suggested the volatilised material was both phenol sulfoxide (M12) and phenol sulfone (M13).

Conclusion:

This study indicates a low propensity for fenamiphos to volatilise from bare soil following application.

Adsorption/Desorption

Report: Simon, 1990
Guidelines: Not stated
GLP: yes

Test System

As part of the Simon (1990) aerobic soil degradation study discussed above, adsorption isotherms according to Freundlich were calculated for fenamiphos in order to clarify to what extent sorptive mechanisms are involved in the formation of unextractable residues. The 16 soils used and their properties have been described previously (Table A1.4).

Findings:

The sorption data according to the Freundlich equation for fenamiphos are shown in the following table. The correlation coefficients indicate that the adsorption isotherms according to this method could be very well described, with all r^2 values >0.99. In the following table, k_d is the adsorption coefficient (the higher the value, the greater the sorption of the test substance), and 1/n is the measure for relative decline or increase of the amount of adsorbed test substance. The final k_{oc} value is calculated with the formula $k_{oc} = k_d$ X 100/%OC.

Table A1.22: Sorption data for the 16 test soils for fenamiphos.

Soil origin	Textural class	k_d	1/n	OC (%)	k_{oc}
Canada	Loam	19.4	0.9	6.52	297.9
Sweden	Loamy sand	3.4	0.9	1.23	279.7
Germany/Puch	Silty loam	1.3	1.1	1.21	111.6
Germany/Speyer	Loamy sand	4.0	1.1	2.22	178.4
The Netherlands	Silty loam	5.8	0.9	1.60	380.0
France	Clay loam	2.5	0.9	1.58	159.5
USA/Indiana	Sandy loam	2.2	0.8	0.95	234.7
USA/Nebraska	Silty clay loam	4.7	0.9	1.51	312.6
Japan/Toyoda	Loam	2.7	1.0	3.53	76.2
USA/Florida	Sand	1.7	0.8	0.77	226.0
Costa Rica	Clay loam	17.3	0.8	4.76	363.4
Brazil/P. Fundo	Clay	2.3	0.9	1.63	140.5
Brazil/Parana	Clay	6.0	0.8	2.28	264.1
Thailand	Silty clay	23.3	0.9	1.63	1431.9
The Philippines	Loam	2.5	0.9	0.73	339.7
Japan/Tsurug.	Loam	7.4	0.9	3.58	205.9

It is not clear in the report whether these results are for the combined fenamiphos/M01 residues, although this appears to be the case given the fast transformation of fenamiphos to M01 and therefore, the relatively quick removal of the parent compound from the test system.

The soil from Thailand with a high clay and silt content showed the highest sorption capacity. High k_d values were obtained for the soils from Canada and Costa Rica and these two soils had the highest humus content.

Conclusion:

Interpreting these results using the adsorption Koc, and based on the McCall Mobility Class scale (McCall *et al*, 1980), the chemical can be classed as having high mobility (k_{oc} of 50-150) in the Germany/Puch, Japan/Toyoda and Brasil/P. Fundo soils to low mobility (k_{oc} 500-2000) in the Thailand soil. Fenamiphos in all other soils is classed as having medium mobility (k_{oc} of 150-500).

Report: Hein, 2000a;
Guidelines: US EPA 161-1
GLP: yes

Test System

The adsorption and desorption characteristics of ^{14}C-fenamiphos, radiolabelled in the phenyl ring, was investigated using a batch equilibrium procedure on four representative soils from the USA with the following characteristics:

Table A1.23: Study Soil characteristics

Texture[1]	Origin	% Sand	% Silt	% Clay	% OC	CEC (meq/100 g)	pH
Silty sand	Sanger, CA	0.1	14.8	85.1	0.57	5	6.62
Sand	Groves Highlands County, FL	<0.1	1.6	98.4	0.53	5	6.99
Silty sand	Fresno, CA	2.2	41.2	56.6	0.15	8	7.16
Silty sand	Byromville, GA	3.7	12.6	83.7	0.63	5	6.22

Characterisation according to DIN19682

The field capacity of the soils was not reported. The tests were carried out with top soil (0-15 cm). Preliminary tests were conducted in order to determine the equilibration time, the soil/solution ratio and the stability of the test substances in the systems.

For the adsorption/desorption experiment, samples were prepared at four nominal concentrations of 0.01, 0.05, 0.50 and 5.00 ppm in aqueous 0.01M calcium chloride for each soil. The samples were equilibrated for 1 hour with shaking following centrifugation and the supernatant then decanted. The resulting supernatant was analysed by LSC to determine the disappearance of radioactivity from solution as a measure of test material adsorption to soil. An aliquot was taken from HPLC analysis from the 5.00 ppm concentration specimens. The supernatant was then removed from each sample and replaced with an equal volume of untreated 0.01M $CaCl_2$. The samples were equilibrated for a further 1 h followed by centrifugation. The supernatant was analysed by LSC to determine desorption. The radioactivity remaining in the soil after desorption was determined by oxidation followed by LSC analysis.

Findings

Mass Balance

The material balance results for the definitive study for all four soils ranged from 99.9 – 109.9%.

Transformation of Parent Compound

Chromatographic analysis of the centrifuged supernatants of the soils after establishment of equilibrium showed that between 90.7 – 93.6% AR was unchanged parent compound. Following desorption, the chromatographic analysis of the centrifuged supernatants showed between 94.0 – 96.2% AR was unchanged parent compound.

Results

Regression analysis of the solution and soil log concentration at all treatment levels was linear in all soil types indicating that adsorption to soil followed the Freundlich equation. Correlation coefficients for adsorption were above 0.99 for all soils.

Table A1.24: Freundlich Adsorption and Desorption Coefficients for Fenamiphos

	Adsorption			Desorption		
Soil	% ads	K_d	K_{oc}	% des	K_d	K_{oc}
Sanger	51.6	1.37	240.9	37.4	1.64	287.1
T&G Groves	42.8	1.10	207.2	43.6	1.33	251.1
Fresno	32.3	0.70	468.9	55.6	0.84	562.8
Bromyville	38.5	0.93	147.9	42.7	1.41	223.6

Conclusion:

Based on mobility classification using the McCall scale, fenamiphos had medium mobility in all soils, although the Bromyville soil was borderline high mobility.

As noted by the authors, although the adsorption and desorption constants obtained in this study are scientifically valid, they should be considered with caution due to a lack of stability of the test compound and the constraints in attaining complete equilibrium during the experiment.

Metabolites

Test Material: M01, M02
Report: Hein, 2000b; Hein, 2000c
Guidelines: US EPA 161-1
GLP: yes

Test System

The adsorption and desorption characteristics of ^{14}C-M01 and ^{14}C-M02, radiolabelled in the phenyl ring, was investigated using a batch equilibrium procedure.

The soils used and test system have previously been described in Hein (2000a) above. However, the following differences are noted:

For M01, the samples were prepared at four nominal concentrations of 0.01, 0.10, 0.50 and 5.00 ppm. The equilibration period for the adsorption phase was 1 h while the equilibration period for the desorption phase was 24 h.

For M02, the samples were prepared at four nominal concentrations of 0.0105, 0.0526, 0.553 and 5.22 ppm. The equilibration period for the adsorption and desorption phases phase was 24 h.

Findings

Mass Balance

The material balance results for the definitive study for all four soils ranged from 97.2 – 103.9% for M01.

Transformation of Parent Compound

Chromatographic analysis of the centrifuged supernatants of the soils after establishment of equilibrium showed that more than 98% of AR was unchanged test substance for both metabolites.

Results

Regression analysis of the solution and soil log concentration at all treatment levels was linear in all soil types indicating that adsorption to soil followed the Freundlich equation. Correlation coefficients for adsorption were above 0.99 for all soils for both metabolites.

Table A1.25: Freundlich Adsorption and Desorption Coefficients for M01

	Adsorption			Desorption		
Soil	% ads	K_d	K_{oc}	% des	K_d	K_{oc}
Sanger	14.9	0.29	50.9	68.4	0.52	90.8
T&G Groves	18.0	0.34	65.0	53.8	0.70	132.4
Fresno	21.1	0.45	299.7	65.8	0.61	404.2
Bromyville	12.7	0.23	37.1	49.4	0.61	96.3

Table A1.26: Freundlich Adsorption and Desorption Coefficients for M02

	Adsorption			Desorption		
Soil	% ads	K_d	K_{oc}	% des	K_d	K_{oc}
Sanger	24.9	0.48	83.4	55.5	0.62	108.1
T&G Groves	24.8	0.50	93.4	47.1	0.91	172.1
Fresno	27.0	0.60	397.5	61.4	0.67	446.2
Bromyville	19.3	0.33	52.4	47.7	0.62	98.9

Conclusion:

With the exception of the Fresno soil, M01 had high to very high mobility while M02 demonstrated high mobility using the McCall classification scale. In the Fresno soil, both metabolites had medium mobility.

Test Material: M01, M02
Report: Fent, 1995a; 1995b
Guidelines: US-EPA Subdivision N; 163-1
GLP: yes

The adsorption and desorption characteristics of ^{14}C-M01 and ^{14}C-M02, radiolabelled in the phenyl ring, was investigated using a batch equilibrium procedure on two representative soils from Europe with the following characteristics:

Table A1.27: Study Soil characteristics

Texture	Origin	% Sand	% Silt	% Clay	% OC	CEC (meq/100 g)	pH
Silt loam	Netherlands	22.7	58.0	19.3	1.60	Not given	6.6
Clay loam	France	32.0	39.9	28.1	1.58	Not given	8.0

For further characteristics of these soils, refer to Simon (1990) in the aerobic soil degradation section above.

The tests were carried out with top soil (0-30 cm). Preliminary tests were conducted in order to determine the equilibration time, the soil/solution ratio and the stability of the test substances in the systems.

For the adsorption/desorption experiment, samples for both compounds were prepared at four nominal concentrations of 0.04, 0.20, 1.01 and 5.09 ppm in aqueous calcium chloride for each soil. The samples were equilibrated for 24 hours with shaking following centrifugation and the supernatant then decanted. The resulting supernatant was analysed by LSC to determine the disappearance of radioactivity from solution as a measure of test material adsorption to soil. The supernatant was then removed from each sample and replaced with an equal volume of untreated 0.01M $CaCl_2$. The samples were equilibrated for a further 24 h followed by centrifugation. The supernatant was analysed by LSC to determine desorption. The radioactivity remaining in the soil after desorption was determined by oxidation followed by LSC analysis and characterisation was performed using TLC.

Findings

Mass Balance

For M01, the material balance results for the definitive study for both soils ranged from 89.4-94.7% in the Netherlands soil and 95.6-100.3% in the French soil.

For M02, the material balance results for the definitive study for both soils ranged from 92.0-98.2% in the Netherlands soil and 95.1-96.4% in the French soil.

Transformation of Parent Compound

For M01, chromatographic analysis of the centrifuged supernatants of the soils after establishment of equilibrium showed that almost the entire measured radioactivity (at least 96%) could be assigned to the unchanged M01.

For M02, chromatographic analysis of the centrifuged supernatants of the soils after establishment of equilibrium showed >99% in the Netherlands soils and 88% in the French soil was unchanged M02.

Results

Regression analysis of the solution and soil log concentration at all treatment levels was linear in all soil types indicating that adsorption to soil followed the Freundlich equation. Correlation coefficients for adsorption were above 0.99 for both soils.

Table A1.28: Freundlich Adsorption and Desorption Coefficients for M01

	Adsorption			Desorption		
Soil	% ads	K_d	K_{oc}	% des	K_d	K_{oc}
Netherlands	69.5	3.60	225.2	40.0	3.10	194.1
France	32.2	0.71	44.8	55.8	1.12	71.2

Table A1.29: Freundlich Adsorption and Desorption Coefficients for M02

	Adsorption			Desorption		
Soil	% ads	K_d	K_{oc}	% des	K_d	K_{oc}
Netherlands	76.4	5.0	311.4	29.5	1.0	66.2
France	41.8	4.6	286.4	49.6	1.6	104.2

Conclusion:

Based on the McCall classification scale, M01 was highly mobile in the French soil and had medium mobility in the Netherlands soil. M02 was classed as having medium mobility in both soils.

Test Material: M12 and M13
Report: Simon, 1990
Guidelines: Not stated
GLP: yes

Test System

As part of the Simon (1990) aerobic soil degradation study discussed above, adsorption isotherms according to Freundlich were calculated for M13 as this metabolite was shown to play a particular role in degradation of fenamiphos, and because a relation could exist between the formation of unextractable residues and the occurrence of this metabolite. For comparison purposes, M12 was also included in this part of the study. The 16 soils used and their properties have been described previously.

Findings:

The sorption data according to the Freundlich equation for M13 and M12 are shown in the following tables.

Table A1.30: Sorption data for the 16 test soils for M13.

Soil origin	Textural class	k_d	1/n	OC (%)	k_{oc}
Canada	Loam	8.7	0.8	6.52	133.1
Sweden	Loamy sand	0.6	0.9	1.23	49.4
Germany/Puch	Silty loam	0.6	0.9	1.21	47.2
Germany/Speyer	Loamy sand	1.3	0.9	2.22	57.7
The Netherlands	Silty loam	1.1	0.9	1.60	66.1
France	Clay loam	0.6	0.9	1.58	40.4
USA/Indiana	Sandy loam	1.0	0.8	0.95	103.4
USA/Nebraska	Silty clay loam	2.3	0.8	1.51	152.9
Japan/Toyoda	Loam	1.1	0.9	3.53	31.0
USA/Florida	Sand	1.1	0.8	0.77	146.8
Costa Rica	Clay loam	9.8	0.8	4.76	206.6
Brazil/P. Fundo	Clay	1.1	0.8	1.63	68.0
Brazil/Parana	Clay	3.7	0.8	2.28	162.4
Thailand	Silty clay	3.2	0.8	1.63	198.5
The Philippines	Loam	0.4	0.9	0.73	52.0
Japan/Tsurug.	Loam	4.4	0.8	3.58	121.5

Table A1.31: Sorption data for the 16 test soils for M12.

Soil origin	Textural class	k_d	1/n	OC (%)	k_{oc}
Canada	Loam	7.0	0.9	6.52	82.6
Sweden	Loamy sand	0.2	0.8	1.23	12.5
Germany/Puch	Silty loam	0.3	0.9	1.21	28.8
Germany/Speyer	Loamy sand	1.0	0.9	2.22	44.5
The Netherlands	Silty loam	0.7	0.9	1.60	41.3
France	Clay loam	0.4	0.9	1.58	25.7
USA/Indiana	Sandy loam	0.8	0.9	0.95	86.4
USA/Nebraska	Silty clay loam	1.8	0.8	1.51	118.3
Japan/Toyoda	Loam	1.0	0.9	3.53	27.2
USA/Florida	Sand	1.0	0.8	0.77	132.1
Costa Rica	Clay loam	7.9	0.8	4.76	165.6
Brazil/P. Fundo	Clay	0.1	0.9	1.63	56.3
Brazil/Parana	Clay	2.8	0.8	2.28	121.7
Thailand	Silty clay	1.7	0.9	1.63	102.4
The Philippines	Loam	0.3	0.9	0.73	44.7
Japan/Tsurug.	Loam	3.9	0.6	3.58	108.8

Conclusion:

Interpreting these results using the adsorption Koc, and based on the McCall Mobility Class scale (McCall *et al*, 1980), the chemicals can be classed as having high to very high mobility in all soils except that from Costa Rica for M13 where it may be considered to have medium mobility.

Leaching Potential

Column Leaching Studies

Soil metabolism data indicated fenamiphos dissipates relatively quickly with formation of the oxidation metabolite M01. Both fenamiphos and M01 are expected to be relatively mobile in soils based on batch equilibrium adsorption/desorption studies. No separate non-aged residue column leaching data were provided. Some data are available on non-aged residue leaching within the aged column leaching study described by Spiteller (1987) below.

Aged Column Leaching Studies

Report: Spiteller, 1987
Guidelines: BBA guideline 4-2 (December 1986)
GLP: No.

Test System

Leaching characteristics of aged residues of ^{14}C-labelled fenamiphos were determined in two soils. The characteristics of the soil were as follows:

Table A1.32: Study Soil Characteristics

Texture	Source	Particle size (≤0.02 mm)	OC	pH	Microbial biomass (mg C/100 g soil)	MWHC (%)
Sand	Speyer (BBA 2.1)	10.7 %	0.69	7.00	131	18.2
Silt loam	Hoefchen	34.7%	2.17	6.05	1283	36.7

g H_2O/100 g dry soil.

The standard 2.1 soil was stored in a greenhouse and had been used for plant cultivation while the Hofchen soil had been freshly obtained from the land a few days prior to starting the experiment. For the experiment, air dried soil was sieved (1 mm). Each total soil sample (1.2 kg dw) was treated with active ingredient (introduced via a sub-sample of ground up soil where the active ingredient was applied dissolved in ethyl acetate). The treated bulk soil was mixed thoroughly. 100 g of treated soil was weighed into each incubation vessel and adjusted to 40% maximum water holding capacity. The application rate was based on 10 kg ac/ha and resulted in around 2 mg ac/column (column diameter 5 cm).

Twelve incubation samples were prepared for each soil with six used for leaching experiments and six for investigating the degradation and metabolite formation of fenamiphos in the soil matrix. On two samples, a leaching experiment was carried out without ageing (on day 0). The remaining eight samples for each soil type were fitted with traps for collecting volatiles. Incubation occurred in the dark at around 21^oC and relative humidity of 80-90%.

To investigate residual radioactivity, soil samples were extracted firstly with acetone/water (10:1 v/v) and twice with $CHCl_3$/methanol (1:1) in an ultrasonic bath. Each step was followed by centrifugation and the organic extracts were combined and analysed using TLC. The unextracted residues were analysed by combustion.

In the leaching experiment, two columns for each soil type were prepared at each stage of the ageing process (filling height after compaction around 26 cm). It appears incubation periods (ageing) prior to leaching were 0, 15 and 63 days. The soil columns were saturated with distilled water and the samples incubated with active ingredient were then added to the top. The columns were watered evenly over a period of 48 h with 393 mL water and the leachate collected in two fractions of around 200 mL each. Once the columns had drained, they were sectioned into 3 segments of equal (10 cm) lengths and examined for radioactivity. Leachate fractions appearing cloudy were centrifuged and the residue then oxidised by combustion to determine radioactivity. If leachate fractions contained >1% radioactivity, they were extracted and analysed by TLC.

Findings:

Mass Balance

Recovery of radioactivity in the standard BBA 2.1 soil was 94.6, 100.9 and 101.8% AR after incubation of 0, 15 and 63 days respectively. The majority of this was extractable residues and at day 63, CO_2 accounted for 4.2% AR and bound residues accounted for 11.2% AR.

In the Hoefchen soil, recovery of radioactivity was 98.2% after 0 and 15 days incubation and 101.4% after 63 days. Production of CO_2 was much higher in this soil accounting for 15.9% AR after 63 days incubation while bound residues were also higher accounting for 20.6% AR after 63 days incubation.

Transformation of Parent

It is unclear whether TLC analysis was performed on the top soil segment only. Metabolism was in accordance with that shown in aerobic soil degradation studies above with oxidation to M01 then further hydrolysis to M02, and after 63 days incubation, 5% AR or less was attributable to parent compound. Both M01 and M02 were found at levels >10% through the experiment. The only other metabolite produced in significant levels was M13, found at 7.8% and 16.8% AR in the Hoefchen soil after 15 and 63 days incubation, and in the BBA 2.1 soil at 6.7% AR after 63 days incubation.

Results

The following distribution of radioactivity in the columns and leachate was found:

Table A1.33: Distribution of radioactivity of aged residues of ^{14}C-Fenamiphos (% AR).

	Incubation period (days) – BBA 2.1 soil			Incubation period (days) – Hoefchen soil		
Segment	0	15	63	0	15	63
0-10 cm	58.8	25.2	25.4	81.8	30.6	39.1
10-20 cm	28.9	8.6	6.8	22.4	59.0	42.0
20-30 cm	10.2	15.3	14.2	0.4	8.8	0.8
Leachate1	3.4	56.8	52.9	0.2	0.7	0.9

1) Combined amounts from two separate leachate fractions.

The leachate from the BBA 2.1 soil was characterised and showed that radioactivity was mainly present as M01.

The results indicate that microbial activity and organic carbon will influence the behaviour of the chemicals with much greater mineralisation occurring in the Hoefchen soil (almost 10 times higher microbial biomass than the BBA 2.1 soil), and very high leaching in the BBA 2.1 soil with up to 57% radioactivity found in the leachate after 2 days of artificial rainfall (organic carbon content of this soil was 3 times lower than the Hoefchen soil).

Conclusion:

The results of this test suggest that fenamiphos does have leaching potential where soils have characteristics supporting leaching. With unaged residues, around 80% of radioactivity in the soil column was attributable to parent compound but only 3.4% AR was found in leachate of the most susceptible soil. After 15 and 63 days ageing, M01 and M02 accounted for the majority of radioactivity. M01 in particular appeared the most mobile metabolite. In the most susceptible soil, in the order of 57% AR was found in the leachate after 15 days ageing, and 53% AR in the leachate after 63 days ageing. The majority of this (up to around 85%) was found to be M01.

Report: Mulford, 1987b
Guidelines: EPA Guideline 161 Leaching and Adsorption/Desorption Studies
GLP: Yes.

Test System

Leaching characteristics of aged residues of ^{14}C-labelled fenamiphos were determined in three soils from the USA. The characteristics of the soil were as follows:

Table A1.34: Study Soil Characteristics

Texture	Source	% Sand	% Silt	% Clay	% OM	pH	CEC[1]
Sandy loam	California	69	21	10	1.2	5.4	12
Sand	Indiana	90	8	2	0.8	4.3	6
Sandy loam	Kansas	66	32	2	2.4	5.1	17

meq/100 g dw soil

All soils were sieved (2 mm) prior to use. Kansas sandy loam was selected for the ageing and the microbial activity of this was established prior to use. A 1 kg sample of air-dried soil was treated with radiolabelled fenamiphos dissolved in acetonitrile. After evaporation of the solvent, the treated soil was thoroughly mixed and the moisture content increased to 75% of 1/3 bar with distilled water. Volatiles were monitored through the ageing process and incubation was at around 23^{o}C. The ageing period was 30 days and after this, aliquots of the soil were analysed for radioactivity using LSC. Columns used in the study were treated with an average of 4.93 mg of aged fenamiphos residues.

The residues aged in the Kansas sandy loam were applied to columns of each different soil type. Columns used for the experiment (length 45 cm, diameter 5.4 cm) contained 100 g washed sea sand and a 30 cm segment of air-dried test soil over the sand. The columns were saturated with 0.01 N calcium chloride solution, then topped with a sample of the aged fenamiphos treated soil and leached with around 1160 mL of 0.01 N aqueous $CaCl_2$ solution continuously over a 2 day period. Leachate was collected in fractions of around 100 mL. A total of six columns were treated and leached allowing duplicate analyses of the three different soil types.

Radioactivity in each leachate fraction was determined by LSC. Those fractions containing significant levels of radioactivity were extracted twice with dichloromethane/acetonitrile (2:1 v/v) with the combined extracts analysed by both TLC and HPLC and radioactivity levels determined by LSC.

After leaching, soil columns were sectioned (6 cm lengths), air dried, ground and determined for radioactivity levels by LSC. Soils were initially extracted with acetonitrile then an acetonitrile/water (23:10 v/v) mix. The soil was separated from the filtrate by suction filtration. Radioactivity in the extracts was determined by LSC and characterised by both TLC and HPLC.

Findings:

Mass Balance

Total recovery of radioactivity in all soils was between 100.4 and 107.8% AR. Of this, between 36.2-83.6% remained in the soil column with 16.2-63.8% being found in the leachate. Production of $^{14}CO_2$ during the ageing process was negligible (<0.2% AR after 30 days) so did not represent any loss of radioactivity from the system.

Transformation of Parent

At the end of the 30 day ageing process, in the Kansas sandy loam, unchanged fenamiphos accounted for 45.6% AR with M01 accounting for 46.9% AR. No other metabolite was present at more than 3% AR.

Distribution of fenamiphos and its main M01 metabolite are shown below. All other metabolites found (M02, M12 and M13) were <1% in any soil segment.

Table A1.35: Distribution of Radioactivity (% AR) in Soil Segments

	California		Indiana		Kansas	
	Fen	M01	Fen	M01	Fen	M01
0-6	9.4	5.5	8.2	3.5	21.2	6.3
6-12	2.8	4.0	2.2	2.2	10.0	7.4
12-18	4.4	5.4	2.0	2.8	3.3	9.3
18-24	4.2	5.5	1.8	3.0	0.3	7.5
24-30	0.9	2.1	1.8	3.7	0.1	5.3

Results

The following distribution of radioactivity in the columns and leachate was found:

Table A1.36: Distribution of total radioactivity of aged residues of ^{14}C-Fenamiphos (% AR).

	California	Indiana	Kansas
0-6	17.2	14.5	31.9
6-12	7.8	4.6	19.5
12-18	10.9	5.0	14.7
18-24	11.0	5.5	9.7
24-30	3.4	6.0	6.9
Sand	0.8	0.6	1.0
Leachate	47.2	63.8	16.2

Distribution of radioactivity in the leachate showed that M01 overwhelmingly accounted for leachate residues. Of the total amount found in leachate, this metabolite accounted for around 88, 78 and 90% of radioactivity in the California, Indiana and Kansas soil leachates respectively. Unchanged fenamiphos accounted for 0-13.7% of radioactivity in the leachates. Other metabolites found included M02 (2-4% of total leachate radioactivity); M12 (1.8-4% total leachate radioactivity) and M13 (<2% total leachate radioactivity).

Conclusion:

The mobility of aged residues appeared inversely related to both organic matter content and CEC of the soils. Fenamiphos was the major residue present in the 0-6 cm soil layers. M01 was the major metabolite present in the leachates.

Lysimeter/Field Leaching Studies

No studies provided.

Modelling Studies – Groundwater contamination

Report: Schäfer, 2002a, 2002b
Guidelines: NA – Modelling Study
GLP: NA

The concentrations of fenamiphos and its main metabolites were predicted in ground water recharge based on FOCUS-PEARL through use in tobacco or sweet peppers in greenhouses in southern Europe. For the modelling, DT50 values obtained in the laboratory from Brumhard (2002 – see above) were used. The values were standardised to 100% field capacity. Following this process, fenamiphos DT50 values for the four soils ranged from 0.3-1.2 days and had a geometric mean of 0.5 days. M01 DT50 values ranged from 3.2-40.9 days (geometric mean of 15.5 days) and M02 DT50 values ranged from 7.9-34.4 days (three soils, geometric mean of 16.3 days).

With the assumption of first order kinetics for each reaction step in the degradation pathway, rate constants were estimated for each step. The transformation rates were standardised to transformation rates at 100% field capacity. Briefly, the degradation pathways and associated rate constants were:

Fenamiphos to M01 (k_1); Fenamiphos to "other compounds" (kB_1);

M01 to M02 (k_2); M01 to M12 (k_3);

M02 to M13 (k_4);

M12 to M13 (k_5);

Dissipation of M13 (k_6).

To characterise adsorption of fenamiphos, the results obtained by Simon (1990) and Hein (2000a) above were used, providing results for 20 soils. The measured K_{om} values ranged from 44.3-832.5 mL/g. To run the model, an average adsorption K_{om} value of 176.4 mL/g was used (1/n = 0.91). For M01, data from Fent (1995a) and Hein (2000b) were used providing data for 6 soils. The arithmetic mean K_{om} of 70.0[2] mL/g was used in the simulations. For M02, data from Fent (1995b) and Hein (2000c) were used providing data for 6 soils. The arithmetic mean K_{om} of 97.3[3] mL/g was used in the simulations.

For the tobacco simulations, an annual application rate of 6 kg ac/ha was assessed with an incorporation depth of 10 cm. Fenamiphos is applied in the form of a slow release formulation, and based on a PhD-D thesis, a release rate of 1.7% per day was used.

The FOCUS working group on groundwater scenarios developed nine scenarios, which cover different pedo-climatological conditions in the European Union. For this study, the four Southern European scenarios were used. In the consideration of tobacco use, the maize scenario was used for

2. [2] Equivalent mean Koc = 121
3. [3] Equivalent mean Koc = 168

two of the locations, as there were no standard scenarios for tobacco. Simulations were carried out over 26 years.

The concentrations in the percolate in 1 m depth were evaluated. For the tobacco scenarios, the results showed that for fenamiphos, no concentrations exceeding 0.001 µg/L are to be expected. For M01, the 80th percentile concentrations ranged from <0.001 to 1.266 µg/L while for M02, they ranged from <0.001 – 1.244 µg/L. For the greenhouse scenarios, all metabolite concentrations were predicted to be <0.001 µg/L.

Report: Di and Aylmore, 1997
Guidelines: NA – Modelling Study
GLP: NA

A simple model was used to assess the groundwater contamination potential of 29 pesticides, including fenamiphos, in the Swan Coastal Plains area of Western Australia. This area is vulnerable to groundwater contamination as the soils are sandy with a low capacity to retain residues. Soil and environmental conditions used were based on the local area being modelled.

The model was formulated assuming pesticide sorption was linear, at equilibrium and reversible; degradation kinetics in soil follow first-order reactions; and the pesticide leaches by steady piston water flow. The soil properties used for modelling were based on three soil depths using mean values for bulk density (g/cm^3), field capacity (%) and OC (%). Values for bulk density, FC and OC for the 0-25 cm soil layer were 1.4, 10.0 and 1.0 respectively, for the 25-50 cm layer were 1.5, 6.0 and 0.5 respectively and for the 50-500 cm layer were 1.5, 4.0 and 0.05 respectively. A representative k_{oc} of 100 and a field half-life of 43 days for fenamiphos were used for modelling. Computations were carried out for travel time and fraction of pesticide remaining at three depths of 150, 300 and 500 cm to accommodate variations of the water table in the Swan Coastal Plains region.

Probability density functions of computed fractions of pesticides remaining and travel times were analysed and calculations made for the means, standard deviations, standard errors of means and cumulative probabilities for pesticides reaching the three depths at fractions >0.01%, and the 95th percentiles of travel times. The value of 0.01% was regarded as a threshold value below which the fraction remaining becomes insignificant.

Judged by the mean residue percentage, 12 of the 29 pesticides modelled were predicted to leach beyond 500 cm. Fenamiphos was in this group. Cumulative probability values were considered to provide a better indication of groundwater contamination potential than the mean values alone. Six of the modelled pesticides (fenamiphos, simazine, metribuzin, linuron, fenarimol and metalaxyl) had cumulative probabilities >0.80 indicating high potential for groundwater contamination beyond 300 cm.

Fate and Behaviour in Air

The calculated Henry's Law Constant of 9.1x10^{-10} atm.m^3/mol (calculated from VP/Sol) is indicative of very slight volatility from water (Mensink *et al*, 1995).

No experimental data for degradation or volatility in the atmosphere were provided. However, the former was considered through modelling.

Report: Hellpointner, 1999, 2000a, 2000b
Guidelines: NA – Modelling Study
GLP: NA

The rate constant for reactions of fenamiphos, M01 and M02 with OH radicals (photochemical oxidative degradation) in the atmosphere was calculated using the AOP program [AOPWIN

Program (Atmospheric Oxidation Program for Microsoft Windows 3.1) Version 1.87], provided as part of the US EPA EPIWIN software. The structure of the compounds were entered into the program with the following SMILES notation:

Fenamiphos	CCOP(=O)(NC(C)C)Oc1ccc(SC)c(C)c1;
M01	CCOP(=O)(NC(C)C)Oc1ccc(S(=O)C)c(C)c1;
M02	CCOP(=O)(NC(C)C)Oc1ccc(S(=O)(=O)C)c(C)c1

First, the rate constant k_{OH} of the active substance was estimated based on the chemical structure. The resulting values were

$$77.7064 \text{ X } E^{-12} \text{ cm}^3\text{/molecule.sec (fenamiphos)}$$

$$128.4048 \text{ X } E^{-12} \text{ cm}^3\text{/molecule.sec (M01)}$$

$$68.4048 \text{ X } E^{-12} \text{ cm}^3\text{/molecule.sec (M02)}$$

The half-life of this process (in seconds) is calculated by the following equation:

$$t_{½} = \ln 2/k' = \ln 2/k_{OH} \text{ X [OH radicals]}$$

The diurnally and seasonally averaged concentration of tropospheric hydroxyl radicals used by the AOP program is $1.5 \text{ X } 10^6$ cm^{-3}. Therefore, half-life for the degradation of the three considered compounds by hydroxyl radicals was calculated based on a 12 h:12 h light:dark day to be:

Fenamiphos	1.65 hours
M01	1.00 hours
M02	1.88 hours

These compounds are not expected to persist in the atmosphere.

Accumulation/Bioaccumulation

Report: Forbis, 1986.
Guidelines: EPA-FIFRA Guidelines 72-6
GLP: Yes.

Test System

A study using ^{14}C-fenamiphos was performed on bluegill sunfish (*Lepomis macrochirus*) to measure bioconcentration (uptake and depuration). Based on a pilot study undertaken to determine toxicity of the test compound (7 d LC50 determined to be 8.3 ppb with a NOEC of 2.8 ppb), an exposure level of 0.8 ppb was set for the bioconcentration study, representing around $1/10^{th}$ of the LC50. Fish used for the experiment had an initial mean weight of 8.2 g and an initial mean standard length of 64 mm.

Before initiating the uptake portion of the study, the test solution was allowed to flow through the test aquaria for a 24-h equilibration period. The test concentration was confirmed by radioanalysis before introducing the fish. Aerated well water was delivered to the test aquaria at an average rate of around 373 mL/minute during the exposure period giving around 7.7 volume replacements in a 24 h period. The diluter system consisted of two exposure and two control aquaria. These were immersed in a water bath and held at around 22^{o}C.

The uptake phase was initiated by transferring groups of 125 previously acclimated fish to each of the control and test chambers. The fish were observed initially and every 24 h during the 28 d exposure period for mortality and adverse effects. Water and fish (3 fish per aquaria) were sampled

throughout the uptake phase at 0, 0.17, 1, 3, 7, 14, 21 and 28 days. Edible and non-edible portions were sectioned and water and tissue samples radioassayed.

Following the exposure period the water in the test aquarium was changed and fish were depurated for a 14 day period with sampling occurring at days 1, 3, 7, 10 and 14.

Water quality parameters of temperature, dissolved oxygen (DO) and pH were measured initially and throughout the study in both control and exposure chambers. Test chambers were aerated throughout the test to maintain DO levels at or above 40% saturation.

Findings:

Dissolved oxygen levels in the control chambers declined steadily during the exposure period from 9.0 mg/L at the start of the test to 7.3 mg/L after 28 days. During the depuration period, DO levels ranged from 7.5-8.4 mg/L. The pH of the water remained in a range of 7.8-8.3 throughout the study. In the test chambers, DO levels ranged from 7.0-8.6 mg/L throughout the study except on the last exposure day where they were 5.8-6.5 mg/L. The pH was always in the range of 7.9-8.2.

Fenamiphos concentrations in the exposure chambers ranged from 0.83-1.1 ppb and no mortality or sub-lethal effects were observed at any time during the study.

Steady state concentrations in the fish appeared to be reached after around 7 days exposure. In the edible portion, after 7 days, the concentration of ^{14}C-fenamiphos was 24 µg/kg and was still 20 µg/kg at the end of the exposure period. Levels in the viscera peaked at 7 days (230 µg/kg) and had declined to 93 µg/kg after 28 days. Consequently, whole fish residues also declined from their peak of 87 and 89 µg/kg at days 7 and 14 respectively to a level of 58 µg/kg at day 28. Following the commencement of depuration, residues were eliminated very quickly from the fish, and at the day 3 sampling time, no quantifiable residues were found.

At day 28, the BCF values for edible, non-edible and whole fish were 21, 98 and 61 respectively. Daily BCF values for the uptake phase ranged from 7.6-26 for the edible portion, 23-250 for the non-edible portion and 14-97 for the whole fish.

Kinetics data were calculated and for the whole fish, a BCF of 110 and depuration half-life of 0.22 days were determined.

Conclusion

Based on the scale of Mensink *et al*, 1995, fenamiphos is considered slightly to moderately concentrating in fish. Once exposure ceases, any accumulated compound is expected to rapidly depurate from the organism.

Report: Hanna and Lenz, 1997
Guidelines: Not stated
GLP: Yes.

Test System

The study was performed to determine uptake and elimination of ^{14}C-Fenamiphos in earthworms (*Eisenia foetida*). Sandy loam (9.5 kg) was fortified with 28.4 mg fenamiphos for a final concentration of 3.0 ppm. The soil was mixed thoroughly in a 18.9 L container for 10 minutes. Corn meal was mixed in to serve as a food source. The soil was kept moist over the 2 month test period.

Two hundred worms were placed in treated soil (sandy loam) for 30 days. At the end of this period they were removed, rinsed with tap water and transferred to another 18.9 L container of untreated sandy loam where they remained for an additional 30 days.

After 0, 3, 7, 14, 21 and 30 days, 10 worms were collected from the treated soil (and at corresponding time intervals during the elimination phase of the experiment). Each sample was rinsed with tap water and weighed. They were placed in liquid nitrogen and ground using a mortar and pestle. Triplicate aliquot samples were assayed by combustion. Multiple soil samples were taken on day 0 to determine uniformity of application. At days 7, 14, 21 and 30, 50 g samples of treated soil were collected (sampling of untreated soils occurred at the same time points during the elimination phase of the experiment). Levels of radioactivity in the soils were determined by combustion.

Findings:

The concentration of ^{14}C residue in the treated soil ranged from 2.87-3.13 ppm with an average radioactivity in the soil of 2.97 ppm.

On the day of application, residue levels in worms was <0.01 ppm. At 3, 7, 14, 21 and 30 days, mean residue levels of 1.87, 1.6, 1.3, 1.6 and 2.52 ppm respectively were found in the worms.

Following removal to the untreated soil, mean ^{14}C-residues after 3, 7, 14, 21 and 30 days elimination were 1.31, 0.96, 1.24, 1.10 and 0.54 ppm respectively were found in the worms.

Worms were not depurated prior to analysis. Therefore, the residue levels found in the worms may well be the result of sorption to soil particles found in the gut. Elimination was not rapid or consistent. The authors note that this may be the result of absorption of excreted ^{14}C-residues.

In any event, even if all residues in worms were the result of accumulation and not association with sediment particles, BCFs at all sampling times were <1.

Conclusion

Fenamiphos is not expected to be accumulated by earthworms following exposure through soil.

Modelling Studies – Predicted Soil Concentrations

Report: Schäfer, 2002c, 2002d
Guidelines: NA – Modelling Study
GLP: NA

The concentrations of fenamiphos and its main metabolites were predicted in soil based on FOCUS-PELMO through use in tobacco or sweet peppers in greenhouses in southern Europe. For the modelling, DT50 values obtained in the laboratory from Brumhard (2002 – see above) were used. The values were standardised to 100% field capacity. Following this process, fenamiphos DT50 values for the four soils ranged from 0.3-1.2 days and had a geometric mean of 0.5 days. M01 DT50 values ranged from 3.2-40.9 days (geometric mean of 15.5 days). M02 DT50 values ranged from 7.9-34.4 days (three soils, geometric mean of 16.3 days). M12 DT50 values ranged from 1.4-9.9 days (three soils, geometric mean of 5.0 days). M13 DT50 values ranged from 7.1-15.7 days (three soils, geometric mean of 13.1 days).

With the assumption of first order kinetics for each reaction step in the degradation pathway, rate constants were estimated for each step. The transformation rates were standardised to transformation rates at 100% field capacity. Briefly, the degradation pathways and associated rate constants were:

Fenamiphos to M01 (k_1); Fenamiphos to "other compounds" (kB_1);

M01 to M02 (k_2); M01 to M12 (k_3);

M02 to M13 (k_4);

M12 to M13 (k_5);

Dissipation of M13 (k_6).

To characterise adsorption of fenamiphos, the results obtained by Simon (1990) and Hein (2000a) above were used, providing results for 20 soils. The measured K_{om} values ranged from 44.3-832.5 mL/g. To run the model, an average adsorption K_{om} value of 176.4 mL/g was used (1/n = 0.91). For M01, data from Fent (1995a) and Hein (2000b) were used providing data for 6 soils. The arithmetic mean K_{om} of 70.0[4] mL/g was used in the simulations. For M02, data from Fent (1995b) and Hein (2000c) were used providing data for 6 soils. The arithmetic mean K_{om} of 97.3[5] mL/g was used in the simulations. For M12 and M13, the results obtained by Simon (1990) were used providing data for 16 soils. The average K_{om} values of 43.6 and 59.5 mL/g was used for M12 and M13 respectively.

For the tobacco simulations, an annual application rate of 6 kg ac/ha was assessed with an incorporation depth of 10 cm, with simulations predicting concentrations in the 0-20 cm soil layer. For sweet pepper use in glasshouses, the application rate of 10 kg ac/ha was assessed in the 0-20 cm soil layer.

The FOCUS working group on groundwater scenarios developed nine scenarios, which cover different pedo-climatological conditions in the European Union. For the tobacco study, two Southern European scenarios (Sevilla and Piacenza) were used (although for Piacenza, the maize scenario was used no standard scenario for tobacco is available for this location). These two Southern European scenarios were also used for predicting concentrations based on use on sweet pepper in greenhouses. The simulations were carried out until 365 days after the day of application.

From the use on tobacco, maximum residues in soil for fenamiphos, M01, M02, M12 and M13 were 55, 487, 157, 39 and 97 ppb respectively in the Sevilla scenario and 42, 386, 144, 28 and 108 ppb respectively in the Piacenza scenario. In both scenarios, fenamiphos residues peaked at 4 days following application, while the metabolites peaked at 28 or 50 days following application except M13 in the Sevilla scenario that peaked at 100 days after application.

From the use on sweet pepper in glasshouses, maximum residues in soil for fenamiphos, M01, M02, M12 and M13 were 199, 2473, 751, 167 and 568 ppb respectively at 2, 50, 100, 50 and 100 days after application respectively in the Piacenza scenario. The corresponding maximum levels (predicted at the same days after application) in the Sevilla scenario were 214, 2606, 768, 174 and 574 ppb respectively.

Field Dissipation Studies

Terrestrial

Report: Grace *et al*, 1990
Guidelines: EPA Guideline 164-1 Soil Field Dissipation
GLP: Yes.

Test System

A field dissipation study was conducted using the formulation Nemacur 3 (fenamiphos at 300 g/L) on established turf plots. Two test sites were chosen, one a Chualar, California and the other at Fresno, California.

4. [4] Equivalent mean Koc = 121
5. [5] Equivalent mean Koc = 168

Each plot received 2 applications of 11.2 kg ac/ha at a 6 month interval. Samples were analysed to determine the kinetics of fenamiphos, including the half-life of the parent compound and the formation of the metabolites (M01 and M02 being the two considered in this study). Leaching potential was also determined. Soil characteristics were variable within the plots and the following soil characteristics are provided for the soils at the test sites from different samples:

Table A1.37: Soil characterisation for Chualar and Fresno Sites

Sample	Texture	Sample depth (cm)	% sand	% silt	% clay	% OM	pH	CEC[1]
Chualar site								
1	Sandy loam	61	68	22	10	1.44	7.8	16.4
2	Sand	46	90	9	1	0.50	6.9	14.1
3	Loamy sand	46	85	12	3	1.24	7.3	15.8
4	Sandy loam	46	62	31	7	1.77	7.0	22.0
5	Sandy loam	61	60	35	5	0.24	8.0	14.0
Fresno site								
1	Sandy loam	30	70	24	6	0.48	6.9	6.1
2	Loamy sand	30	78	19	3	0.39	6.3	5.5
3	Loamy sand	30	79	17	4	0.43	6.9	5.3
4	Loamy sand	30	78	17	5	0.33	6.7	5.2

1) meq/100 g dw soil

Plot dimensions were in the order of 1200 m^2. The test product was applied by a spray boom to the plots with calibrated equipment. All applications were diluted to the equivalent of 560 L water/ha.

Each plot was divided into 3 equal sections with each section further divided into subsections, depending on the number of sampling intervals. Only 1 core was pulled from each subsection with at least 1 metre between cores. 15 cores were taken per sampling interval (5 cores per section). Immediately following each spray application for both plots, 15 random 15 cm cores were taken to verify application and rate of test material. After the first application, soil cores of 1.2 m deep were taken at various intervals. In Chualar, after the first application, sampling occurred on days 3, 7, 14, 28, 62, 90, 131 and 178. The post-second application sampling occurred on days 0, 3, 7, 12, 28, 60 and 270 after the second application (the final sampling time being 450 days after the first application). At the Fresno site, sampling occurred on days 0, 3, 7, 14, 28, 60, 90, 112 and 179 after the first application, and 0, 3, 7, 14, 28, 61, 91 and 180 after the second application (the final sampling time being 360 days after the first application). Soil cores were "re-cored" to overcome artifactual residues from occurring in lower segments as a result of pushing the steel probe through the various soil horizons.

Day 0 samples from both applications were analysed individually to characterize uniformity of application to the plot. Soils were analysed using shaker extraction of the soil with dichloromethane, followed by filtration and evaporation. Quantitation was achieved via gas chromatography using a nitrogen/phosphorous detector.

Gross residue data were not considered directly comparable. When sample weights were compared, as much as a two-fold range of weights per 15 cm soil horizon was observed. It was therefore considered apparent that a two-fold variation in residue levels could be observed, which would have been the result of sample dilution and not reflective of fenamiphos kinetics. Consequently, raw data were converted to residues in terms of "total pesticide mass" (µg per soil horizon). The result of this

normalization procedure was residue levels in terms of μg/100 cm^2 that were considered directly comparable with each other.

Findings:

Recoveries of all three analytes of interest from field control soil were conducted. With fortification levels of 0.01, 0.02 and 0.05 ppm in the 0-15 cm soil horizon of the Fresno site, recoveries for all three analytes ranged from 75-109.1% with a mean of 94.2%. From the 15-90 cm soil horizon at Fresno and the 0-90 cm soil horizons at Chualar, recoveries were performed in each horizon at the 0.01 ppm level. Overall recoveries of all three analytes ranged from 81.3-113% with a mean of 95.9%.

In addition to this, recoveries of all three analytes were conducted concurrently with each analytical run of the field treated samples to verify the integrity of the analysed residues found in sets of samples analysed on respective days. The concurrent recoveries were performed at either the 0.05 of 0.1 ppm fortification level. Recoveries of fenamiphos ranged from 69.6-126.3% (mean 102.2%). Recoveries of M01 ranged from 47.8-141.7% (mean 92.7%). Recoveries of M02 ranged from 70.5-126.8% (mean 98.5%).

Application rates

Based on a nominal application rate of 11.2 kg/ha, the theoretical rate achievable is 112 μg/cm^2. A total of 15 0-15 cm cores were analysed for total residues immediately following application. At the Chualar site, the average normalized residue levels found averaged 34.31 μg/sample. This equates to around 6.8 μg/cm^2, or around 6.1% of the nominal application rate. By comparison, at the Fresno site, the average normalized residue immediately following application was 434.3 μg/sample. This equates to around 85.7 μg/cm^2, or 76% of the nominal application rate.

It is unclear why the achieved application was so low at the Chualar site. The report offers no explanation, but the same pattern was found following the second application where the rate achieved at the Chualar site was only around 10% of that found at the Fresno site. While the plots were irrigated, the level of irrigation was insufficient to result in any substantial pesticide loss. Additionally, irrigation did not occur on the day of application, and no rainfall was recorded on the days of application.

Dissipation of Fenamiphos Residues

The following table shows mean residue data based on the normalization process, that is, residue levels are from all soil horizons and expressed as μg/100 cm^2.

Table A1.38: Residue Mass per Normalised Surface Area (µg/100 cm^2) at Chualar

	Days after application	Fen	M01	M02	TOTAL
Chualar Site 1st application	0	443.4	233.9	-	677.2
	3	345.8	979.9	93.3	1419.0
	7	275.8	1595.1	249.0	2119.9
	14	192.6	1414.7	386.1	1993.4
	28	113.3	2063.5	680.5	2857.3
	62	31.7	1174.7	327.2	1533.6
	90	7.7	1418.7	271.0	1697.4
	131	-	722.7	91.3	814.0
	178	-	508.4	28.9	537.2
Chualar Site 2nd application	0	393.7	804.9	19.7	1218.4
	3	103.5	579.5	67.1	750.1
	7	23.7	588.6	36.4	648.7
	14	42.2	1483.1	156.2	1681.4
	28	53.6	2758.4	363.2	3175.2
	62	33.8	1991.5	380.2	2405.5
	92	34.9	2149.0	455.0	2638.9
	182	-	832.6	90.1	922.7
	272	-	396.6	-	396.6

Table A1.39: Residue Mass per Normalised Surface Area (µg/100 cm^2) at Fresno

	Days after application	Fen	M01	M02	TOTAL
Fresno Site 1st application	0	5603.5	2928.5	39.8	8571.8
	3	135.8	401.5	64.5	601.8
	7	146.2	1171.9	378.2	1696.2
	14	76.0	1510.4	707.2	2293.5
	28	63.1	1478.2	717.2	2258.5
	60	11.5	2243.2	1095.4	3350.1
	90	24.0	939.8	724.2	1688.0
	112	-	1236.7	735.0	1971.8
	179	-	591.8	390.8	982.6
Fresno Site 2nd application	0	5471.2	3028.9	491.9	8992.0
	3	700.4	2186.8	754.4	3641.6
	7	210.3	1857.2	834.7	2902.1
	14	75.9	1581.0	642.3	2299.1
	28	39.3	1341.1	738.1	2118.4
	61	-	1197.9	939.1	2137.0
	91	9.3	751.6	649.0	1409.9
	180	-	299.7	73.5	373.1

Despite the very low application rates achieved at Chualar, dissipation of fenamiphos followed a steady first-order process. In contrast, dissipation at the Fresno site was more erratic. After the first application, high levels of fenamiphos were found at day 0 with a very rapid drop initially before following a more gradual decline. Based on the fenamiphos residue data following the first application in the above tables, and calculating the half-life using the first-order equation t1/2 = -ln(2)/k, the following half-lives have been calculated:

Table A1.40: Half-lives following first applications.

Compound	Test site	k	r^2	DT50 (days)
Fenamiphos	Chualar	0.0429	0.996	16.2
Fenamiphos	Fresno	0.0409	0.4929	17.0
M01[1]	Chualar	0.009	0.91	77.0
M01[1]	Fresno	0.0098	0.79	70.7
M02[1]	Chualar	0.0201	0.99	34.5
M02[1]	Fresno	0.0082	0.96	84.5

1) Half-lives calculated by DSEWPAC from the time residues peaked, that is, from day 28 at Chualar and Day 60 at Fresno.

The poor correlation of residue data for fenamiphos degradation at the Fresno site is due to the high residues found at day 0. If the regression equation is obtained using data from day 3, the half-life is predicted to be 27.6 days ($r^2 = 0.74$, k = 0.0251). It was shown in laboratory studies that initial degradation of fenamiphos can be fast followed by a second phase of slower degradation.

In terms of estimating degradation/dissipation half-lives using total residues (fenamiphos + M01 + M02), regression equations were poorly correlated. However, if the day 0 results at the Chualar site were omitted from the regression, the r^2 was an acceptable 0.73 and the predicted half-life for dissipation of total residues was 96.3 days (k = 0.0072). No clear dissipation kinetics could be observed using total residues following the first application at the Fresno site. However, using the dissipation data of total residues following the second application, a half-life of 52.5 days was predicted ($r^2 = 0.83$, k = 0.0132).

Leaching of Residues

The following tables describe the movement of total fenamiphos residues (parent + M01 + M02) through the soil profiles. Fenamiphos itself was the least mobile of the analytes. It was found in the top 0-15 cm soil layer in both test plots only with no detections below this layer at any sampling time.

Considering movement further through the soil profile, M01 was by far the dominant metabolite. In the Chualar test plot, following the first application, residues detected at levels below 15 cm were almost fully attributable to M01. M02 was only detected in one sample at 15-30 cm on day 131.

Following the second application at Chualar, at sample days 28 to 182, M02 was found in all samples at 15-30 cm, but at levels substantially less than those of M01. M02 was never found below 30 cm.

The metabolites were more mobile in the Fresno soil. Again, M01 was the dominant metabolite. Following the first application, both M01 and M02 were found in the 15-30 cm layer on days 60 and 90 with M01 found in the 30-45 cm layer in one replicate at this time. At day 112, both metabolites were found as low as the 30-45 cm layer. Residues of M01 were found in one replicate as low as the 45-60 cm layer at the last sampling time (179 days) after the first application.

After the second application, both metabolites were consistently detected at 30-45 cm by day 3. From day 14 onwards, M02 was detected sporadically in this layer, otherwise, it was largely confined to the 0-30 cm soil layers. On one occasion, it was found in one replicate in the 45-60 cm layer. M01 was found as low as the 75-90 cm layer (one replicate on day 91). It was consistently found as low as 45-60 cm and on three sampling occasions, found in the 60-75 cm layer in one or two replicates.

Table A1.41: Mobility of Fenamiphos (total residues of parent + M01 + M02), µg/100 cm^2

	Days after application	0-15 cm	15-30 cm	30-45 cm	45-60 cm
Chualar Site 1st application	0	677.24			
	3	1419.03			
	7	2119.92			
	14	1993.43			
	28	2857.29			
	62	1533.61			
	90	1565.41	63.89	41.67	
	131	526.87	221.87	65.22	
	178	253.01	243.06	31.54	
Chualar Site 2nd application	0	943.13	243.06	31.54	9.61
	3	435.17	282.35	32.56	
	7	427.94	182.82	37.96	
	14	1452.18	198.93	23.26	7.06
	28	2504.72	484.74	114.83	70.94
	62	2021.73	283.02	71.40	18.60[1]
	92	2033.50	496.29	87.63	21.47
	182	308.06	379.69	176.78	58.16
	272	136.51	237.84		22.22

1) on this sampling day, 10.70 µg/100 cm^2 was also found in the 60-75 cm soil layer

Table A1.42: Mobility of Fenamiphos (total residues of parent + M01 + M02), µg/100 cm^2

	Days after application	0-15 cm	15-30 cm	30-45 cm	45-60 cm
Fresno Site 1st application	0	8571.78			
	3	601.80			
	7	1696.23			
	14	2293.53			
	28	2258.46			
	60	2835.13	493.48	24.54	
	90	1449.58	223.67	14.74	
	112	1268.54	533.04	170.17	
	179	435.27	512.20	21.88	13.25
Fresno Site 2nd application	0	8444.66	512.20	21.88	13.25
	3	2690.36	699.23	252.00	
	7	2060.13	719.52	122.44	
	14	1625.78	526.16	77.45	30.82[1]
	28	1421.16	570.59	171.63	
	61	760.04	1259.28	108.50	9.16[2]
	91	462.73	670.85	194.77	45.16[3]
	180	21.77	101.73	152.80	88.00

1) on this sampling day, 20.53 µg/100 cm^2 was also found in the 60-75 cm soil layer and 18.40 µg/100 cm^2 was found in the 75-90 cm layer; 2) on this sampling day, 29.06 µg/100 cm^2 was also found in the 60-75 cm soil layer and 7.29 µg/100 cm^2 was found in the 75-90 cm layer; 3) on this sampling day, 8.81 µg/100 cm^2 was also found in the 60-75 cm soil layer

Conclusion:

Data presented in this study show fenamiphos to have a field half-life of 16-28 days with M01 being the main metabolite produced. This substance had a field half-life in the order of 70-80 days. Dissipation of total fenamiphos residues from the test fields (fenamiphos + M01 + M02) were generally poorly correlated but appeared to range between 50-100 days.

At no time did fenamiphos migrate lower than 0-15 cm. M01 was the most mobile metabolite and the one produced in the largest quantities. Following a single application, neither M01 nor M02 were found below 60 cm in the soil, and generally, residues of these metabolites were restricted to the top 45 cm. After the second application, much higher concentrations of M01 were found at the 45-60 cm layer with some detections as low as 75-90 cm.

Terrestrial and Groundwater

Report: Lenz, 1997
Guidelines: EPA Guideline Subpart N, 166-2
GLP: Yes.

Test System

A groundwater monitoring study was designed to evaluate the effects of continued use of fenamiphos on shallow, vulnerable groundwater. The site used for the study was located in Lake Placid, Florida, USA. It was treated annually with fenamiphos since 1985. The subsoil at the site is comprised of highly permeable sands with a water permeability of 20 inches (~51 cm) per hour. Groundwater at the site is available in unconfined aquifers at a depth of 4 to 28 feet (~1.2-8.5 m):

The groundwater monitoring site was around 10 acres (4.05 ha) in size and part of a 160 acre (~65 ha) irrigated citrus grove. Fenamiphos had been applied to the entire 160 acre site since 1985. The test site consisted of 12 wells, 6 being off the application zone in an untreated pasture, down the gradient from the application area, and 6 in three clusters of 2 wells located within the 4 ha treatment zone.

Fenamiphos, as NEMACUR 3, was applied to the test site at a rate of 9.9 lb/A (11.1 kg ac/ha) in the total test area. However, application was as a 50% band meaning the actual nominal application rate was around 22.2 kg ac/ha in the treated zone. Applications were made in 1990 (18 April), 1991 (21 May) and 1992 (1 July). There was no primary soil incorporation following application, although it is noted the sites were irrigated. Immediately before the 1990 and 1991 applications were made, five solvent pads were placed in the field to trap the spray formulation in order to verify the application rates.

Both soil and groundwater were sampled. Groundwater samples were taken monthly from January 1990 to November 1992. Soil samples were collected at around 0, 3, 7, 14, 28, 60, 90, 180 and 365 days after each application in 1990 and 1991. At day 0, the 0-6 inch (0-15 cm) was sampled with sampling thereafter in 6 inch (15 cm) increments. The test area was subdivided into 15 sections and a soil sample taken from each section. The first 187 samples were analysed in duplicate with the remaining samples analysed once. Analysis was performed for parent fenamiphos, M01 and M02.

Findings:

Based on analysis of the solvent pads, the final estimated recovery for the 1990 application was 68.3% while that for the 1991 application was 70.4%. The method of detection in soil showed average recoveries of 88%, 102% and 100% for fenamiphos, M01 and M02 respectively from spiked samples

Dissipation of Fenamiphos Residues from Soil

Despite the application rate being nominally the same, and verification of the rate showing similar levels, soil residues following the 1991 application were more than twice those following the 1990 application. The reason for this is unclear. However, residue data showed a consistent pattern of decline from both years with the major metabolite found being M01. Fairly minor amounts of M02 were found in both years, generally between 3 and 30 days following application and generally much less than 10% of total residues.

The following table shows the pattern of decline of fenamiphos, M01 and total soil residues through the whole soil profile, as measured down to a depth of 36 inches (~92 cm). These values refer to quantifiable levels only.

Table A1.43: Pattern of Soil Residue Decline for Fenamiphos, M01 and Total Residues Following 1990 and 1991 Applications (µg/kg).

	1990 Application			1991 Application		
Day	Fen	M01	TOTAL	Fen	M01	TOTAL
0	5590.9	705.1	6298	13547.7	1551.7	15099.4
3	2096.2	1183.5	3333.6	3930.2	3973.3	7979
7	917.5	754.2	1718.4	1885.2	1782.3	3770.6
14	422.8	385	827.5	668.1	1275.6	2174.2
28	217.3	326.1	543.4	178.4	219.9	398.3
60	21.8	101.5	123.3	10.6	171.9	182.5
90		47.2	47.2	22	30.3	52.3
180		31.6	31.6		88.4	88.4
365					46.4	46.4

These data have been used to determine total soil half-lives (DT50 = -ln(2)/*k*). Following both applications, fenamiphos degradation followed a bi-phasic pattern with a first phase half-life of 2.7 to 3.4 days and a longer second phase half-life of 10.1 to 17.3 days.

M01 also showed a bi-phasic degradation pattern following both years application with a first phase half-life of 6.8 to 8.5 days and a longer second phase half-life of 81.5 to 150.7 days.

Table A1.44: Soil Half-lives of Fenamiphos and M01 Following 1990 and 1991 Application.

		1990		1991	
		DT50	r^2	DT50	r^2
Fen	1st phase	2.7	0.98	3.4	0.94
	2nd phase	10.1	0.99	17.3	0.96
M01	1st phase	8.5	0.95	6.8	0.98
	2nd phase	81.5	0.8	150.7	0.98

Leaching of Residues

Rainfall data were collected from weather stations north and south of the test site. While it is unclear when any irrigation was applied, in terms of rainfall, following the first application in 1990 no rain was recorded until 6 DAT when 0.28 inches (7 mm). At 11 DAT a further 1.8 mm fell. In the first month after treatment, rain fell on 5 days and a total rainfall for the month of 19.5 mm was recorded. Parent fenamiphos was not found below 60 cm (3 and 28 DAT) and was generally only found in the top 45 cm of the soil layer. Conversely, residues of M01 were detected through the soil profile (to 122 cm) within 3 days of application. M02 was only found in minor amounts up to 14

DAT after which it was not detected, and was found at quantifiable levels as low as 45 cm after 7 days.

Conditions were much better for incorporation by rainfall with the second application in 1991. On the day of application 3.3 mm of rain was recorded with a further 35 and 15.7 mm falling on 2 and 3 DAT. For the month following the second application rain fell on 16 days with 241 mm recorded. Within 3 days of treatment, fenamiphos was found through the soil profile down to 91 cm and to the maximum measured 122 cm horizon within 7 days. Parent fenamiphos continued to be found down to 122 cm until 30 days after treatment. At the next sampling time (60 DAT), fenamiphos was only found in the top 0-15 cm and was no longer found after 90 DAT. M01 was found throughout the soil profile after 3 days and continued to be found all through the soil profile (to 122 cm) up to 60 DAT. M02, while still only found at relatively low levels, was found throughout the soil profile to 122 cm on 7 and 14 DAT. From that time on, this metabolite was not found at quantifiable levels in any soil sample.

Groundwater findings

A total of 5 clusters of wells were sampled. The following diagram shows the positioning of the wells:

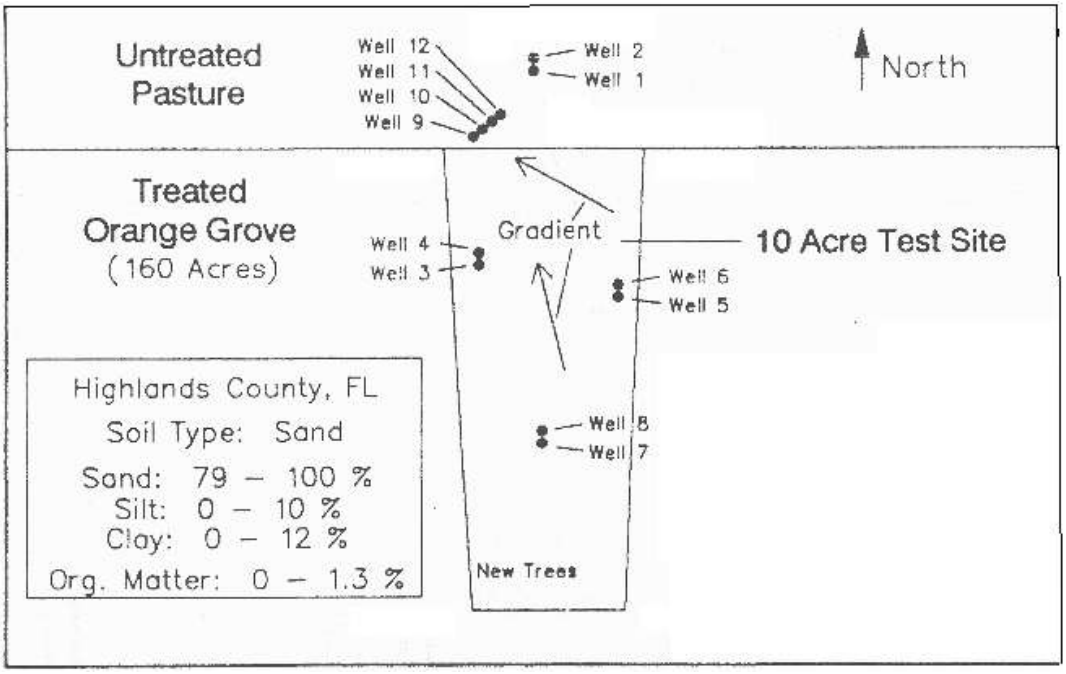


Figure 1: Position on wells in Groundwater Monitoring Study

Three clusters (each with two wells) were in the test application area. On cluster (4 wells) was found just north (~20 m) and down gradient from the edge of the test application area while the other offsite cluster (2 wells) was about 70 m north and slightly up-gradient from the field plot. The depth to groundwater was measured during the study from the different well clusters and ranged from between 2.6 m and 9 m.

The following table shows the range of residues of M01 found in the wells over the course of the study:

Table A1.45: Minimum, Maximum and Mean M01 Concentrations found in Groundwater

			OFF SITE			
	Cluster 1		Cluster 5			
	Well 1	Well 2	Well 9	Well 10	Well 11	Well 12
Min	<0.01	<0.01	0.83	0.25	<0.01	<0.01
Max	0.27	0.5	3.86	1.08	0.43	0.5
mean	0.03	0.09	2.12	0.64	0.20	0.19
			ON SITE			
	Cluster 2		Cluster 3		Cluster 4	
	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8
Min	0.43	0.34	<0.01	<0.01	4.92	1.74
Max	129.5	59.5	9.11	1.91	187	78.13
mean	15.4	11.1	0.93	0.41	33.9	15.0

Fenamiphos was occasionally found in groundwater samples, and where found, was usually at <1 µg/L. However, following the first application in 1990, fenamiphos was found at every sampling event through the year in groundwater in well 7 except the last one, and at levels of 7.43 to 22.53 µg/L during the first six months of the year.

This well showed the highest overall residues during the study. The authors note this may be because well 7 contained a clay layer at the bottom of the well that may have trapped residues in the area thereby arresting the leaching process and allowing them to percolate through the soil over a long period of time. However, they also note that the area near Cluster 4 had a past history of nematode problems and grove maintenance in this area was suspect when several empty cans of NEMACUR were found among the citrus trees. No correlation was found between the appearance of the maximum residues in groundwater and days post application for the on-site wells. Further, no correlation was found for total fenamiphos residue migrating from the shallow well to the deep well, although, in general, residues found in the on-site deep wells were less than those found in their adjacent shallow wells.

Despite the relatively low formation of M02 in soil columns, this metabolite was found in groundwater at concentrations as high as 5 µg/L (well 3, 4 months after the second application) and 19.7 µg/L (well 7, one week after the first application). Interestingly, this metabolite was also found at 6.57 µg/L in well 8 two weeks prior to the first application.

The residence time, or elimination time, for residues in groundwater monitoring could be observed best in wells 7 and 8. The residue found in these wells at the beginning of the study took approximately 256 days to return to background.

Conclusion:

Fenamiphos had a short residence time in soil following application with around half of the total residues of fenamiphos and metabolites in the soil at the time of application being removed by 3 days after application. Fenamiphos and M02 were found in groundwater, but at much lower concentrations and much less frequently than the main M01 metabolite. Generally residues found in shallow wells were greater than concentrations found in their adjoining deep wells. Therefore, fenamiphos and metabolites may tend to disperse laterally rather than penetrate to deeper depths of an aquifer.

The maximum concentration of fenamiphos found in groundwater on-site was 22.5 µg/L, and in off-site, down-gradient wells was 0.31 µg/L. The maximum concentrations of M01 found in groundwater on-site was 187 µg/L, and in off-site, down-gradient wells was 3.86 µg/L. The

maximum concentrations of M02 found in groundwater on-site was 19.7 µg/L, and in off-site, down-gradient wells was 0.19 µg/L.

Report: Dyer *et al*, 1999.
Guidelines: EPA Guideline Subpart N, 166-1
GLP: Yes.

Test System

A small scale prospective ground water monitoring study was conducted two miles south of Byromville in Dooly County, Georgia, USA. The site consisted of a 2.5 acre (1 ha) test plot and a 0.4 acre (0.16 ha) control plot. The surficial soils (0-15 cm) were relatively consistent across the study area and were comprised of loamy sand with around 87, 5 and 8% sand, silt and clay respectively and 1.4% organic matter.

Fenamiphos was applied to the test plot as a broadcast spray on 5 June 1996 at a target rate of 6.6 lb/A (7.4 kg/ha), which was 110% of the label rate for tobacco. Application verification containers containing soil indicated the application was 98% of the label rate. Potassium bromide was applied on the same day at 50 lb/A (56 kg/ha) as a tracer of water movement.

The test plot contained eight instrument clusters, each containing suction lysimeters at 3.5, 6, 9 and 15 ft soil depth (1.1, 1.8, 2.7 and 4.6 m respectively) for monitoring soil pore water. Each cluster also contained a shallow well screened to intercept the water table, and a deep well placed to allow sampling 5 ft (1.5 m) below the shallow well for monitoring ground water. A single instrument cluster was installed in the control plot.

Soil to 12 inches (30 cm) was collected at 15 intervals over a 2 year period. Soil pore water and ground water were collected pre-application, 14 DAT, around 33 DAT and then monthly through to the end of the 2 year interval (June 1998), every second month through to the end of 1998 and in March 1999 (1007 DAT). Soil pore water was also collected at 7 DAT.

Fenamiphos, M01 and M02 were measured with a LOQ of 0.01 mg/kg soil and 0.1 µg/L in water. The LOD in water was 0.02 µg/L for fenamiphos and 0.04 µg/L for M01 and M02. Bromide ion was also measured in the soil and water samples.

Findings

Following application, there was no irrigation for 7 days. However, rainfall of 13.5 mm and 11.7 mm occurred at 2 and 3 DAT respectively.

Dissipation of Fenamiphos Residues from Soil

The residues detected were generally low as shown in the following table, with an apparent spike in fenamiphos residues found at 7 DAT. Fenamiphos itself was only found in the 0-15 cm layer and even at day 0, had almost been completely oxidised to M01. A summary of soil residues found are as follows:

Table A1.46: Fenamiphos, M01 and M02 residues in soil to 30 cm (mg/kg)

	0-15 cm soil layer			15-30 cm soil layer	
DAT	Fen	M01	M02	M01	M02
0	0.37	2.78	0.04	-	-
1	0.14	0.7	0.06	-	-
3	0.08	0.6	0.06	-	-
7	0.34	0.88	0.17	0.01	-

DAT	0-15 cm soil layer			15-30 cm soil layer	
	Fen	M01	M02	M01	M02
14	0.09	1	0.37	0.07	0.01
34	0.04	0.64	0.36	0.07	0.02
119	0.02	0.24	0.17	0.21	0.08
181	0.02	0.21	0.13	0.08	0.02
272	0.02	0.22	0.14	0.12	0.04
362	0.02	0.17	0.1	0.1	0.04
447	0.02	0.13	0.08	0.1	0.04
544	0.01	0.13	0.07	0.08	0.03
635	0.02	0.12	0.06	0.08	0.03
727	0.01	0.1	0.06	0.05	0.02

Half-life calculations need to be treated with some caution. The data were not well correlated in half-life predictions (r^2 values ranging from 0.16 to 0.69). Fenamiphos degraded rapidly in the soil to M01 through 34 DAT followed by a slower degradation phase. The study authors calculated half-lives for fenamiphos and total residues, assuming first order kinetics (PRISM v 2.01). A bi-phasic model was determined to give the best fit of the data, and assumed rapid initial degradation through 34 DAT for fenamiphos and 119 DAT for total residues. DSEWPAC re-calculated the data based on DT50 = -ln(2)/*k*, and confirms the bi-phasic nature. Generally, better correlations were found in the DSEWPAC calculations, but the half-lives were in good agreement with those found in the study and the study calculated values are reported. The first phase half-life for fenamiphos was 14 days with 498 days for the second phase. For total resides detected above the LOQ, the first phase half-life was 126 days with the second phase half-life being 495 days. It should be noted, these values were calculated despite a reduction of total residues of well over 50% by the first day following application. If total residue data over the first week are considered (where DT50 = -ln(2)/*k*), just based on 0 and 7 DAT (this is where a spike in levels of fenamiphos was observed), the first order half-life is around 6 days, and from day 7 onwards, a second phase half-life of 300 days (r^2 = 0.87) is predicted.

Leaching of residues

At the 18 month sampling interval, deeps soil cores (1.2 m) were collected to try and define the extent of leaching. The results indicated that fenamiphos residues were primarily in the 0-30 cm soil layer with limited residues (<0.01 mg/kg) in the 30-45 cm layer. Fenamiphos residues were <0.005 mg/kg (half the LOQ) in the soil layers between 45-106 cm indicating minimal leaching.

Groundwater findings

Bromide moved through the soil profile and into ground water, indicating that sufficient water was applied to the site (5000 mm or rain and irrigation)). However, movement of fenamiphos residues was not observed. In the 821 soil pore water samples, fenamiphos was detected in three samples (≤0.14 µg/L) and M01 was detected in five samples (≤0.20 µg/L). In the 464 groundwater samples, there were two detections of M01 at 0.04 and 0.05 µg/L. In pre-application samples, fenamiphos was detected at 0.02 µg/L and M02 was detected at 0.06 µg/L.

Conclusion

Fenamiphos residues did not appear to leach under the conditions of this study. In the soil, fenamiphos degraded with a bi-phasic degradation pattern including a first phase half-life of 14 days and a much longer second phase half-life of almost 500 days.

Report: Dyer *et al*, 1998
Guidelines: EPA Guideline Subpart N, 166-1
GLP: Yes.

Test System

A small scale prospective ground-water monitoring study was conducted near Lake Placid in Highlands County, Florida, USA. The test site consisted of a 5 acre (2 ha) test plot ant two one acre (0.4 ha) control plots. The soil was a highly permeable sand from the ground surface to the water table with >96% sand, <3% silt and <2% clay. Organic matter was <0.2%. The depth to ground water beneath the test plot was around 6.2 m at the beginning of the study.

Fenamiphos was applied on 19 April 1995 at a target rate of 5.5 lb/A (6.2 kg/ha) per grove acre. The application was made as a 50% band along the tree row resulting in an actual application rate in the treated area of 12.3 kg/ha. The application rate was verified using sample containers containing soil and results indicated application occurred at 75% of the target rate.

The test plot contained three on-site well clusters with each cluster containing a shallow well screened from 2.5 ft (0.76 m) below to 7.5 ft (2.3 m) above the water table, and intermediate and deep wells with 5 ft (1.5 m) screens, laced 5 ft (1.5 m) and 10 ft (3 m), respectively, below the shallow well. Off-site well clusters were installed 15 and 30.5 m west and east of the test plot (ground-water flow direction was to the east). The test plot also contained twelve suction lysimeter clusters with lysimeters at depths of 3, 6, 9 and 14 ft (0.9, 1.8, 2.7 and 4.3 m respectively). A single cluster of lysimeters was installed in the control plot.

Fenamiphos, M01 and M02 were monitored in soil, soil pore water and ground water. Bromide was also monitored as a tracer for water movement. Soil (0-91 cm) was collected at 13 intervals over a 454 day period (15 months post application). Soil pore water was collected at pre-application, 7, 14 and 28 DAT, and monthly thereafter through 18 months post application. Ground water was collected at the same intervals as soil pore water, except no collection was made at 7 DAT. The LOQ for fenamiphos was 0.01 mg/kg soil and 0.1 µg/L in water.

Findings

The day following application 0.73 inches (18.5 mm) irrigation was applied. No rain was recorded until 6 DAT. At 6 and 7 DAT, 3 and 2 mm rain respectively fell. However, at 6 DAT, an additional 57 mm was applied as irrigation. During the study, water input was approximately 3530 mm (1980 mm as rain and 1550 mm as irrigation).

Dissipation of Fenamiphos Residues from Soil

Fenamiphos itself was essentially retained in the 0-15 cm soil horizon. In the 15-30 cm layer it was only found at 0.1 mg/kg at day 3, and then only at minor amounts (0.02 mg/kg) at days and 56.

The following table shows the soil residues in the top 0-30 cm soil layers.

Table A1.47: Fenamiphos, M01 and M02 residues in soil to 30 cm (mg/kg)

	0-15 cm soil layer			15-30 cm soil layer	
DAT	Fen	M01	M02	M01	M02
0	2.63	1.77	0.02	0	-
1	1.73	0.97	-	0.04	-
3	0.56	0.8	0.03	0.03	-
7	0.51	2.8	0.1	0.01	-
14	0.16	0.4	0.11	0.02	-
28	0.3	1.39	0.14	0.01	-
56	0.06	0.72	0.25	0.07	0.02
84	-	0.09	0.04	0.01	-
182	0.01	0.04	0.03	0.01	0.01
272	-	0.02	0.01	-	-
363	-	0.06	0.03	-	0.01
454	-	0.04	0.03	-	-

Parent fenamiphos was rapidly converted to M01. The half-life of fenamiphos itself was biphasic with an initial half-life (0-14 DAT) of 3.8 days (k = -0.1835; r^2 = 0.882). DSEWPAC has re-calculated the study second phase half-life from 14-182 DAT to be 37 days (k = -0.0186; r^2 = 0.93). In terms of total residues, M01 was found throughout the soil profile, down to 106 cm, on days 3 to 56 (0.01-0.02 mg/kg). M02 was found intermittently below 30 cm, but never found below 60 cm.

Dissipation of total residues again appeared biphasic. However, the variability in residues made half-life determination more difficult to calculate. Total residue half-life to 84 DAT was predicted by DSEWPAC to be 25 days (k = -0.0277; r^2 = 0.67). From this time, residues until day 454 essentially halved from 0.18 mg/kg to 0.09 mg/kg.

Leaching of residues

Apart from the distribution of residues through the soil profile as described above, leaching through the soil was also addressed through measurement of resides in soil pore-water. Suction lysimeters were used to sample soil pore water at 0.9, 1.8, 2.7 and 4.3 m in the treated plot (6 samples from each depth at each sampling interval). In the control plot, no fenamiphos residues were detected at any depth in the soil pore water. The following table provides mean residue data collected from the test plot.

Table A1.48: Fenamiphos, M01 and M02 residues in soil pore water to 4.3 m (µg/L)

DAT	0.9 m	1.8 m	2.7 m	4.3 m	TOTAL
7	815.6	43.7	43.3	-	902.6
14	976	91.7	90.3	-	1158
28	631.8	118.5	216.1	70.7	1037.1
56	653	76.5	173	133.8	1036.3
84	51.3	48.1	118.1	93.9	311.4
111	258.8	19.6	81.1	68.4	427.9
133	119.6	12.1	50.9	47.7	230.3
182	85.5	4.9	21.7	16.6	128.7
210	3.6	3.1	10.3	5.2	22.2
238	3.2	2.6	6.5	3	15.3

DAT	0.9 m	1.8 m	2.7 m	4.3 m	TOTAL
273	2.5	2.2	3.7	2.2	10.6
302	60.1	1.5	2.4	1.1	65.1
335	1	1.3	1.9	0.6	4.8
364	4.4	0.7	1.4	0.4	6.9

Parent fenamiphos was only a minor contributor to the detected residues. In a single sample at 7 DAT at 0.9 m, fenamiphos was found at 288.2 µg/L, and again at 14 DAT from the same lysimeter at 0.9 m, at 77.2 µg/L. Otherwise, detections were almost all in the low to sub µg/L range. The major contributor to residues was M01. M02 contributed more at the shallower depth (0.9 m) where on average, 29% of residues were M02 (range of 7 to 57%). However, at 1.8, 2.7 and 4.3 m, M01 contributed on average 88, 85 and 92% of total residues respectively based on all sampling times, and at any one sampling time, the lowest contribution of M01 was 78% of total residues.

Total residues persisted in the soil pore water with a half-life around 40 days. This must be considered a dissipation half-life as residues could be removed through either leaching further down the soil horizon in pore water, or degradation. The following table summarises half-life data by sampling depth and for total residues, based on the equation DT50 = -ln(2)/*k*. The half-lives followed first-order kinetics in all cases.

Table A1.49: Dissipation half-lives of total fenamiphos residues (fenamiphos+M01+M02) in soil pore-water.

	0.9 m	1.8 m	2.7 m	4.3 m	TOTAL
k	-0.0195	-0.0149	-0.0164	-0.0202	-0.0174
r^2	0.84	0.96	0.99	0.99	0.95
DT50(d)	36	47	42	34	40

Groundwater findings

Fenamiphos, M01 and M02 were quantified in groundwater with an LOQ of 0.1 µg/L. Fenamiphos residues were first detected in groundwater at 84 DAT. The following table shows mean (values from three onsite wells) resides over time. At the last sampling time of 553 DAT, no residues were found.

Table A1.50: Total (Fenamiphos, M01 and M02) residues in Ground water (µg/L)

DAT	Shallow	Intermediate	Deep
84		3.4	
111	0.4	1.8	
133	3.6	0.6	
183	35.7	1	
209	17.9	15.1	1.2
237	10.2	7.3	0.2
272	14	5.9	0.2
301	7.9	13.5	
334	4.7	4.7	2.9
364	1.8	4.4	
392		1.7	0.2
419		0.8	0.7
454	0.34	1	0.7

DAT	Shallow	Intermediate	Deep
489	0.14	0.4	0.2
518		0.1	

Residues varied significantly between the wells. Approximately 95-100% of the ground-water residues were detected as M01, which is supported by the residues above as found in the soil pore-water. Total residues peaked at 183 DAT. Dissipation from the on-site wells from the peak levels at 183 DT until 489 DAT followed first order kinetics with a half-life of 53 days ($r^2 = 0.91$).

In off-site wells, M01 was detected in the hydraulically upgradient wells, but only intermittently and at levels <0.5 µg/L (with one exception of 2 µg/L being detected in the intermediate well 183 DAT). Conversely, in the 15 m downgradient well, M01 was found regularly at all depths from 209 DAT until the end of the sampling (553 DAT). Maximum residues found were 9.76 µg/L (419 DAT, intermediate well). The average of all detections in the 15 m downgradient well was 2.60 µg/L.

In the 100 ft (30 m) downgradient well, resides were reasonably intermittent until 419 DAT where they were found regularly at all depths until the end of the study. Residue levels were generally <1 µg/L with two exceptions of 1.2 and 2.12 µg/L at 489 and 518 DAT respectively in the intermediate well. The average of all detections in the 30 m downgradient well was 0.51 µg/L.

Conclusion

Under the conditions of this study (highly permeable sandy soils with high water input), fenamiphos residues leached rapidly through the soil profile. In all media tested (soil, soil pore water and ground water), M01 was the major contributor to residues. Fenamiphos was largely retained in the top 15 cm of soil.

In soil, the dissipation half-life of total fenamiphos followed a bi-phasic pattern with the first (quicker) half-life being around 84 days and a much slower second half-life in the order of 1 year. In soil pore-water, the half-life of total residues followed first order kinetics and was around 40 days. In groundwater as measured in the on-site wells, residues peaked at shallow levels after 183 days. Total residues from these on-site wells dissipated with a half-life around 53 days. There was a degree of dilution (possibly including some further degradation) as groundwater moved downgradient with concentrations peaking at 15 m downgradient between 334-420 DAT and at levels several times lower than the on-site ground water, then reduced even further in concentration (by around a further factor of 5) in the 30 m downgradient well.

Report: Lenz *et al*, 2000; Helfrich *et al*, 2001
Guidelines: EPA Guideline Subpart N, 166-1
GLP: Yes.

Test System

A small scale prospective groundwater monitoring study was conducted south of Sanger in Fresno County, California. The test site consisted of a 2.9 acre (1.2 ha) test plot and a 1.3 acre (0.53 ha) control plot located within an established grape vineyard. The surficial soils (0-15 cm) were comprised of loamy sand and sand containing approximately 86% sand, 8% silt, 6% clay and 0.9% organic matter. This soil series extended from the surface to around 8 feet (2.4 m) below the ground surface. Sand lies below these soils from 8 feet to the depth of the soil borings (9.1-10.7 m).

Fenamiphos was applied to the test plot as a foliar banded spray on 15 October 1997 at a rate of 8.3 kg/ha. Soil trays and solvent saturation pads placed in the field before application indicated that the

target rate was achieved. Potassium bromide was applied on the same day at 60.5 kg/ha as a tracer for following water movement through the soil profile.

The test plot contained eight instrument clusters containing suction lysimeters at 0.9, 1.8, 2.7 and 3.7 m deep for monitoring soil-pore water. Each cluster also contained a shallow well screened to intercept the groundwater table, and a deep well screened directly below the shallow well. A single instrument cluster was installed in the control plot. Soil to 15 cm was collected at 15 intervals over a 2 year period and again at 4.1 years to check for any remaining fenamiphos residue. Soil pore water and groundwater were collected at pre-application, approximately 16 and 30 DAT and monthly, except for one sampling interval each year when the grapes were harvested. Soil pore water was also collected at 9 DAT.

Soil residues of fenamiphos, M01 and M)2 were measured with a LOQ of 0.01 mg/kg. The LOD in soil was 0.001 mg/kg for fenamiphos and 0.002 mg/kg for M01 and M02. Groundwater and soil pore water residues for all analytes were measured with a LOQ of 0.1 µg/L. The LOD in pore water was 0.006 µg/L for fenamiphos and 0.015 µg/L for M01 and M02. The LOD in groundwater was 0.006 µg/L for fenamiphos, 0.008 µg/L for M01 and 0.003 µg/L for M02.

Findings

On the day of application, 0.03 inches (0.76 mm) rain was recorded, while the day following application, 0.69 inches (17.5 mm) irrigation was recorded. No further rainfall or irrigation was applied to the test plots for 2 weeks after this. Total water input on the site after the first month was 1.8 inches (45.7 mm).

Dissipation of Fenamiphos Residues from Soil

Routine measurements of fenamiphos and metabolites were only taken in the 0-15 cm soil layer. The following table summarises mean residue values (25 samples from day 0 with 15 samples at other sampling times):

Table A1.51: Fenamiphos, M01 and M02 residues in soil to 15 cm (mg/kg)

DAT	Fen	M01	M02	TOTAL
0	2.893	1.509	0.021	4.423
1	1.049	2.956	0.297	4.302
5	0.635	2.369	0.273	3.277
8	0.623	1.952	0.265	2.84
14	1.089	2.106	0.125	3.32
29	0.702	3.05	0.358	4.11
62	0.269	1.018	0.372	1.659
96	0.274	0.4	0.307	0.981
180	0.01	0.037	0.016	0.063
273	0.002	0.006	0.002	0.01
373	0.001	0.002	0.001	0.004
457	0.001	0.004	0.001	0.006
554	0.001	0.002	0.001	0.004
642	0.001	0.001	0	0.002
737	0	0.001	0	0.001

M01 was the main contributor to total residues following initial rapid conversion of fenamiphos to this metabolite. The study authors had calculated the half-life of fenamiphos and total residues based on 0-180 day data. DSEWPAC has calculated half-lives for fenamiphos, metabolites and total

residues, generally to 373 days. Degradation/dissipation to this time was followed first order kinetics and provided better correlation than that obtained by the study authors. The following DSEWPAC calculated values (based on DT50 = -ln(2)/*k*) are:

Table A1.52: Half-lives (d) for Fenamiphos, M01, M02 and total residues in soil to 15 cm

	Fenamiphos	M01	M02	TOTAL
k	-0.021	-0.021	-0.0166	-0.0202
r^2	0.95	0.98	0.9	0.98
DT50 (d)	33	33	42	34

Leaching of residues

Movement of residues through the soil profile was only measured once at 29 DAT. As shown above, total residues in the 0-15 cm layer at this time were 4.11 mg/kg. This compared to mean total residues of 0.46, 0.126 and 0.235 mg/kg at 15-30, 30-45 and 45-60 cm respectively. Therefore, there appeared to be some movement of residues through the soil profile, but the majority of applied chemical tended to reside in the top 15 cm of soil.

A further indication of leaching came from considering the residues in soil pore water. The data in this regard are somewhat difficult to summarise as at a very large number of sampling times, residues in the report are noted as "NS", that is, no sample could be obtained from the lysimeter. Considering the data available, fenamiphos itself was only sporadically found in lysimeters at low concentrations (mostly <0.1 µg/L). After 90 DAT, parent fenamiphos was never found in the 3.7 m deep lysimeters and only found in the 2.7 m lysimeters at a couple of other sampling days. Again, the main metabolite found in the soil pore water was M01. This metabolite was found consistently to 2.7 m up to 671 DAT. The highest levels found were at 1.8 m with mean concentrations of 39.4 to 32.8 µg/L found between 156 and 245 DAT. The maximum concentration found was 315 µg/L at 156 DAT (with maximum total residues of 343 µg/L also found at this time). Low levels of M01 (mean values 0.06 µg/L or less) were found at 0.9 m from 820 to 944 DAT.

M02 contributed smaller residues to the soil pore water. Again, highest levels were found at 1.8 m with mean residues of 2-4 µg/L found between 156 and 300 DAT. The highest concentration found was 31.6 µg/L, 218 DAT at 1.8 m.

Groundwater findings

Detections in groundwater were very infrequent. Parent fenamiphos residues were only found on 2 sampling days (17 DAT – three wells; and 216 DAT – 1 well), always at 0.05 µg/L or less. Similarly, M02 was only found once in one well at 216 DAT (0.53 µg/L)

The biggest contributor to ground water residues was M01. The highest residues found were 2.13 µg/L in one shallow well 302 DAT. Between 17 and 462 DAT, a total of 240 samples were taken (120 each from deep and shallow wells). M01 was detected in 39 samples (~16%), and 35 of these were <0.1 µg/L.

Conclusion

Under the conditions of this study fenamiphos residues had a limited potential for leaching to ground water. Initially, fenamiphos degraded in the soil to M01 and then M02. The half-life of fenamiphos, M01 and total residues were 33 to 34 days in the top 15 cm soil. The maximum concentration of total residues in soil pore water was 343 µg/L at 1.8 m and 156 days after application. The maximum concentration of total fenamiphos residues in ground water was 2.13 µg/L 302 days after the application.

APPENDIX 4 Technical report for environmental effects of fenamiphos

Contents

Avian Toxicity

Acute Oral

Several studies were provided to the APVMA for review with the following results:

Table A2.1. Summary of Acute Bird Toxicity Results for Fenamiphos and Metabolites

Species	LD50 (mg ac/kg bw)	NOEC (mg ac/kg bw)	Reference
Fenamiphos technical			
Japanese quail	1.28	<0.9	Barfknecht, 1998
Bobwhite quail	1.6	0.25	Lamb, 1982
Mallard duck	1.0	0.5	Nelson and Burke, 1977a
Bobwhite quail	0.7 (males)	0.46 (males)	Lamb, 1978
Mallard duck	1.1 (males)	0.68 (males/females)	Lamb, 1978
M01			
Bobwhite quail	1.8	1.0	Lamb, 1978
Mallard duck	1.5	0.68 (males)	Lamb, 1978
M02			
Bobwhite quail	1.9 (males)	1.0	Lamb, 1978
Mallard duck	1.1 (males)	0.68	Lamb, 1978

Test Substance: Fenamiphos technical
Report: Barfknecht, 1998
Guidelines: FIFRA Guideline 71-1
GLP: yes

Test System

The study aimed to establish toxicity of fenamiphos to Japanese quail (*Coturnix coturnix japonica*). Five males and five females were allocated randomly to each of three treatment groups and one control group. Around 24 h prior to dosing, body weights were determined. The birds were starved for 15 h prior to oral administration of the test substance. Dose levels of 0.9, 1.5 and 2.5 mg ac/kg bw were chosen. The dose was administered through a gelatin capsule with control birds receiving an empty capsule.

During acclimatisation and exposure, the test units were maintained at around 22-26^{o}C, relative humidity of 45-55% and a 16:8 h light:dark photoperiod. Observations on mortality and signs of intoxication were made around one hour after dosing and at least once each workday throughout the 14 day observation period. Body weights were recorded at day –1, 7 and 14. On study days 3, 7 and 17 all remaining feed amounts were replaced with fresh food and food consumption recorded. At the end of the study, all surviving birds were sacrificed. Gross necropsies were carried out on all premature dead birds and on all survivors at the end of the study.

The LD50 was calculated by non-linear interpolation.

Findings

All test substance-treated birds showed severe signs of acute intoxication immediately after treatment. At the higher dosage groups, most of the affected birds died within the first 4 hours after

treatment (3 male/5 females at 1.5 mg/kg bw; 5 males/5 females at 2.5 mg/kg bw). The remaining survivors did not completely recover until one day after treatment.

Negative effects on body weight development of treated birds were not evident. All survivors showed a slight increase of body weight over the study period. As treated survivors showed a slightly decreased feeding rate during the first three days after test substance administration, a dosage dependence was not evident. During the further observation period, the feeding rates of treated survivors recovered.

Gross necropsy examination revealed a dose-response relationship in quantity of the pathological findings, particularly based on the appearance of spleen. Therefore, the observed effects on spleen must be assumed as treatment-related. Treatment related effects on testicles and ovaries were not detectable. Only one bird, treated with 1.5 mg/kg showed no sexual maturity.

Conclusion

Of the three dose levels tested, the lowest lethal dose was 1.5 mg/kg bw (80% mortality at this level). The LD50 was calculated to be 1.28 mg/kg bw (confidence intervals not reported). The LOEL was 0.9 mg/kg bw. A NOEC could not be determined due to toxic effects apparent in all treated birds at the lowest test level.

Test Substance: **Fenamiphos (Nemacur) technical**
Report: Lamb, 1982
Guidelines: Not stated
GLP: No

Test System

This older study aimed to establish the acute oral LD50 of fenamiphos technical to bobwhite quail (*Colinus virginianus*). Groups of five male and five female birds were treated at 0.25, 0.5, 1.0, 2.0, 4.0 and 8.0 mg/kg bw with a control group treated with the vehicle (carbowax). Birds were fasted for 20 hours prior to dosing. The test material was administered orally at 1% (v/w) of the bird's body weight. Feed was withheld for one hour following administration of the test material. Birds were housed at room temperature (19-21^{o}C) with ambient relative humidity and 12 hours of light per day.

The quail were observed for mortality and symptoms of toxicity at 0.5-1 hours post treatment and twice daily for 14 days after treatment. Body weights were recorded at the time of treatment and after 14 days. Feed consumption was recorded daily. All birds were examined for gross lesions at the time of death, or at the end of the study.

Mortalities were analysed by the method of Carrol S. Weil, Biometrics, 8, No.3, Sept. 1952 to determine the LD50.

Findings

Birds in the control group and 0.25 and 0.5 mg/kg bw treatment groups appeared normal throughout the study. Two birds at 1.0 mg/kg had ataxia, but there was no mortality.

The mortality rates at 2.0, 4.0 and 8.0 mg/kg were 90, 90 and 100% respectively. Salivation, tremors, convulsions, ataxia and wing droop were observed as signs of toxicity in these birds.

Body weight changes were consistent between treatment groups over the 14 day period. There was a slight decrease in the amount of feed consumed for the first two days of the study for treatment

groups 1.0, 2.0 and 4.0 mg/kg. Feed consumption for the remainder of the study was consistent between the groups.

No dose-related or compound-related lesions were apparent.

Conclusion

The LD50 was determined to be 1.6 mg/kg bw (95% CI 1.3-1.9 mg/kg bw). There were no observable toxic effects at the levels of 0.25 and 0.5 mg/kg bw.

Test Substance: **Fenamiphos (Nemacur) technical**
Report: Nelson and Burke, 1977a
Guidelines: Not stated
GLP: No

Test System

This older study aimed to establish the acute oral LD50 of fenamiphos technical to mallard duck (*Anas platyrhnchos*). Male and female ducks were housed by sex with 10 birds per cage. Ten animals of each sex were used for one dose level and they were fasted for 18-22 hours. A geometric scale of 1.5 was used to determine dose levels of 0.5, 0.8, 1.1 and 1.7 mg/kg bw. The compound was diluted in Lutrol (polyethylene glycol) and administered orally to the birds at a rate of 0.1% of their body weight. After dosing the animals were observed daily over a 14 day period for signs of toxicity and mortality. Necropsies were performed on all animals on day 14 or at the time of death. Mortalities were analysed by the method of Carrol S. Weil, Biometrics, 8, No.3, Sept. 1952 to determine the LD50. No other experimental details are provided.

Findings

Ataxia and immobility were seen as signs of toxicity. The survivors did not show any signs of toxicity after 16 hours. At the lowest level there were no deaths in either sex. There was 100% mortality in both sexes at the 1.7 mg/kg level. The other two levels had mortalities in both sexes. At 0.8 mg/kg, 15% mortality was observed (1 male/2 females) while at 1.1 mg/kg, 70% mortality was observed (6 males/8 females).

The birds did not have any gross lesions when the necropsies were performed.

Conclusion

The LD50 was determined to be 1.0 mg/kg bw (95% CI 0.9-1.2 mg/kg bw) to males and 0.9 mg/kg bw (95% CI of 0.8-1.1 mg/kg bw) to females. There were no observable toxic effects to either males or females at 0.5 mg/kg bw.

Test Substance: **Fenamiphos (Nemacur) technical; M01; M02**
Report: Lamb, 1978
Guidelines: Not stated
GLP: No

Test System

This older study was conducted to determine the acute oral toxicity of technical fenamiphos and its sulfoxide and sulfone metabolites when each was administered in a single dose to male and female bobwhite quail (*Colinus virginianus*) and mallard ducks (*Anas platyrhnchos)* with a 96 h observation period. Each of the three compounds was diluted with a solution of propylene glycol

and ethanol (80/20 respectively). The final solution for each level contained the required dose in 1 mL/kg bw.

Groups of four male and four female birds were treated differing levels shown in the table below. Birds were fasted for 17-24 hours prior to dosing. Birds were housed at ambient temperature (-10^{o}C to 19^{o}C) in outside pens. A snow fall of 3 mm fell on day 4 of testing for the technical compound.

Body weights were taken prior to dosing and again on day 4. The birds were observed for 96 h for toxic signs and mortality.

Mortalities were analysed by the method of Carrol S. Weil, Biometrics, 8, No.3, Sept. 1952 to determine the LD50.

Findings

The results showed all compounds to be fast acting. Signs exhibited by both species included ruffled feathers, tremors, laboured breathing, hypoactivity and complete immobility. The following table shows mortality results for quail and ducks in terms of percent mortality (based on four individuals per sex per treatment level).

Table A2.2: % Mortality for Quail and Ducks exposed to Fenamiphos, M01 and M02

Bobwhite Quail								
Technical: doses (mg/kg)	0.00	0.46	0.68	1.00	1.50			
Male mortality %	0	0	50	100	100			
Female mortality %	0	0	0	75	100			
M01: doses (mg/kg)	0.00	0.68	1.00	1.50	2.20	3.20		
Male mortality %	0	0	0	25	75	100		
Female mortality %	0	0	0	25	75	100		
M02: doses (mg/kg)	0.00	0.68	1.00	1.50	2.20	3.20	3.20	6.80
Male mortality %	0	0	0	0	50	50	75	100
Female mortality %	0	0	0	50	0	75	50	100
Mallard Ducks								
Technical: doses (mg/kg)	0.00	0.46	0.68	1.00	1.50	2.20		
Male mortality %	0	0	0	25	100	100		
Female mortality %	0	0	0	25	75	100		
M01: doses (mg/kg)	0.00	0.68	1.00	1.50	2.20	3.20		
Male mortality %	0	0	25	50	75	100		
Female mortality %	0	0	0	50	100	100		
M02: doses (mg/kg)	0.00	0.68	1.00	1.50	2.20			
Male mortality %	0	0	50	75	100			
Female mortality %	0	0	25	50	100			

Birds that exhibited extreme signs and did not die recovered within two hours except for four quail, which died as late as 67 hours after treatment. Average body weights of the quail showed that the majority of surviving quail maintained their initial weight. Average body weights for the ducks showed that the majority of the birds used for the technical compound maintained their initial body weight. However, ducks used for the sulfoxide and sulfone including the controls did not return to their normal weight. The two metabolite groups were treated at a different time and experienced different environmental conditions.

Conclusion

The following LD50 and associated confidence intervals were found:

Species	Compound	Sex	LD50 (mg/kg)	95% CI (mg/kg)
Quail	Technical	M	0.7	0.5-0.8
		F	0.9	0.7-1.1
	Sulfoxide	M	1.8	1.4-2.3
		F	1.8	1.4-2.3
	Sulfone	M	1.9	1.2-3.1
		F	4.3	3.2-5.8
Duck	Technical	M	1.1	0.9-1.3
		F	1.2	0.9-1.6
	Sulfoxide	M	1.5	0.9-2.4
		F	1.5	1.2-1.8
	Sulfone	M	1.1	0.8-1.5
		F	1.3	1.0-1.8

Short-Term

Three avian dietary studies were provided to the APVMA for technical fenamiphos. No data for metabolites were provided.

Table A2.3. Summary of Short-Term Bird Toxicity Results for Technical Fenamiphos

Species	LC50 (mg ac/kg diet)	NOEC (mg ac/kg diet)	Reference
Fenamiphos technical			
Bobwhite quail	78	9.84	Bowers and Webster, 2002
Bobwhite quail	38	<10	Nelson and Burke, 1977b
Mallard duck	94	<46.4	Fink, 1977

Test Substance: **Fenamiphos technical**
Report: Bowers and Webster, 2002
Guidelines: FIFRA Guideline 71-2
GLP: yes

Test System

The study aimed to evaluate the toxicity of fenamiphos when administered to juvenile bobwhite quail (*Colinus virginianus*) in the diet for 5 days. Nominal test levels were 5, 10, 24, 40 and 80 ppm. The test consisted of an acclimation period of 10 days, an exposure period of 5 days and a post exposure observation period of 3 days.

The birds were 13 days of age at the initiation of the study. Birds were assigned to 5 test groups and a control group. Each treatment and control group contained 10 birds that were not differentiated on sex due to their age. Test diets were prepared by mixing the test substance into the diet following dissolution in acetone. No oil or other carriers were used. The diet was analysed for homogeneity and stability prior to study initiation. Average ambient room temperature was around 22^{o}C and the

average relative humidity was approximately 53%. The photoperiod was 16 hours of light per day during acclimation and through the study.

Following test initiation and continuing until termination, all birds were observed daily. Observations of mortality, signs of toxicity and abnormal behaviour were recorded. Individual body weights were measured at day -3, test initiation, on day 5 and at termination of the test on day 8. Feed consumption during the exposure period and observation period was recorded for each pen.

Findings

Mean measured diet concentrations were 4.55, 9.84, 18.3, 39.3 and 78.0 mg/kg feed (ppm) representing a range of 91-98% nominal values.

There was no mortality in the control or three lowest test concentrations. During the 5 day exposure period, two deaths (20%) were recorded in the 39.3 ppm group, and four deaths (40%) in the highest test group. An additional death was recorded in this group during the recovery period. Several of the birds at the two highest treatment levels were showing symptoms of hyporeactivity and wing drop. Three birds that were found dead were emaciated, probably caused by starvation due to feed aversion.

Statistical analysis was performed on day 0, day 5 and day 8 body weights and showed a significant difference at the three highest treatment levels compared to the controls. The day 8 data indicated that the 18.3 ppm group had recovered, but a significant difference remained at the two highest test levels compared to the control.

Statistical analysis was also performed on growth from day 0-5, day 5-8 and day 0-8. The day 0-5 growth analysis indicated a significant difference at the three highest test levels compared to the control while the day 0-8 data showed significant differences in the two highest test groups.

Feed consumption was evaluated as g/bird/day. Prior to exposure, feed consumption was equal at all levels. After commencement of exposure, consumption declined slightly at 18.3 ppm and very noticeably in the 39.3 and 78 ppm levels. Feed consumption at the three highest levels remained lower for all 5 days of the exposure period. Birds surviving in the three highest exposure levels showed an increase in consumption and body weight during the recovery phase.

Apart from the emaciated birds, post mortem examination revealed no unusual trends or findings in any birds from any test level. Necropsy results indicated no gross lesions.

Conclusion

No treatment related findings were noted at 4.55 and 9.84 ppm. Based on the results of this study, fenamiphos contaminated feed decreases food consumption in young bobwhite quail at 18.3, 39.3 and 78 ppm. The NOEC for sublethal or behavioural effects was 18.3 ppm. The NOEC for food consumption and growth was 9.84 ppm. The NOEC for mortality was 39.3 ppm. The subacute dietary LC50 of fenamiphos in bobwhite quail in this test was 78 ppm (95% CI 52 – 293 ppm).

Test Substance: **Fenamiphos technical**
Report: Nelson and Burke, 1977b
Guidelines: Not stated
GLP: no

Test System

The study aimed to evaluate the toxicity of fenamiphos when administered to juvenile bobwhite quail (*Colinus virginianus*) in the diet for 5 days. Nominal test levels were 0, 10, 15, 22, 32, 47 and

69 ppm. The test consisted of an exposure period of 5 days and a post exposure observation period of 3 days. An acclimatisation period was not reported.

The birds were 13 days of age at the initiation of the study. Birds were assigned to 6 test groups and a control groups. Each treatment and control group contained 10 birds that were not differentiated on sex due to their age. Test diets were prepared by mixing the test substance into the diet with corn oil as the carrier. No analysis of the diet for homogeneity, stability or actual concentrations was undertaken. Exposure conditions (temperature, humidity, and photoperiod) are not reported.

Body weights were measured at day 0 and day 5. On day 5, feed consumption was measured and untreated feed given to the birds. Body weights and feed consumption were measured again on day 8 and the birds were sacrificed. Signs of toxicity and mortality data were taken on each day of the study.

Findings

Mortality of 0, 20, 0, 10, 30, 70 and 100% was found in the control, 10, 15, 22, 32, 47 and 69 ppm treatment groups respectively, with all deaths occurring by days 3 and 4 of the exposure period. Birds at all treatment levels were noted as exhibiting signs of toxicity (20, 10, 30, 30, 100 and 100% of birds in the 10, 15, 22, 32, 47 and 69 ppm treatment groups respectively). Signs included wing drop, ataxia and immobility. These signs persisted throughout the study in the four highest levels. In the two lower levels, all surviving birds appeared normal by day 6.

Survivors at the 22, 32 and 47 ppm exposure groups showed a decrease in the body weights from day 0 to 5 and an increase in their body weights was seen from day 5 to 8. The birds on the lower levels showed an increase in their body weights throughout the study. However, while not reported by the study authors, this increase in body weight was quite a bit lower by comparison with the control birds. Control birds average body weight increased by 65% over the 5 day exposure period (average of 20 g at day 0 to 33 g at day 5). By comparison, average weights in the 10, 15, 22, 32 and 47 ppm groups increased by 13, 4, -4, -13 and -30% over the same period. This is despite greater feed consumption in the two lower treatment groups (an average of 5.7 and 5.9 g/bird/day in the 10 and 15 ppm group) compared with the control birds (average of 4.9 g/bird/day), although there is not mention of possible spillage by birds. In the 22 and 32 ppm treatment groups, average consumption was 3.3 and 3.8 g/bird/day over the exposure period.

Conclusion

The dietary LC50 was calculated to be 38 ppm (95% CI 32-47 ppm) calculated by the method of Carrol S. Weil, Biometrics, 8, No.3, Sept. 1952. NOECs are not reported in this study. However, based on observations of sub-lethal effects and the apparent adverse effect on body weight at all treatment levels, the NOEC is considered to be <10 ppm, the lowest rate tested.

Test Substance: **Fenamiphos technical**
Report: Fink, 1977
Guidelines: Not stated
GLP: no

Test System

The study aimed to evaluate the toxicity of fenamiphos when administered to juvenile mallard duck (*Anas platyrhynchos*) in the diet for 5 days. Nominal test levels were 0, 46.6, 100, 215, 464 and 1000 ppm. In addition, positive control groups exposed to dieldrin up to 269 ppm were maintained. The test consisted of an exposure period of 5 days and a post exposure observation period of 3 days.

The birds were 13 days of age at the initiation of the study. Birds were assigned to 6 test groups and a control group with each level containing 5 pens with 10 birds per pen. Test diets were prepared by mixing the test substance into the diet with corn oil as the carrier. No analysis of the diet for homogeneity, stability or actual concentrations was undertaken. Temperature was maintained at 35.5^{o}C throughout the study. Other environmental parameters (humidity, photoperiod) are not reported.

Body weights were recorded by pen at initiation and termination of the study. Food consumption was recorded by pen during the exposure period. It was measured accurately, but is presented as an estimate due to unavoidable wastage by birds. Symptoms of toxicity and mortality were recorded daily throughout the study. Mortality was analysed statistically by probit analysis.

Findings

There were no deaths in the negative control groups and birds were normal in appearance and behaviour throughout the study. In the fenamiphos treatment groups, no mortalities were recorded in the two lowest treatment levels. In the 215, 464 and 1000 ppm treatment levels, mortalities of 20%, 60% and 60% were recorded respectively at the end of the exposure period, and 40%, 60% and 100% respectively by the end of the study.

Symptoms of toxicity were evident immediately at the 1000 ppm dose level and included depression, reduced reaction to external stimuli (sound and movement) salivation, loss of coordination, prostrate posture, loss of righting reflex, lower limb rigidity, shallow and rapid respiration and minor muscle fasciculations. Those birds which did not die on Day 1 remained in a profound state of depression until death.

Symptoms were similar at 464 and 215 ppm with surviving birds showing lethargy and ataxia through today 8. At the 100 ppm dose level hyperexcitability proceeded the onset of depression, reduced reaction to external stimuli, salivation, and loss of coordination. Overt signs of toxicity at the lowest 46.4 ppm treatment level were limited to lethargy with a transient period of depression and ataxia.

There was a dramatic dose related reduction in feed consumption and body weight gain. Total feed consumption at the 1000 ppm dose level was only 18 g, and at the 464 ppm level the 5 day feed consumption was 27 g. Even at the lowest test concentration, feed consumption to day 5 was <1000 g. This compared to over 3000 g in control pens. The only birds exposed to fenamiphos to show body weight gain over the exposure period were those in the lowest exposure level of 46.4 ppm. However, the gain in body weight was on average around 20% compared to a minimum average pen weight gain of around 55% in control birds.

Conclusion

The dietary LC50 was calculated to be 94 ppm (p = 0.1; 95% CI 78-112), 122 (p = 0.5; 95% CI 108-137), and 158 ppm (p = 0.9; 95% CI 131-189). While not reported in this study, the NOEC must be considered to be <46.4 ppm, the lowest tested rate, due to toxicity signs observed at this level effects on body weight.

Reproduction (Chronic)

Two avian reproduction studies were provided to the APVMA for technical fenamiphos.

Table A2.4. Summary of Chronic Bird Toxicity Results for Technical Fenamiphos

Species	LD50 (mg ac/kg diet)	NOEC (mg ac/kg diet)	Reference
Fenamiphos technical			
Bobwhite quail	-	1.8	Lamb and Carsel, 1982a
Mallard duck	-	3.6	Lamb and Carsel, 1982b

Test Substance: Fenamiphos technical
Report: Lamb and Carsel, 1982a
Guidelines: Not stated
GLP: No

Test System

A reproduction study was conducted with bobwhite quail (*Colinus virginianus*). Quail were fed diets containing 0, 0.5, 2.0 or 8.0 ppm fenamiphos technical for 25 weeks. The purity of the compound is stated as 90%. When the study was initiated, birds were 21 weeks old and their weight range was 160-210 g (males) and 165-220 g (females). Birds were acclimatised for 5 weeks prior to test initiation. For the test, each group had 24 cages with one male and one female per cage.

Fenamiphos was administered to the birds in their diet. The test article was dissolved in acetone mixed with corn oil. The control group received a diet containing 1% corn oil. After one week, all uneaten diet was removed and replaced with fresh food. The test diet was administered for 10 weeks prior to the onset of egg laying and during egg laying. It does not appear as though the diet was analysed for homogeneity, stability or actual test concentrations. Temperature and humidity were maintained at 20.5-23^{o}C and 35-55% respectively. For the first 8 weeks, the birds were kept under a regime of 7.5 h light per day for maximum egg production. The photoperiod was then increased to 17 h light per day for the duration of the study.

Adult birds were observed daily throughout the study for sub-lethal effects and mortality. Body weights were recorded at weeks 0, 2, 4, 6, 8 and 25. Food consumption was determined weekly. At the onset of laying (10th week), eggs were collected twice daily until week 25. These were candled to detect shell cracks before being set, then incubated. Eggs were candled on day 11 of incubation to measure fertility, and on day 21 to measure embryo survival. On day 21 of incubation, the eggs were placed in a hatcher and allowed to hatch. Throughout incubation, the temperature was maintained at 37.5^{o}C and humidity of 84%. They were rotated each hour through day 21 of incubation.

Hatchlings were removed from the hatcher on day 25 of incubation and average body weight determined. Hatchlings were maintained at 38^{o}C until day 14 of brooding. At 14 days of age, the chicks were weighed and sacrificed. On one day in the first, third, fifth, seventh and ninth week of egg laying, all eggs laid on the day were used to measure eggshell thickness.

Gross post-mortem examinations were conducted on the four birds that died during the study, and on ten cages of birds selected at random from each test group at the end of the study.

Reproductive parameters considered in this study were subject to statistical analysis and all significant differences were expressed at the 95% level.

Findings

No compound related signs or lesions were observed during the study. Two males from the control group and one female each from the 0.5 and 2.0 ppm treatment groups died during the study.

There were no significant differences in mean body weights between control and exposed groups. There were no significant differences between groups in feed consumption.

The following table summarises reproductive parameter findings.

Table A2.5: Reproductive Performance from the Bobwhite Quail Reproduction Study.

Experimental Group (mg/kg diet)				
Reproductive Parameter	**Control**	**0.5**	**2.0**	**8.0**
Eggs laid	1506	1606	1652	1555
Eggs cracked (% of eggs laid)	14	12	11	15
Mean egg shell thickness (mm – week 9)	0.20	0.21	0.21	0.20
Eggs set (% of eggs laid)	81	83	85	81
Fertile eggs (% of eggs set)	94	97	93	91
Viable 3-week embryos (% of fertile eggs)	96	95	93	96
Hatchlings (% of fertile eggs)	71	70	65	67
14 day survivors	574	601	606	375*
14 day survivors (% of hatchlings)	70	66	72	48*
14 day survivors (% eggs laid)	38	37	37	24*

* - statistically significantly different from the control.

The only parameter significantly different from the control group related to 14 day old survivors at the highest rate tested. There were no significant differences among groups for weight of 14 day old survivors.

At the termination of the 25 week study, brain cholinesterase activities from compound-exposed birds were 9-15% below those from control birds. No biological significance was attached to reductions of this magnitude.

Conclusion

Fenamiphos had no significant effects on adult body weight, feed consumption, brain cholinesterase, survival or egg production, shell thickness, cracking, fertility or hatching; or on weight of chicks. Chick survival to 14 days was reduced by 31% in the 8.0 ppm group. Therefore, the NOEC from this study was the next highest level tested, 2.0 ppm (1.8 ppm corrected for purity).

Test Substance: **Fenamiphos technical**
Report: Lamb and Carsel, 1982b
Guidelines: Not stated
GLP: No

Test System

A reproduction study was conducted with mallard duck (*Anus platyrhynchos*). Ducks were fed diets containing 0, 4, 8 and 16 ppm fenamiphos technical for 19 weeks. The purity of the compound is stated as 90%. When the study was initiated, birds were 19 weeks old and their weight range was 13.07-1.57 kg (males) and 0.88-1.35 kg (females). Birds were acclimatised for 3 weeks prior to test initiation. For the test, each group had 14 cages with one male and one female per cage.

Fenamiphos was administered to the birds in their diet. The test article was dissolved in acetone mixed with corn oil. The control group received a diet containing 1% corn oil. After one week, all uneaten diet was removed and replaced with fresh food. The test diet was administered for 3 weeks prior to the onset of egg laying and during egg laying. It does not appear as though the diet was analysed for homogeneity, stability or actual test concentrations. Temperature and humidity were maintained at 20.5-23^{o}C and 35-60% respectively. For the first 6 weeks, the birds were kept under a

regime of 7.5 h light per day for maximum egg production. The photoperiod was then increased to 17 h light per day for the duration of the study.

Adult birds were observed daily throughout the study for sub-lethal effects and mortality. Body weights were recorded at weeks 0, 2, 4, 6 and 19. Food consumption was determined weekly. At the onset of laying (4th week), eggs were collected daily until week 19. These were candled to detect shell cracks before being set, then incubated. Eggs were candled on day 14 of incubation to measure fertility, and on day 23 to measure embryo survival. On day 23 of incubation, the eggs were placed in a hatcher and allowed to hatch. Throughout incubation, the temperature was maintained at 37.5^{o}C and humidity of 84%. They were rotated each hour through day 23 of incubation.

Hatchlings were removed from the hatcher on day 29 of incubation and average body weight determined. Hatchlings were maintained at 38^{o}C until day 14 of brooding. At 14 days of age, the chicks were weighed and sacrificed. On one day in the eighth, tenth, twelfth, fourteenth and sixteenth week of egg laying, all eggs laid on the day were used to measure eggshell thickness.

Gross post-mortem examinations were conducted on the bird that died during the study, and on all other birds at the end of the study.

Reproductive parameters considered in this study were subject to statistical analysis and all significant differences were expressed at the 95% level.

Findings

One duck, a female in the 16 ppm group, died during the study. Another in that group was thin for 3 weeks but recovered. One female in the 4 ppm group had transient ataxia. One control and one 4 ppm female had decreased activity.

At necropsy incidental lesions such as pale livers, congested visceral organs and testicular atrophy were seen infrequently without apparent relationship to dose. Some lesions were seen more frequently among the 16 ppm ducks: tapeworms, gizzard enlargement, firm pancreas, yolk peritonitis and emaciation.

The 16 ppm group consumed significantly less feed than the other groups and a few females in that group lost substantial amounts of body weight.

The following table summarises reproductive parameter findings.

Table A2.6: Reproductive Performance from the Mallard Duck Reproduction Study.

	Experimental Group (mg/kg diet)			
Reproductive Parameter	**Control**	**4.0**	**8.0**	**16.0**
Eggs laid	730	750	591	159*
Eggs cracked (% of eggs laid)	4	4	3	6
Mean egg shell thickness (mm – week 9)	0.37	0.36	0.38	0.34
Eggs set (% of eggs laid)	88	88	87	74
Fertile eggs	531	518	433	98*
Fertile eggs (% of eggs set)	82	79	84	84
Viable 3-week embryos (% of fertile eggs)	90	89	84	59*
Hatchlings (% of fertile eggs)	54	50	48	35
14 day survivors	279	251	201	34*
14 day survivors (% of hatchlings)	98	97	97	100
14 day survivors (% eggs laid)	38	33	34	21

* - statistically significantly different from the control.

The 16 ppm group laid significantly fewer eggs than the other groups. They were not significantly different in their cracking or fertility rates, but significantly fewer embryos survived to three weeks. The number of viable three week embryos which hatched was slightly reduced but the difference was not statistically significant. The survival rate of two weeks was not concentration-related. The weight of hatchlings was statistically less in the 16 ppm group but not sufficient to be considered of biological significance.

The number of live 14 day old ducklings produced in the 4, 8 and 16 ppm groups were 90, 72 and 12% respectively of the number produced in the control group, however, despite an almost 30% reduction in the 8 ppm group, only that at the highest rate was deemed statistically significant.

Brain cholinesterase activity in the treated groups was 3-16% less than control values, but these were not considered biologically significant. Random significant differences in eggshell thickness were observed. For example, there were significantly thinner eggshells in the 8 ppm group on the third week and the 4 ppm group in week five. In the 8 and 16 ppm groups, eggshells were statistically significantly thinner than controls in the seventh week.

Conclusion

Fenamiphos significantly reduced food consumption and egg production at 16 ppm. Total live duckling production as a percent of control production was 90, 72 and 12% respectively in the 4, 8 and 16 ppm groups. Statistical analysis only deemed the highest exposure group to be significantly different to the control resulting in a NOEC of 8 ppm (7.2 ppm corrected for purity). However, a reduction of almost 30% in live 14 day old ducklings in this test group is still large and it may be more appropriate to consider the reproduction NOEC as the lowest tested rate of 4 ppm (3.6 ppm corrected for purity).

Avian Field Data

Citrus groves

Test Material:	**Fenamiphos, formulated as a 35% emulsifiable formulation, NEMACUR® 3**
Report:	Temple *et al*, 1995
Guidelines:	US EPA Guidelines, FIFRA, Section 71-5
GLP:	Yes

Test system:

The study was performed to determine if fenamiphos had an adverse effect on avian populations associated with citrus groves on the Central Florida Ridge. Four specific objectives of the study were to (1) document the number and kinds of birds exposed and the magnitude and duration of the exposure; (2) document the numbers and kinds of birds dying as a result of exposure; (3) estimate the impact of fenamiphos applications on survival of selected resident species; and (4) determine environmental concentrations of fenamiphos in soil and ground-dwelling invertebrates.

The field portion of the study was conducted during the 1991 and 1992 spring application seasons. Six paired replicates were used in the study, each consisting of a treated and control replicate (three treated and three control replicates in each year). Two applications were made 2 weeks apart to each of the replicates at the nominal rate of 5 kg ac/ha for control of burrowing nematodes. The sites were selected to bias test conditions toward worst-case exposure of birds. The replicates ranged in size from 9.3 to 26.3 ha with a minimum of 0.16 km between the 1991 and 1992 replicates, and a minimum of 0.48 km between replicates in the same year. The test product was applied through chemigation using low-volume under-tree irrigation systems.

Birds were captured using mist nets and ground traps, banded and blood sampled from 10 focal species prior to release. Capture and recapture data were used to assess whether exposure to fenamiphos reduced avian survival. Casualty searches were conducted to document mortality of vertebrate species on test replicates. Additionally, levels of fenamiphos and its toxic metabolites were measured in selected samples of soil (top 2.5 cm), irrigation water and, if possible, invertebrates (pit traps) from the 6 treated groves.

To assess levels of avian exposure, an unacceptable adverse effect (based on mortality as the end-point of concern) was defined as a 20% or greater reduction in average avian survival at sites treated with fenamiphos compared to control sites. A survival index was inferred from measurements of blood cholinesterase (ChE) activity in birds trapped on test replicates. Blood samples from each individual bird of a focal species captured pre-application on treated and control replicates yielded a mean ChE value. One-half of the overall mean ChE value was defined to be the diagnostic threshold (DT) for each species. The lowest ChE value for each individual captured pre-application and post-application were then compared to its species respective DT. Individuals with blood ChE levels below the DT were classified as exposed to significant levels of the toxicant and thus potential "non-survivors".

Findings:

Avian

In the control replicates, 1834 birds were captured (570 pre-treatment and 1264 post-treatment). A total 1165 birds were captured in the treated plots (around 64% that of the control plots). However, this lower number was observed during both the pre-treatment sampling (366 birds) and post-treatment sampling (799 birds). A similar pattern was observed for the 10 focal species where 1296 were captured in the control replicates (386 pre-treatment and 910 post-treatment) compared to 882 in the treated plots (266 pre-treatment and 616 post-treatment).

Based on blood cholinesterase measurements from the focal species, the percentage of birds with ChE above the DT from pre-application samples was 2.1% in the treated plots and 4% in the control plots. In the post-application samples, the percentage of birds with ChE above the DT from the treated replicates was 16% compared with 2.6% from the control plots. Based on a direct correction from control to treatment values following exposure, this suggests that around 13% of birds at the treated sites were exposed to a significant dose of the test substance.

The proportion of birds with blood ChE values greater than the DT was used to calculate a conservative avian survival index for each replicate. Only birds with ChE values >DT were assumed to survive. The mean survival indices were 0.98 pre-application and 0.85 post-application on treated sites compared to 0.96 and 0.97 pre-application and post-application respectively on the control sites.

Vertebrate mortalities

Eighty five vertebrate mortalities were found during the field portion of the study. Of these, 39% were on treated replicates (being mean numbers per replicate of 3.0 birds, 1.3 mammals, 1 reptile and 0.17 amphibians) and 61% on control replicates (being mean numbers per replicate of 4.8 birds, 2.5 mammals, 1 reptile and 0.33 amphibians). The highest residues found in an avian mortality were 1.04 ppm in the GI tract and 0.32 ppm in the liver (stated as NEMACUR® 3 residues). This bird was found the day following application and no other avian carcass analysed contained detectable residues. Residues were also detected in a scavenged anole (8.87 ppm NEMACUR® 3 residues, two days after the second application). The relatively high values found in these two animals support a presumption that death was caused by exposure to the test substance. Concentrations in

two other carcasses, a six-lined racerunner and an unidentified toad, were relatively low at 0.29 and 0.16 ppm respectively.

For the 46 mortalities resulting from trapping, 41 birds were analysed. Two (both rufous-sided towhees) had NEMACUR® 3 residues in their GI tracts of 0.14-0.18 ppm and were captured a day after the second application.

In addition to the mortalities recorded, five live birds were observed exhibiting behaviour typical of cholinesterase inhibition. Four of these were observed on treated replicates following application while the fifth was observed pre-application.

Measured levels in soil, irrigation water and invertebrates

Post application residues of total fenamiphos in soil ranged from <0.05 to 346 ppm with the highest daily mean (88.5 ppm) occurring the day after the first application. The calculated half-life for fenamiphos after the first application was 2.7 days and after the second, was 5.8 days. Half-life calculations were based on dissipation of total fenamiphos residues in soil.

Post application NEMACUR® 3 residues in invertebrate samples ranged from <0.10 – 227 ppm. The highest daily mean residue value for invertebrates collected post application was 26.8 ppm.

Total fenamiphos residue in irrigation water collected during applications ranged from 0.28-6842 ppm with a mean of 1056 ppm.

Conclusions:

The criteria set for the study of an unacceptable adverse effect (based on mortality as the end-point of concern) was defined as a 20% or greater reduction in average avian survival at sites treated with fenamiphos compared to control sites. Under the conditions of this study, it can be concluded that fenamiphos application did not result in an unacceptable adverse effect on avian mortality (using this criterion).

However, exposure to birds was apparent. Also, if it was assumed that birds with ChE levels lower than the DT values all died, then mortality in exposed birds was around 13% higher than that in non-exposed birds. In addition, residue levels found in post application sampling of invertebrates were at levels known to be toxic to birds thereby raising the prospect of secondary poisoning. Residues in irrigation water possibly available for birds to drink in the event of puddling, were at levels higher than those known to cause toxicity.

Test Material: **Fenamiphos, formulated as a 15% granular formulation**
Report: Parrish *et al*, 1991
Guidelines: US EPA Guidelines, FIFRA, Section 71-5
GLP: Yes

Test system:

The objectives of this study were to determine species and relative numbers of birds on and around test citrus groves; determine relative numbers of birds in citrus groves exposed to fenamiphos treatment and quantify the magnitude and duration of exposure; quantify the impact of treatment on survival of a marked population; and determine the environmental concentrations and persistence of fenamiphos, M01 and M02 in soil, water and potential wildlife foods (vegetation and invertebrates). The period for the field portion of the study was 2 April to 1 June 1990.

Citrus groves for the study were within or near Merritt Island National Wildlife Refuge, Florida, USA. Six groves were selected for the study with characteristics previously identified as being most

attractive to birds. The size of groves was based on the number of resident bird species present and experience gained in previous studies.

Three blocks (pairs) of groves were used with no plot in the same block being <400 m apart. In general, plots were largely independent, although some birds did move from one plot to another. Two treatment combinations were monitored, namely, application of blank granules and application of NEMACUR® 15G granules, applied at 22.4 kg ac/ha. A granular applicator with a 1.2 m application boom and 8 drip-line openings was used for application. A spiked drag (around 1.2 m wide and 1.8 m length) was attached to the boom to allow for incorporation of the granules.

Residue analyses were performed on all avian carcasses collected with intact GI tracts. Analysis of avian liver and GI tract for fenamiphos, M01 and M02 was performed. Soil samples were collected at 3 randomly selected locations within study plots prior to application and at 0, 4, 7, 14 and 28 days. Six sub-samples were taken to a depth of 2.5 cm from each plot. Sub-samples were pooled and analysed for parent and the two main metabolites. Invertebrates were collected at 3 randomly selected locations within study plots at days 1, 4, 7, 14 and 28 following application. At each site, 25 pitfall traps were established in such a way as to allow for sampling of both treated and non-treated regions at each sampling station. Captured invertebrates were pooled by sampling location within a given study plot and analysed. Samples of vegetation were collected in and around soil sampling locations during scheduled soil sampling times. Samples included annual weeds and grasses.

Based on results of previous studies, the study focussed on 4 avian species (Northern cardinal, Brown thrasher, Rufous-sided towhee and Northern mockingbird). All are ground foragers. In determining relative numbers of birds, all avian species were considered. Mist nets were used to capture and recapture representatives of the focal species and other bird species occurring in the study groves. Netting operations were conducted on each plot within a given block on every fourth day throughout the study period. Each captured bird was marked, and focal species were fitted with a separate coloured leg-band. For re-sighting, each plot was surveyed for the presence of marked birds beginning the day after initial banding operations (at least 15 days prior to treatment. Re-sighting surveys continued every other day for at least 30 days after treatment. Blood was sampled from each captured bird for plasma cholinesterase (ChE) determination. Toenail clippings were used in this study as a back-up method for blood sampling. Each blood sample was centrifuged and plasma analysed using pre-prepared ChE kits. Mean and standard deviation of plasma ChE values were separated into categories as either treatment or controls. Treatment observations recorded between 0 and 7 days post-treatment were considered as exposed, and all control observation combined with all pre-treatment/treatment observation were considered as non-exposed.

Formal carcass searches were not conducted, although carcasses/featherspots were collected whenever present; while a carcass recovery experiment was performed using one hundred carcasses of Japanese quail randomly placed in each study grove. Survival estimates were performed for focal species statistically based on capture/recapture and re-sighting data. The Lincoln-Petersen Method of estimating population size was used as a means of determining relative abundance from capture data of focal species.

Findings:

Observed application rates varied from 93-129% of nominal rates. The largest discrepancy (129% nominal in Plot 2) could not be explained.

Avian findings

Ninety-three species of birds representing 13 orders were recorded on and around the citrus groves during the studies. Of the focal species, Northern cardinals occurred in the greatest numbers and

appeared to be the best choice for monitoring exposure and effects of fenamiphos applications. Numbers of focal species tended to increase in each block throughout the study. Total numbers of focal species caught were 367, 61, 35 and 13 for the Northern cardinal, Brown thrasher, Rufous-sided towhee and Northern mockingbird respectively. Of the total individuals banded for focal species, 41% (195 birds) were recaptured at least once during the study. More Northern cardinal recaptures (165, or 45%) occurred than with any other focal species. While some movement by birds between plots took place, only 2.6% of focal individuals recaptured during the study had moved between study plots. While the probability of recapture of focal species varied within plots, no overall significant difference in recapture rate was found within pairs of study plots except on Block 3. Furthermore, no significant difference was detected when all blocks were combined.

For the focal species, species specific comparisons were restricted to the Northern cardinal due to inadequate sample sizes for other species. No significant difference in survival of Northern cardinals was found between all treatment and all control plots combined. However, a two-way ANOVA indicated a significant difference between blocks, but not between treatments. Overall, survival was independent of treatment.

In order to investigate the power of the beta-binomial test in detecting varying degrees of effect on cardinal survival caused by fenamiphos application, 16,000 computer simulations were analysed. The overall indication was that if applications had reduced avian survival by 10% or more, it should have been observed in the capture/recapture data. Since such an effects was not found, if further supports a conclusion that survival was independent of treatment.

Baseline plasma ChE values were calculated for each focal species captured. Due to generally low sample sizes for other species, only ChE values for the Northern cardinal were analysed statistically. Greater ChE exposure occurred in Block 1 than other study blocks and may have been related to the elevated application rate (129% nominal) observed for Plot 2 of this block. 410 (99%) of 415 control observations for Northern cardinals occurred <2 standard deviations below the mean (non-exposed). Of the 209 treatment observations, around 32% (67 observations) occurred >2 standard deviations below the mean. This suggests that approximately one third of the captured cardinals had been exposed to fenamiphos. Generally, the greatest decrease in plasma ChE occurred within 7-10 days post treatment. Plasma ChE values gradually increased from here and started to approach baseline values again before completion of the study (30 days after application).

Some carcasses or featherspots were found incidentally by field workers. Four carcasses/featherspots of wild birds were found on treatment plots after applications; two were found on control plots. Only one from the treatment plots had sufficient tissue to permit residue analysis and no detectable residues of fenamiphos were found.

Measured levels in soil, irrigation water and invertebrates

Post application residues of total fenamiphos in soil ranged from <0.05 to 85.52 ppm with the highest daily mean (48.97 ppm) occurring immediately after application. Half-life calculations were based on dissipation of total fenamiphos residues in soil and ranged from 6.8 to 30.9 days among the three test plots. Based on mean residues from all plots, the half-life was 19.4 days.

Residues in insects ranged from <0.10 to 27.0 ppm. A peak in residues for insects appears to have occurred around 14 days after application with mean levels up to 14 ppm at one plot. The data set was not complete enough to enable half-life estimation. However, it is noted that some insect residues were high enough to represent an important source of exposure for birds.

Total residues in vegetation ranged from <0.10 to 7.65 ppm. Mean residues were highest at 4 days after application (1.5-3.0 ppm). Residue half-lives in vegetation ranged from 9.4 days to 26.5 days.

Combined half-life estimates for residues in vegetation were 13.1 days with a lower limit of 6.9 days.

No standing water was available for collecting on treatment citrus groves during the study.

Conclusions:

Under the conditions of this study, it can be concluded that fenamiphos application as an incorporated granular formulation did not result in an unacceptable adverse effect on avian mortality. Using the results of one focal species, around 1/3 of birds appeared to be exposed to fenamiphos based on plasma ChE levels. Following the drop in ChE levels after exposure, these levels began to increase, and approached baseline levels by the end of the study. Survival, as determined by analysis of capture/recapture and re-sighting data combined, was found to be independent of exposure to fenamiphos.

Tobacco fields

Test Material:	**Fenamiphos, formulated as a 35% emulsifiable formulation**
Report:	Temple *et al*, 1991a
Guidelines:	US EPA Guidelines, FIFRA, Section 71-5
GLP:	Yes

Test system:

The study was conducted to evaluate effects of NEMACUR® 3 on birds associated with tobacco fields in Pitt and Beaufort counties in north-east North Carolina. Conditions were biased toward maximum hazard by choosing replicates that were surrounded by relatively high quality wildlife habitat, and applying the product at its maximum rate of 6.7 kg ac/ha. Replicates consisted of three pairs of fields, each pair consisting of one replicate treated and one untreated, tilled control. Sampling was concentrated along portions of the field bordered by relatively high quality wildlife habitat where avian use of the field was expected to be highest. One application was made to each of the replicates and control replicates served as the primary basis for comparisons of post-application sampling. The determination of whether an appreciable treatment related effect occurred was made by searching for dead or behaviourally impaired animals on both treatment and control replicates, and comparing these results. Additionally, avian censuses, wildlife crop use observations, determination of environmental residues in soil, water and invertebrates were used to further document and define conditions under which the study was conducted and identify potential exposure routes.

The product was applied with broadcast ground sprayers and soil incorporated. Avian abundance was estimated using a circular plot census technique with five plots surveyed per replicate on scheduled sampling days. Avian use of tobacco fields and adjacent habitats was documented to assist in identifying species at greatest risk of exposure. Observations of crop use were collected during avian censuses, during application and in conjunction with other activities. Wildlife use of tobacco fields was monitored continuously during application and for approximately one hour following application, when possible, to detect any immediate post-application hazards to wildlife.

To monitor wildlife mortality, five pre-treatment casualty searches were conducted on each replicate to assess pre-application mortality and remove existing signs of mortality. During and following application, searches for casualties were made along permanent transects located on tobacco field interiors and perimeters of each replicate. The search effort was concentrated in, but not limited to, an area up to 5 m into the field and 3 m from the transect into adjacent habitats, and 5 m to either side of field interior transects. Casualty searches were around 3 man-hours in duration with approximately 3.5 ha effectively covered per replicate. Carcasses were subject to residue

analysis. Carcass detectability trials were undertaken, and information obtained from these trials was used in conjunction with avian census data and casualty data to evaluate the ability of carcass searches to detect avian mortality.

Residues of fenamiphos were measured in selected samples of soil, water, and when present, invertebrates from each of the three treated fields. Samples were collected from field interior stations, and invertebrates were collected from stations in the adjacent habitat. Samples were collected prior to and following application and samples analysed for NEMACUR residues, including fenamiphos, M01 and M02. Soil was collected from the top 2.5 cm soil layer; water, when available, was collected in approximately three 750 mL samples from each treated plot; invertebrates were collected in pittraps. Twenty traps were set, approximately 1 m apart, in a line parallel to and approximately 1 m into the adjacent habitat at each perimeter sample station. Another 20 traps were set approximately 1 m apart at each field interior sample station.

Findings:

Mean numbers of birds observed per census were 33.8 for controls, 32.3 for treatments, and ranged from 26.8-40.4 across replicates. The similarity in the census data between control and treatment groups is indicative of no treatment related effects. In total, 108 avian species were observed in the study area. The number of species observed per replicate during avian censuses ranged from 40-53. Diversity, as measured by the Brillouin Index, ranged from 1.2-1.3 for all replicates, suggesting treatment and control groups were comparable with respect to avian species composition and abundance.

Observations of birds in test fields and other habitats during census operations (within 50 m radius of plot centres) provided a standardised unit of time and area for observing birds on each replicate. Thirty-nine avian species were observed in test fields during the study. In terms of total numbers, most species were observed exclusively in adjacent habitats while a few abundant species made relatively low use of tobacco fields. Only 4% of the observations for controls and 7% for treatments actually in the test fields. Some species (e.g., ring-billed gull) were observed in tobacco fields in relatively high numbers, but almost exclusively during or immediately following application (foraging extensively behind tractors).

Twenty avian casualties (15 pre and 5 post-application) were found during the study. These are likely to underestimate actual mortalities as recovery rates carcasses in the detectability trials ranged from 8-40% on control replicates and 14-28% on treatment replicates. However, they do show that in the sampling areas, no greater mortality was found resulting from treatment than in control plots.

Fifteen species of mammals, fifteen species of reptiles and ten species of amphibians were observed in the study area. In addition to avian casualties, 8 mammals (2 treatment, 6 control) and 11 reptiles/amphibians (7 treatment, 4 control) were found post-application. Of these casualties, a leopard frog and two eastern spadefoot contained detectable fenamiphos residues.

Samples of soil and water were analysed for fenamiphos, M01 and M02 to a limit of detection of 0.05 ppm, while the limit of detection for invertebrate samples was 0.1 or 0.25 ppm depending of the weight of the sample. In soil, at each sampling time (0, 1, 4, 7 and 14 days), three samples were analysed from each of the three treated replicates. At every sampling time, residues were detected above the limit of detection except for one sample in one replicate on days 0, 1 and 4. Mean residue levels of 8.25, 9.69, 3.79, 3.62 and 5.49 were found on days 0, 1, 4, 7 and 14 respectively. A half-life of around 20 days was calculated, but the relationship between concentrations over time is poorly correlated.

Mean water residues were determined in one replicate (2 samples) on day 0 as 1.14 ppm, and one replicate (2 samples) on day 1 as 1.06 ppm. After 7 days, 1 sample from two replicates gave a mean water concentration of 0.62 ppm, and after 14 days, one replicate (3 samples) still showed a mean water concentration of 0.80 ppm.

Residue values for invertebrate samples collected from the field interiors ranged from <0.1 ppm to 2.3 ppm. Samples collected from adjacent habitats ranged from <0.1 to 0.72 ppm.

Conclusions:

The authors conclude that avian census data show treatment and control groups were similar with respect to avian species composition and abundance. Avian crop use data showed overall use of tobacco fields by birds was relatively low. The number of vertebrate mortalities on treated fields was similar to the number found on control replicates, and casualty search data did not suggest that fenamiphos applications resulted in an appreciable increase in mortality of vertebrate species compared to controls.

It is finally concluded that detectability rates and casualties found both prior to application and on control replicates suggest that had appreciable acute mortality (e.g., 20% or more) of abundant avian species occurred, it is likely that avian carcasses would have been found. However, as only a small area of adjacent habitat was surveyed, this statement does not allow for the possibility of affected birds leaving the treatment area prior to death.

Test Material: **Fenamiphos, formulated as a 35% emulsifiable formulation**
Report: Temple *et al*, 1991b
Guidelines: Not stated.
GLP: Yes

Test system:

A further study was conducted to evaluate effects of NEMACUR® 3 on birds associated with tobacco fields in Pitt and Greene counties in north-east North Carolina. Experimental (including application method) and residue sampling methodologies are essentially the same as those described above in Temple *et al* (1991a). In addition to the avian census and avian crop-use observations, this experiment also studied banded birds to document avian survival and further characterise use of tobacco fields by bird populations. Birds were captured and banded during a 3.5 week period beginning approximately four weeks prior to application with an emphasis on capturing ground foraging and resident edge species. Because it was unlikely that all banded birds would remain on a study site or be detected by observers, the proportion remaining through the post-treatment period is considered an estimate of the minimum survival rate. Searches to locate banded birds were made throughout the study. Re-sightings of banded birds were reported for each replicate. Attempts were made to evaluate post-application survival based upon the proportion of individuals banded, which were observed following applications. However, this was found to be insensitive, so singular observations were eliminated from the data set and the proportions of the remaining birds which were observed following application were calculated for control and treatment groups. Using the control group as a standard, treatment related effects on the proportion of banded birds observed were evaluated.

Findings:

Mean numbers of birds observed per census were 35.5 for controls, 31.8 for treatments, and ranged from 28.2-42.9 across replicates. In total, 114 avian species were observed in the study area. The number of species observed per replicate during avian censuses ranged from 40-63. Diversity, as

measured by the Brillouin Index, ranged from 1.1-1.3 for control replicates and 1.2-1.4 for treatment replicates, suggesting treatment and control groups were comparable with respect to avian species composition and abundance.

Observations of birds in test fields and other habitats during census operations (within 50 m radius of plot centres) provided a standardised unit of time and area for observing birds on each replicate. A total of 35 avian species were observed in test fields during the study. In terms of total numbers, most species were observed exclusively in adjacent habitats while a few abundant species made relatively low use of tobacco fields. Only 5% of the observations for controls and 3% for treatments were actually in the test fields. Some species (e.g., ring-billed gull) were observed in tobacco fields in relatively high numbers, but almost exclusively during or immediately following application (foraging extensively behind tractors).

With the exception of one pre-application featherspot, all avian casualties (2 pre-application and 6 post-application) found during the study consisted of domestic poultry remains. These are likely to underestimate actual mortalities as recovery rates carcasses in the detectability trials ranged from 19-22% on control replicates and 17-37% on treatment replicates. Remains of only one bird were found on a treated plot following application with all others on control plots.

Thirteen species of mammals, two species of reptiles and five species of amphibians were observed in the study area. In addition to avian casualties, 6 mammals (3 treatment, 3 control) were found along with 2 reptiles and 4 amphibians, all within treated plots. Analysis of the GI tracts and livers of two eastern spadefoot, one banded watersnake and one pond slider did not detect residues of fenamiphos-sulfone.

Prior to application, 245 birds representing 20 species were banded. Avian survival was assessed based on post-application re-sightings of birds known to have been present after initial banding. For the control group, 15-33 banded birds were recaptured or re-sighted during the study compared to 20-35 banded birds being recaptured or re-sighted for the treatment group. Comparisons of re-sighting rates did not indicate any apparent treatment related effects on avian survival resulting from fenamiphos application.

In the residue analysis component of the study, detection limits were 0.05 ppm in soil and water and 0.1 ppm in invertebrates. Post application residues were highest in soil samples and ranged from 0.13-12.88 ppm (top 2.5 cm) and 0.22-4.99 ppm (0-15 cm). The highest residues were found immediately following application, and by day 14, the overall mean value for soil had decreased to 1.19 ppm (top 2.5 cm). The half-life calculated for soil was roughly 5 days.

Water samples were first available 5 days after application. Daily mean values for water samples from puddles on tobacco fields ranged from 0.08-0.83 ppm with the maximum level of 2.02 ppm observed on day 5.

Detectable residues were found in only one of 26 invertebrate samples collected from the field interiors and in only 3 of 31 invertebrate samples collected from adjacent habitats. Residues detected in these samples were 0.11, 0.12 and 0.12 ppm (fenamiphos-sulfone equivalents) for the adjacent habitat samples and 0.10 ppm for the one in-field sample.

Conclusions:

No apparent treatment related mortality was detected in this study. All post-treatment avian casualties consisted of domestic poultry remains. Avian survival, as indicated by re-sightings of banded birds, was not found to differ between treatment and control groups.

Golf courses

Test Material: **Fenamiphos, formulated as a 35% emulsifiable formulation**
Report: Whitmore *et al*, 1991
Guidelines: FIFRA Guideline 71-5.
GLP: Yes

Test system:

Data to assess the effect of a treatment with fenamiphos as the NEMACUR® 3 Turf Nematicide on birds were collected during the spring of 1989 and 1990 on six golf courses (three in each year) in central Florida. Specific operational objectives were to determine bird species and their relative abundances; quantify the number of birds dying on or near golf course application sites as a result of fenamiphos treatment; quantify the impact of the treatments on survival of a colour-marked population of birds thought to be at risk; and finally, to determine the environmental concentrations and persistence of total fenamiphos in soil, water, grass and invertebrates emerging after treatment. Golf courses were selected following a baseline study of 11 golf courses in 1988. Each course selected for the final study was sub-divided into a treatment and control plot, primarily by grouping fairways so that groupings of fairways on each course comprised either the treatment or control plot.

The compound was applied to 4-7 fairways on each golf course at a target rate of 11.2 kg ac/ha using an applicator towed behind golf course vehicles. It is unclear whether or how incorporation took place, but was possibly due to irrigation. Prior to treatment, a population of birds deemed to be at risk (primarily ground foraging insectivores) was colour marked on each course in an attempt to assess treatment related mortality and to arrive a pre- and post-treatment population estimates using mark-recapture procedures. A concerted effort was made to relocate and verify survival of all colour marked birds at two critical times: 3 days before treatment and day 5 after treatment. These efforts enable the calculation of the proportion of birds known to survive through the period of potential hazard. As birds that disappeared between capture and post-treatment searches may have dispersed rather than died, resighting rates on treatment plots were also compared with those on control plots.

In addition, the plots were searched before, during and after treatment to document the occurrence of mortality as evidenced by the presence of carcasses. A carcass recoverability trial was conducted to ascertain the efficiency of searchers in finding carcasses. The mortality rate was estimated from the number of carcasses found, the carcass detectability rate and the estimate of the size of the local population.

Field workers also observed bird behaviour to document signs of intoxication. It is noted that during the 1990 part of the study, if a bird was observed in a behaviour deficit, the field observer followed the bird in an attempt to determine its ultimate fate.

Environmental samples of soil, vegetation (grass clippings), water and ground-inhabiting invertebrates were collected from three of the treatment fairways per plot during pre-scheduled times. In 1990, an additional sample of vegetation was taken after treatment but before irrigation. Further, it was discovered in 1989 that obtaining invertebrate samples more than one day post-treatment was nearly impossible, so in 1990, invertebrates were samples only on the day of treatment and the day following treatment. Soils were sampled to a depth of 15 cm and water was collected only if standing water puddles were available on fairways.

Findings:

The results of a weighted General Linear Models Procedure indicated a lack of significant “golf course to golf course” variation. Therefore, the proportions of birds remaining could be pooled

across courses. The results are discussed in terms of total findings rather than those specific to any particular course.

Combining all six courses into one data set totalled 216 control plot birds and 280 treatment birds, of which 132 were Northern mockingbirds and 130 were Northern cardinals. A total of 124 control plot and 179 treatment plot birds were still present on the plots 3 days prior to treatment. Of these, 85.5% (106 birds) remained on control plots with 77.6% (139 birds) remaining on treatment plots at 5 days after treatment. The resulting one tailed chi-square test of independence demonstrated that statistically significantly more birds survived on control plots than treatment plots, that is, there was an overall reduction in avian survival attributable to fenamiphos applications. The magnitude of the reduction in survival (as inferred from resighting rates) between controls and treatments averaged 9.3% and ranged from –7% to 23% for individual golf courses. The 80% upper confidence limit for this reduction was 13.3%.

In the carcass detectability trial, total recovery of placed carcasses was 71% indicating a relatively high efficiency of recovery. Treatment related avian mortalities ranged from 1 to 7 per treatment plot across all golf courses with a total of 18 treatment related bird deaths recorded. Four birds in this total were initially found alive, but showed behavioural symptoms of intoxication and were followed until they died. In addition, 23 behaviourally impaired birds were documented. 21 of these recovered and the fate of the remaining 2 birds was unknown. Most of the treatment related deaths and behavioural impairments (93%) were found on the day of application or the next day, and only one occurred later than 2 days post-application. By species, the Northern mockingbird was most likely to receive a fatal dose of the compound.

Based on carcass recoverability and estimations of bird populations, mortality rates for the focal species in this study ranged from 0% to 6.82% between courses. Combining all courses and calculating a single percentage produced a mortality estimate of 2.64%.

Soil residues found in the 1989 samples were much lower than those found in the 1990 samples. In 1989, peak levels were found on the day of application and ranged from (mean of 3 samples per plot) 0.09-1.63 ppm. By contrast, in the 1990 samples, levels peaked on the day following application and ranged from 0.62-10.63 ppm. In the 1990 samples, following this peak, residues declined following first order kinetics and a half-life of around 5 days is calculated.

Samples of vegetation taken in 1990 showed much higher levels on the day of treatment (mean 797.17 ppm) prior to irrigation (233.81 ppm following irrigation). Residue levels in vegetation dissipated following first order kinetics and a half-life of around 3 days was demonstrated based on mean residue levels.

Water samples were opportunistically collected due to the ephemeral nature of standing water on fairways. This resulted in variable residue levels. Post-treatment water samples were high on the day of treatment with mean levels for all samples combined of 9.35 ppm, and a range in individual samples of <0.05 to 87.35 ppm. Levels dropped relatively quickly and after 3 days, most samples showed levels of not detected to <1 ppm with two samples at one golf course showing levels of 4.1 and 6.1 ppm at day 7 following treatment.

Like water, invertebrate samples were highly ephemeral. Generally, insect sampling had to be completed within two hours of dawn since birds would effectively remove all dead or dying insects by that time. On the day of treatment, invertebrate samples (principally mole crickets and cut worms) averaged 96.27 ppm, but by 2 days after treatment, this was down to 2.12 ppm.

Conclusions:

The results of this field study suggest the effect of fenamiphos treatment at 11.2 kg/ha were a loss (either through mortality or emigration) of about 9% of the avian population at treatment sites with

the 80% upper confidence limit for this loss being 13.3%. Analysis of birds found dead on treatment plots indicated that species in the family Mimidae were more vulnerable to intoxication with heavier birds more likely to recover than lighter birds.

Abnormal behaviours were observed and for those that were followed, recovery rates were high. Although calculated mortality rates were low, there was an overall significant difference in the disappearance of colour marked birds between treatment plots and control plots.

On numerous occasions, birds were seen eating "dosed" invertebrates, and subsequently became sick. Residue monitoring indicated that concentrations of total fenamiphos were initially high in invertebrates, but decreased to relatively safe levels within a few days. Most of the treatment related deaths and behavioural impairments were found on the day of application or the next day.

Test Material:	**Fenamiphos, formulated as a NEMACUR 10% Granular Insecticide**
Report:	Toll and Fischer, 1995.
Guidelines:	FIFRA Guideline 163.71-5.
GLP:	Yes

Test system:

The study was undertaken to determine hazard to birds of a granular form of fenamiphos applied at 11.2 kg ac/ha to turf grass sites (golf courses). The specific objectives of the study were to determine species and relative numbers of birds on and around test fairways; quantify the impact of treatment on survival of a marked population of birds thought to be at risk; determine treatment related avian mortality occurring on or near golf course application sites; and determine environmental concentrations of fenamiphos and metabolites in soil, water, grass and invertebrates at golf course treatment sites.

A single application was made to three courses in Tallahassee (Florida) in 1991, and an additional three courses in central Florida (Orlando area) in 1992. Two plots (control and treatment) were established on each course, with each plot consisting of at least 7 golf holes. Plots were separated by a buffer zone of at least two fairway widths (~80 m). Methods of incorporation are not reported.

During the pre-application period (3-21 days), birds were captured, marked with a unique colour combination and released. Survival of a marked population of birds was monitored by visual recaptures. The treatment was considered to adversely impact avian survival if survival of birds on pesticide treated sites was reduced by at least 20% compared to control sites post-application. Mortality was monitored by conducting carcass searches (including a trial to determine carcass search efficiency). Focal species were chosen on the basis they were ground foraging species, were resident at golf courses, occupy relatively small home ranges, could be easily monitored visually and were abundant enough to permit statistical evaluation of results. Six focal species were selected, northern cardinal, blue jay, brown thrasher, northern mockingbird, loggerhead shrike and rufous-sided towhee.

For residue sampling, samples were taken from three randomly selected locations on the treated plots of each course. Soil (10 sub-samples, 7.5 cm deep) and turf (collected using hand clippers) were collected from the same station while water and invertebrates were collected at separate stations. Soil and turf were collected on days –4, 0, 4, 8, 16 and 31. Water samples were collected on days 0, 4, 8, 16 and 31 if there was available surface water in treated areas. Invertebrates were collected immediately after application and on days 1 and 4.

Findings:

Results for all six sites are combined for comparisons. All golf courses were very similar in terms of species diversity. Between 45 and 60 different species (including focal species) were observed on control plots and 51-67 different species on treatment plots. The average number of birds banded and marked (focal species) at the six golf courses was 85 for the control plots (range 54-143) and 90 for the treatment plots (range 45-131). Visual censuses indicated an average of 38% (14-54%) of the individuals of the focal species was marked. Population estimates for all focal species combined ranged from 112 to 1021 birds per plot.

The percentage of marked birds surviving until at least 3 days after application was determined using visual observations. Visual recapture data showed a mean survival index of 67% (42-83% between courses) for control plots and 69% (46-88% between courses) for treatment plots. There was no significant difference in survival at treatment plots compared to control plots.

Search efficiency results showed between 31-57% of carcasses should be recovered (mean 40%). When all mortality data including all vertebrates were analysed, the mean number of carcasses found after application on treatment plots was 3.5 (range 0-12). The mean number found on control plots was 4.8 (range 2-9). Looking only at adult bird intact carcass data, the mean number of carcasses found after application was 0.33 (range 0-2) for treatment plots and 0.17 (range 0-1) for control plots. There was no significant difference between control and treated plots in number of vertebrate mortalities detected.

All intact carcasses found after application were analysed for fenamiphos concentrations. If the GI tract was removable, then it was analysed, otherwise the whole carcass was assessed. Of the 25 intact carcasses, only 10 had detectable residues. In the 6 birds that had residues in the GI tract, they ranged from 1-36 ppm. In the cases where the whole carcass was analysed, the concentrations detected were in birds where there was evidence of exposure ranged from 0.11-10.4 ppm.

Residues found in soil averaged 21.2 ppm on the day of application (mean concentrations per treatment plot of 11.1-34.0 ppm) and declined with a 5 day half-life. Turf residues averaged 208 ppm on the day of application (mean concentrations per treatment plot of 87.4-342.2) and declined with a 3 day half-life. Water and invertebrate samples were not always obtainable during the sample period; however, from the samples available, peak residues (found at day 0) averaged 13.8 for water (mean plot range of 3.2-24.2 ppm) and 35.2 for invertebrates (mean plot range of 1.9-64.3 ppm).

Conclusions:

Study sites contained large and diverse bird populations and birds were observed foraging after application on golf course fairways. Bird survival rates (based on population calculations) were not statistically significantly reduced by pesticide treatment compared to control rates. Similarly, there was no evidence that pesticide treatment increased bird mortality (based on carcass recovery).

Conclusions for Avian Toxicity

Acute oral toxicity results were available for fenamiphos (4 studies, 3 species), M01 (1 study, 2 species) and M02 (1 study, 2 species). The studies were all relatively old (1982 or earlier) except one more recent result for fenamiphos toxicity to Japanese quail (1998 study). Of the available results for technical fenamiphos, all LD50 values were in the range of 0.7-1.3 mg ac/kg bw, indicating fenamiphos is very highly toxic to birds. Similar results were found for the two metabolites, with LD50s between 1 and 2 mg/kg bw for both metabolites tested, again, indicative of very high toxicity to birds. NOECs for all three compounds ranged from 0.25-1.0 mg/kg bw.

Three short term toxicity tests were reviewed, all for technical fenamiphos. Two studies considered toxicity to bobwhite quail and one to mallard duck. Bobwhite quail appeared more sensitive

(LC50's of 38 and 78 ppm) than mallard duck (one LC50 result of 94 ppm). These results indicate the compound is highly to very highly toxic to birds when consumed through the diet.

In addition, two reproduction studies were provided, one for bobwhite quail and one for mallard duck. For bobwhite quail, the main adverse effect related to chick survival (14 days), which was reduced by 31% in the 8.0 ppm group. Therefore, the NOEC from this study was the next highest level tested, 2.0 ppm (1.8 ppm corrected for purity). In the mallard duck test, there was a reduction of almost 30% in live 14 day old ducklings at 8 ppm. This was deemed not statistically significant (and resulted in a NOEC of 8 ppm), however, it is considered more appropriate by DEH to consider the reproduction NOEC as the lowest tested rate of 4 ppm (3.6 ppnm corrected for purity).

Given the high hazard of fenamiphos to birds, several avian field studies were undertaken assessing potential adverse effects on birds in citrus groves, tobacco fields and golf courses. Application rates to citrus groves included 5 kg ac/ha (applied through chemigation; statistically, no significant effects found, however, mortality in exposed birds based on ChE levels was around 13% higher than that in non-exposed birds) and 22.4 kg/ha (granule application, soil incorporated; no significant adverse effects found on avian mortality). Application rates to tobacco fields in both tests were 6.7 kg ac/ha. Application was by broadcast spraying with soil incorporation. Different methods were used to assess impacts on avian mortality, but in both studies, no significant effects were found. Application rates to golf courses in both studies was 11.2 kg ac/ha with one study applying the substance as an EC formulation and the other as a granular formulation. Incorporation was achieved through irrigation. While no significant effects on bird survival rates were found in the granule study, in the first study, there was an effect of fenamiphos treatment being a loss (either through mortality or emigration) of about 9% of the avian population at treatment sites with the 80% upper confidence limit for this loss being 13.3%. Analysis of birds found dead on treatment plots indicated that species in the family Mimidae (34 species including thrashers and mockingbirds) were more vulnerable to intoxication with heavier birds more likely to recover than lighter birds.

Abnormal behaviours were observed and for those that were followed, recovery rates were high. Although calculated mortality rates were low, there was an overall significant difference in the disappearance of colour marked birds between treatment plots and control plots. On numerous occasions, birds were seen eating "dosed" invertebrates, and subsequently became sick. Residue monitoring indicated that concentrations of total fenamiphos were initially high in invertebrates, but decreased to relatively safe levels within a few days. Most of the treatment related deaths and behavioural impairments were found on the day of application or the next day.

In all studies, residues were found where tested in all media (soil, water and invertebrates), but these varied widely between studies.

Aquatic Toxicity

Fish – Acute

The APVMA received several studies for acute toxicity of fenamiphos and its main metabolites to fish with the following results:

Table A2.7. Summary of Acute Fish Toxicity Results for Fenamiphos and Metabolites

Test species	System	LC50/NOEC (µg ac/L)	Reference
Fenamiphos, technical			
Rainbow trout (*O. mykiss*)	96 h static	58.4/50.6	Lamb and Roney, 1972
Bluegill sunfish (*L. macrochirus*)	96 h static	14.3/10.4	Lamb and Roney, 1972
Bluegill sunfish (*L. macrochirus*)	96 h static	9.3/3.8	Dorgerloh and Sommer, 2001
Sheepshead minnow (*C. variegatus*)	96 h ft	17/<3.8	Suprenant, 1988a
Bluegill sunfish (*L. macrochirus*)	96 h static	8.4/6.8	Lamb and Roney, 1977
Fenamiphos, 15% GranularFormulation			
Rainbow trout (*O. mykiss*)	96 h static	84.4/36	Lamb and Roney, 1972
Bluegill sunfish (*L. macrochirus*)	96 h static	22.6/7.4	Lamb and Roney, 1972
M01 (nominal)			
Bluegill sunfish (*L. macrochirus*)	96 h static	2600/1000	Lamb and Roney, 1977
M02 (nominal)			
Bluegill sunfish (*L. macrochirus*)	96 h static	1200/680	Lamb and Roney, 1977
M12 (nominal)			
Rainbow trout (*O. mykiss*)	96 h static	NOEC>100000	Waggoner, 1989
Bluegill sunfish (*L. macrochirus*)	96 h static	NOEC>100000	Waggoner, 1989
M13 (nominal)			
Rainbow trout (*O. mykiss*)	96 h static	NOEC>100000	Waggoner, 1989
Bluegill sunfish (*L. macrochirus*)	96 h static	NOEC>100000	Waggoner, 1989

Test Material: **Fenamiphos technical; Fenamiphos 15% Granular**
Report: Lamb and Roney, 1972
Guidelines: Stated as following "Environmental Protection Agency" guidelines.
GLP: No

Test system:

Toxicity of fenamiphos was studied on a warm water fish (bluegill sunfish, *Lepomis macrochirus*) and a cold water fish (rainbow trout, *Onchorhynchus mykiss*) in both its technical form and as a 15% granular formulation. The test was performed under static conditions for 96 hours.

The technical fenamiphos was stated as being 81% pure. Preliminary range finding tests were conducted to determine the general toxicity of the compound to the fish. For the definitive test, water was used as a stock solution solvent for the granule formulation while acetone was used as a solvent for the technical grade material.

Table A2.8: Test Concentrations (µg/L)

Bluegill sunfish	Fenamiphos technical	0	6.1	10.4	17.5	29.8	50.6
	Granular formulation	0	49	84	142	241	410
Rainbow trout	Fenamiphos technical	0	17.5	29.8	50.6	86.2	146.4
	Granular formulation	0	142	241	410	698	1186

It is assumed the concentrations for the granular formulation represent total formulation concentration for which fenamiphos comprises 15% by weight.

Fish were acclimated to reconstituted deionised water with pH of 7.0-7.4. Bioassay vessels contained 15 litres of bioassay water. Ten fish were placed in each vessel with a loading factor of approximately 1 g fish/L. Temperatures were maintained at 13^{o}C for the rainbow trout and 22^{o}C for the bluegill sunfish. Prior to introducing the test fish, the water was saturated with dissolved oxygen. During the 96 h exposure period, the fish were not fed, the water was not aerated and mortality data were recorded at 24 hour intervals.

Approximate LC50 values and 95% confidence limits were calculated according to Carrol S. Weil, Biometrics, 8, No.3, Sept. 1952.

Findings:

No observations on sub-lethal effects are noted in the study report. The following results were reported for 96 hours:

Table A2.9: Mortality of Bluegill Sunfish and Rainbow Trout exposed to Fenamiphos Technical and Fenamiphos 15% Granular formulation

Bluegill sunfish	Fenamiphos technical	0	6.1	10.4	17.5	29.8	50.6
	96 h mortality (%)	0	10	0	60	90	100
	Granular formulation	0	49	84	142	241	410
	96 h mortality (%)	0	0	10	60	70	100
Rainbow trout	Fenamiphos technical	0	17.5	29.8	50.6	86.2	146.4
	96 h mortality (%)	0	0	10	0	80	100
	Granular formulation	0	142	241	410	698	1186
	96 h mortality (%)	0	0	0	20	70	100

Rainbow trout were less sensitive than bluegill sunfish. Concentrations of 50.6 ppb and 146.4 ppb of technical fenamiphos were needed to induce 100% mortality in bluegill and rainbow trout respectively. Similarly with the granular formulation, bluegill were more sensitive with 100% mortality at 410 ppb (61.5 ppb ac) compared to rainbow trout where doses less than 1186 ppb (178 ppb ac) did not induce 100% mortality.

Conclusion:

The following 96 h LC50 values with confidence intervals were calculated (corrected for purity in the case of the technical product, and active constituent in the case of the formulated product):

	Bluegill sunfish		Rainbow trout	
	96 h LC50 (µg/L)	95% CI (µg/L)	96 h LC50(µg/L)	95% CI (µg/L)
Fenamiphos technical	14.3	11.7-17.5	58.4	49.6-68.6
Fenamiphos granular	22.6	17.1-30.2	84.4	68.1-105

Test Material: **Fenamiphos technical**
Report: Dorgerloh and Sommer, 2001
Guidelines: FIFRA 72-1; OECD 203; OPPTS 850.1075
GLP: Yes

Test system:

Acute toxicity of fenamiphos technical was studied in a 96 hour static test with Bluegill sunfish (*Lepomis macrochirus*). The purity of the test substance was 96.2%. Fish had a mean body weight at the beginning of the test of 2.5±0.6 g and mean body total length of 5.8±0.46 cm. The biomass loading was 0.625 g fish/L test medium.

Reconstituted water was used for the test, prepared by adding salt stock solutions to demineralised water. The hardness was reported at 40-60 mg $CaCO_3$/L, pH 7.1-7.4, dissolved oxygen of 92-102% and a water temperature of 21.3-22.5^oC. The photoperiod was maintained at 16:8 h light:dark.

Test doses were determined based on historical data, and were set at 2.50, 5.00, 10.0, 20.0 and 40.0 µg/L. A control and solvent control were maintained. Test aquaria contained 40 L dilution water. At the start of the test, ten fish were randomly introduced into each aquarium. During the test, fish were examined after 4 hours then daily for mortalities and sub-lethal effects. Water parameters were determined daily and temperature monitored hourly. Analytical determinations of the active ingredient concentrations were made in the test medium at the beginning of the test, on day 2 and at the end of the test.

Where possible, the LC50 and 95% confidence limits were calculated every 24 hours based on the methods of Stephan.

Findings:

Measured concentrations were 1.75, 3.38, 7.03, 14.0 and 32.4 µg/L. There were neither adverse effects nor mortality in the control and solvent control fish. No deaths or sub-lethal effects were found at the two lowest concentrations. After 96 hours, 30%, 80% and 100% mortality was observed in the 7.03, 14.0 and 32.4 µg/L test groups, with 100% mortality in the highest group occurring by 48 hours. Sub-lethal effects were first observed in the highest three exposure groups after 24 hours. All fish in these treatment groups were recorded as being affected and behavioural observations included inactivity, laboured respiration, laying at the bottom of the tank, weaker coloration and fish laying on their sides or backs.

Conclusion:

The 96 h LC50 was calculated by probit analysis to be 9.30 µg/L (95% CI 6.85 – 12.8 µg/L) based on measured concentrations. The NOEC was 3.8 µg/L.

Test Material: **Fenamiphos technical**
Report: Surprenant, 1988a
Guidelines: FIFRA 72-3
GLP: No

Test system:

Acute toxicity of fenamiphos technical was studied in a 96 hour flow-through test with sheepshead minnow (*Cyprinodon variegatus*). The purity of the test substance was 88.7%. Fish had a mean body weight at the beginning of the test of 0.26 (0.11-0.62) g and mean body total length of 24 (20-33) mm.

Natural filtered sea-water was used for the test, prepared. The water had salinity of 31-34‰ and a pH of 8.0. The test system was designed to provide 5 concentrations of the test material, one dilution water control and one solvent control (14 ppb acetone). All treatments were maintained in duplicate. Test aquaria contained a constant volume of 11 L with the system allowing around 6.5 volume replacements per aquarium every 24 hours. The water was maintained at around 22^{o}C. The photoperiod was maintained at 16:8 h light:dark.

Based on results of preliminary testing, nominal concentrations chosen for the definitive study were 18, 27, 42, 65 and 100 µg/L. A control and solvent control were maintained. At the start of the test, ten fish were randomly introduced into each replicate aquarium. During the test, fish were examined at test initiation then daily for mortalities and sub-lethal effects. Water parameters were determined daily. Analytical determinations of the active ingredient concentrations were made in the test medium at the beginning of the test, on day 2 and at the end of the test.

Where possible, the LC50 and 95% confidence limits were calculated every 24 hours based on the methods of Stephan.

Findings:

Water quality parameters measured remained within acceptable ranges for the survival of sheepshead minnow and were unaffected by the concentrations of fenamiphos tested. Exposure solutions were clear with no sign of insoluble test material throughout the study.

Based on mean measured concentrations at days 0, 2 and 4, actual exposure concentrations in this study were 11, 26, 40, 56 and 96 µg/L. The following mortalities (based on mean of two replicates) were observed as follows:

Table A2.10: Mortality of Sheephead Minnow exposed to Fenamiphos Technical

Concentration (µg/L)	24 h	48 h	72 h	96 h
Control	0	0	0	5
Solvent Control	0	0	5	5
11	0	0	10	30
26	5	10	35	65
40	0	45	85	95
56	40	85	100	100
96	35	90	100	100

Sub-lethal effects were noticed at all treatment levels, starting from the first 24 h observation. Such effects included partial or complete loss of equilibrium, lethargy, darkened pigmentation and anterior extension of the pectoral fins.

Conclusion:

The 96 h LC50 was calculated by probit analysis to be 17 µg/L (95% CI 12-21 µg/L) based on measured concentrations. The NOEC <3.8 µg/L based on sub-lethal effects and mortality observed at this, the lowest tested concentration.

Test Material: **Fenamiphos technical; Fenamiphos Sulfoxide; Fenamiphos Sulfone**
Report: Lamb and Roney, 1977
Guidelines: Stated as "following guidelines recommended by the Environmental Protection Authority".
GLP: No

Test system:

Toxicity of fenamiphos technical, fenamiphos sulfoxide and fenamiphos sulfone was studied on (bluegill sunfish, *L. macrochirus*). The test was performed under static conditions for 96 hours.

The technical fenamiphos was stated as being 88% pure. Acetone was used as a solvent for the test materials.

Table A2.11: Test concentrations (µg/L)

Fenamiphos technical	0	4.6	6.8	10.0	15.0	22.0
Sulfoxide metabolite	0	1000	1500	2200	3200	4600
Sulfone metabolite	0	460	680	1000	1500	2200

Fish were acclimated to reconstituted deionised water with pH of 7.2. Bioassay vessels contained 15 litres of bioassay water. Ten fish were placed in each vessel with a loading factor of approximately <1 g fish/L. Temperatures were maintained at 19^{o}C. Prior to introducing the test fish, the water was saturated with dissolved oxygen. During the 96 h exposure period, the fish were not fed, the water was not aerated and mortality data were recorded at 24 hour intervals.

Approximate LC50 values and 95% confidence limits were calculated according to Carrol S. Weil, Biometrics, 8, No.3, Sept. 1952.

Findings:

No observations on sub-lethal effects are noted in the study report. The following results were reported for 96 hours:

Table A2.12: Mortality of Bluegill Sunfish exposed to Fenamiphos Technical, Fenamiphos Sulfoxide and Fenamiphos Sulfone

Fenamiphos technical	0	4.6	6.8	10.0	15.0	22.0
96 h mortality (%)	0	0	0	60	100	100
Sulfoxide metabolite	0	1000	1500	2200	3200	4600
96 h mortality (%)	0	0	20	40	60	90
Sulfone metabolite	0	460	680	1000	1500	2200
96 h mortality (%)	0	0	0	10	100	100

Conclusion:

The following 96 h LC50 values with confidence intervals were calculated (corrected for purity in the case of the technical product):

	96 h LC50 (µg/L)	95% CI (µg/L)
Fenamiphos technical	8.4	7.4-9.6
Fenamiphos sulfoxide	2600	2000-3400
Fenamiphos sulfone	1200	1100-1300

Test Material: **M11; M12**
Report: Waggoner, 1989
Guidelines: FIFRA 72-1.
GLP: No

Test system:

Toxicity of two fenamiphos metabolites, M11 and M12, were studied on a warm water fish (bluegill sunfish, *Lepomis macrochirus*) and a cold water fish (rainbow trout, *Onchorhynchus mykiss*). The test was performed under static conditions for 96 hours.

Both fish were exposed to both metabolites at 0, 0.01, 0.1, 1.0, 10 and 100 ppm nominal. No co-solvents were used in preparing stock solutions. For bluegill sunfish, groups of 10 fish per treatment were acclimated in 100% dilution water with aeration for 2 days preceding the test. Test vessels contained 12 L test medium with a fish loading at initiation of <0.1 g/L for rainbow trout and <0.5 g/L for bluegill. Mortality and sub-lethal effects were observed at 2, 6, 12, 24, 48, 72 and 96 hours. Water quality parameters were measured at test initiation and then at 24 hour intervals.

Bluegill sunfish experiments were done with water at 22^{o}C while rainbow trout experiments were done with water at 12^{o}C.

No statistical treatment of the data was undertaken due to a lack of definitive results.

Findings:

Dissolved oxygen ranged from 6.8-8.9 mg/L, pH from 7.3-7.8 and alkalinity from 188-205 mg/L as $CaCO_3$ throughout the tests. Analysis of test solutions (from the 10 and 100 ppm solutions at test initiation and 24 hour intervals) resulted in measured values ranging from 88.9-99.2% of nominal.

No mortalities or sub-lethal effects were recorded for either species exposed to either of the metabolites at any of the test concentrations.

Conclusion:

M11 and M12 were not toxic to bluegill sunfish or rainbow trout under the static conditions of this test, with NOECs ≥100 ppm.

Fish – Subchronic/Chronic

Test Material: **Fenamiphos technical**
Report: Surprenant, 1989.
Guidelines: US EPA Guideline 72-4
GLP: yes

Test system:

The study was undertaken to determine the chronic toxicity of technical fenamiphos (purity 88.7%) to rainbow trout (*Onchorhynchus mykiss*) embryos and larvae during an early life stage test with continuous aqueous exposure over 91 days (60 days post hatch).

A modified constant flow serial diluter with a 50% dilution factor delivered the test concentrations. Dilution and control water was well water characterised with total hardness and alkalinity of 26-32 mg/L and 21-29 mg/L as $CaCO_3$ respectively and pH of 7.0-7.4. Nominal test concentrations were 1.1, 2.2, 4.5, 9.0 and 18 µg/L along with a dilution water control and a solvent control (40 µL/L acetone). All levels were tested in duplicate. Test aquaria maintained a constant exposure solution volume of 11 L with 10 volume replacements every 24 hours. A 16:8 hour light:dark photoperiod

and test solution temperature of around 12°C was maintained. From day 19 of exposure, test aquaria were replaced weekly to minimise the increase in microbial activity.

The test was initiated with a couple of hours of egg fertilisation when 50 freshly fertilised eggs were placed in incubation cups (50 eggs/cup, 2 cups/aquaria). A definitive determination of viability was made on day 19 where any egg exhibiting embryonic development, whether dead or alive, was considered fertile for purposes of determining % viability. At this stage, all live viable embryos from the two cups/aquaria were combined. 20 live and viable embryos were then impartially selected and placed into an incubation cup suspended in the respective exposure aquarium. The remaining live, viable embryos were then suspended in a second incubation cup. The larvae that hatched from the isolated embryos were used to initiate the swim-up stage of the study. To initiate the 60 day post-hatch exposure, surviving larvae from each of the isolated embryo incubation cups were released into their respective aquaria, providing up to 20 larvae per replicate aquaria.

When the fish reached swim-up stage (around 11 days post hatch), larvae were fed live brine shrimp nauplii. Behaviour and appearance of larvae were observed daily and mortality estimated twice weekly. At 60 days post hatch, the larvae from each aquarium were recorded for % survival, mean length and mean weight. Water quality parameters (dissolved oxygen, pH) were measured daily. Total hardness and total alkalinity were measured at day 0, then weekly. Temperature was continuously monitored. Exposure concentrations were confirmed analytically. Data were analysed statistically using a variety of standard techniques.

Findings:

Results of water quality determinations indicated the test substance did not affect water quality, and conditions maintained throughout the exposure were satisfactory for the survival and growth of rainbow trout embryos and larvae. Based on measured concentrations, the treatment levels were defined as 1.1, 2.1, 3.8, 7.4 and 15 µg/L.

Biological results are summarised in Table A2.13 below.

Table A2.13: ELS toxicity of Fenamiphos to Rainbow trout embryos and larvae

Concentration [µg ac/L]	Control	Solvent control	1.1	2.1	3.8	7.4	15.0
Embryos viability (%)	89	92	94	91	91	95	91
Survival at Hatch (%)	100	99	100	100	100	100	100
60 days post hatch:							
Larval Survival (%)	98	95	100	98	88	98	93
Mean Wet Weight (g)	2.09	1.98	1.81	1.84	2.01	1.77*	1.76*
Mean Length (mm)	61.0	59.9	58.8	58.4	59.7	57.2*	56.3*

* - Statistically different from the control.

Fenamiphos did not adversely affect embryo viability at the concentrations tested. After completion of the hatching period (31 days), survival of embryos in all treatments groups was comparable to the controls. The incubation period of 31 days was generally consistent between treatment levels and within the expected time interval for this species at the test temperature. By day 47 (16 days post hatch), nearly all exposed larvae completed their development to the swim-up stage. At the end of the test, mean survival of exposed larvae was statistically comparable to controls.

Larvae length and weight were the most sensitive parameters and at the two highest test concentrations, both these were statistically significantly lower than control values.

Conclusion

Based on the significantly reduced larval growth ($p \leq 0.05$) following 60 days post-hatch exposure, the LOEC was estimated to be 7.4 µg/L. The NOEC for this study was 3.8 µg/L. Therefore, the MATC was calculated to be 5.3 µg/L.

Aquatic Invertebrates – acute

The APVMA received a limited number of studies addressing acute toxicity of fenamiphos and its main metabolites to aquatic invertebrates with the following results:

Table A2.14: Summary of Acute Aquatic Invertebrate Toxicity Results for Fenamiphos and its Main Metabolites

Test species	System	LC50/NOEC (µg ac/L)	Reference
Fenamiphos technical			
Daphnia magna	48 h static	1.9/<1.0	Surprenant, 1988b
Mysid shrimp (*M. bahia*)		6.2/-	See 1) below
Eastern oyster *(C. virginica*)		1,650/630	See 1) below
Daphnia magna[2]	24 h	<10/<10	Losel and Keppler, 2001
Mosquito (*A. aegypti*)[2]	24 h	10-100/<10	Losel and Keppler, 2001
M01			
Daphnia magna	48 h static	15/4	Hendel and Sommer, 2001a
M02			
Daphnia magna	48 h static	3.2/1.0	Hendel and Sommer, 2001b
M12			
Daphnia magna	48 h static	~100,000/10,000	Hendel, 2001a
M13			
Daphnia magna	48 h static	20,200/5,600	Hendel, 2001b
M24			
Daphnia magna[2]	24 h	>100,000/10,000	Losel and Keppler, 2001
Mosquito (*A. aegypti*)[2]	24 h	Both >100,000	Losel and Keppler, 2001

1) Results reported in US EPA Environmental Fate and Effects Division (EFED) report, Patrick *et al* (2001). Studies not provided to APVMA for review. 2) Non-standard screening test.

Test Material: **Fenamiphos technical**
Report: Surprenant, 1988b
Guidelines: US EPA Guideline 72-2
GLP: no

Test system:

Acute toxicity of technical grade fenamiphos (purity 88.7%) was studied on *Daphnia magna* in a 48 hour flow through test.

Dilution water consisted of filtered well water with total hardness and alkalinity of 160 and 120 mg/L $CaCO_3$ respectively and pH of 8.0. The test system was designed to deliver five test concentrations (1.3, 2.2, 3.6, 6.0 and 10 µg/L, based on range-finding results), a dilution water control and a solvent control (acetone, 20 µL/L). All levels were maintained in duplicate and the

test was conducted with a water temperature of around 20^{o}C with a 16:8 hour light:dark photoperiod. Exposure vessels were glass battery jars containing constant 1.8 L test water volume with the test system delivering 6 volume replacements per day.

The test was initiated with 20 daphnids (<24 h old, 10 per replicate), were distributed among treatment and control solutions. Daphnids were recorded for immobilisation and biological effects at 24 and 48 hours. Water quality parameters (dissolved oxygen, temperature and pH) were measured once daily. Test concentrations were analytically verified.

The EC50 and 95% confidence intervals were determined using the methods of Stephan.

Findings:

Throughout the test, all measured water quality parameters remained within acceptable limits for the survival and normal behaviour of daphnids. Measured concentrations at 0 hours averaged 115% nominal. Analyses at 24 and 48 hours established that the concentration of fenamiphos was consistently decreasing with time. Mean measured concentrations at 24 and 48 hours decreased by an average of 58% and 82% respectively relative to the time 0 measurements. Based on the 0, 24 and 48 hour analyses, the exposure concentrations were defined as 1.0, 1.5, 2.4, 4.2 and 6.9 µg/L (presumably as the pure substance).

After 24 hours, all daphnids in the 1.0, 1.5 and 2.4 µg/L groups as well as the controls were unaffected. In the 4.2 and 6.9 µg/L groups, immobility was recorded as 35% and 100% respectively with all surviving daphnids in the 4.2 µg/L group exhibiting erratic swimming behaviour.

After 48 hours, 100% immobility was found in the two highest test groups. 0%, 20% and 85% immobility was found in the 1.0, 1.5 and 2.4 µg/L groups respectively, with 5% in both controls. All surviving daphnids in all treatment groups were noted as having erratic swimming behaviour.

Conclusions:

Based on sub-lethal effects at the lowest tested concentration, the NOEC was established at <1.0 µg/L. The 48 h EC50 was determined using probit analysis and calculated to be 1.9 µg/L with 95% confidence limits of 1.7-2.1 µg/L.

Test Material: **Fenamiphos technical; Fenamiphos phenol sulfonic acid (M24)**
Report: Losel and Keppler, 2001
Guidelines: None
GLP: Yes

Test system:

In this non-standard screening test, different concentrations of M24 were tested for their toxicity to *Aedes aegypti* (mosquito) and *Daphnia magna* at concentrations of 0.01, 0.1, 1, 10 and 100 mg/L. To verify the sensitivity of the test system, the parent compound, fenamiphos (99.5% purity) was additionally tested at three concentrations, 0.01, 0.1 and 1 mg/L. The solutions containing the test substances were pipetted into 96 well plates with 10 replicates per concentration. Afterwards, one larva of each species were given into each well. Mortality of the test organisms was determined 4 and 24 h after the start of the experiment.

No other experimental details are given.

Findings:

In the fenamiphos controls, complete mortality was observed after 4 hours for both species at 1 mg/L. *Daphnia magna* showed 100% mortality after 24 hours in the 0.01 and 0.1 mg/L treatment

levels while *Aedes aegypti* had 100% and 10% mortality after 24 h in the 0.1 and 0.01 mg/L levels respectively.

By comparison, no mortality was recorded for any treatment level of M24 tested with *Aedes aegypti*. *Daphnia magna* had no mortality at any treatment level except the highest test rate of 100 mg/L where 10% mortality was recorded after 4 h and no further mortality after 24 h.

Conclusions:

In this screening toxicity study, the M24 metabolite was not toxic to either *Aedes aegypti* or *Daphnia magna* up to 100 mg/L (0% and 10% mortality after 24 h respectively). By comparison, the parent compound, fenamiphos, was highly toxic resulting in 100% mortality to *Daphnia magna* at the lowest tested concentration of 0.01 mg/L after 24 hours, and 100% mortality to *Aedes aegypti* at the second lowest concentration tested of 0.1 mg/L.

Test Material:	**Report:**
Fenamiphos sulfoxide (M01)	Hendel and Sommer, 2001a
Fenamiphos sulfone (M02)	Hendel and Sommer, 2001b
Fenamiphos sulfoxide phenol (M12)	Hendel, 2001a
Fenamiphos sulfone phenol (M13)	Hendel, 2001b
Guidelines:	OECD TG 202
GLP:	Yes

Test system:

The above fenamiphos metabolites were studied for their acute toxicity to *Daphnia magna* during 48 hour static exposure.

Neonates (<24 h old) were used for the study. Test vessels consisted of 100 mL glass beakers containing 50 mL test solution with 10 animals per vessel and three replicates per concentration. Beakers were covered and placed in an environmental chamber at around 20^{o}C with a 16:8 hour light:dark photoperiod. Test exposure concentrations (pure metabolite) were as follows:

Table A2.15: Test exposure concentrations of pure metabolites

M01 (µg/L)	1	2	4	8	16	32	64	128	256
M02 (µg/L)	0.5	1	2	4	8	16	32	64	
M12 (mg/L)	10	18	32	56	100				
M13 (mg/L)	5.6	10	18	32	56	100			

After 24 and 48 h daphnids were evaluated for mobility and swimming movements. Water hardness and alkalinity were measured at the start of the test in the dilution water control. The pH and dissolved oxygen were measured in the control and every test concentration at days 0 and 2. Temperature was measured at the start and end of the study in one vessel of the control and one vessel of the highest test concentration, and continuously in the environmental chamber. Test concentrations were analytically determined.

If possible, the EC50 values and 95% confidence limits were calculated by an EC50 computer program using the Probit-Analysis after the "Maximum-Likelihood" Method (according to Finney, 1952).

Findings:

Throughout the test, all measured water quality parameters remained within acceptable limits for the survival and normal behaviour of daphnids. Water hardness and alkalinity for all tests was 196 and 50 mg/L $CaCO_3$ respectively. The following table provides dissolved oxygen and pH ranges at

the start and end of the studies in the exposure vessels. They were in good agreement with control vessels.

Table A2.16: Dissolved oxygen (mg/L) and pH ranges at the start and end of exposure.

	Start		End	
	DO	pH	DO	pH
M01	8.4-8.7	8.0-8.1	8.7-8.7	8.0-8.1
M02	8.0-9.1	8.0-8.1	8.8-10.1	8.0-8.1
M12	8.6-8.7	7.6-8.1	8.8-8.9	8.0-8.1
M13	8.7-8.9	7.5-8.0	8.8-8.9	7.9-8.1

Average measured concentrations at the start and end of the study were 97 and 99% respectively for M01, 99 and 99% respectively for M02, 105 and 105% respectively for M11 and 100 and 99% respectively for M12. Therefore, nominal concentrations are used for reporting.

The following 48 hour immobilisation results were found (results reported from the highest test concentration where no immobility was found, or from the lowest test concentration if immobility found at that level):

Table A2.17: 48 hour immobility (%), nominal concentrations.

M01 (µg/L)	4	8	16	32	64	128	256
% immobility	0	38	67	63	90	100	97
M02 (µg/L)	1	2	4	8	16	32	64
% immobility	0	30	63	80	93	97	100
M12 (mg/L)	10	18	32	56	100		
% immobility	3	10	13	10	53		
M13 (mg/L)	5.6	10	18	32	56	100	
% immobility	3	17	43	97	90	83	

For all test substances, sub-lethal effects were observed. However, they were not observed at levels where immobility was not recorded, that is, for M01 and M02, sub-lethal effects (including laying at the bottom, differing antennae movements, lack of coordination) were not observed at test concentrations below 8 and 2 µg/L respectively. No sub-lethal effects were observed in the lowest test concentrations for M12 and M13, but were found at all levels higher than this.

Conclusions:

The following results were calculated:

Metabolite	EC50	95% CI	NOEC
M01	15 µg/L	7-27 µg/L	4 µg/L
M02	3.2 µg/L	2.3-4.1 µg/L	1.0 µg/L
M12	~100 mg/L	-	10 mg/L
M13	20.2 mg/L	3.3-77.7 mg/L	5.6 mg/L

Aquatic Invertebrates - Chronic

In support of the review of fenamiphos in Australia, the following study was provided and has been reviewed by DEH.

Test Material: Fenamiphos technical
Report: Surprenant, 1988c
Guidelines: US EPA Guideline 72-4
GLP: yes

Test system:

^{14}C-phenyl Fenamiphos was tested for chronic effects on the survival, reproduction and growth of *Daphnia magna* in a 21 day flow through test. Dilution water consisted of fortified well water with a reported hardness of 160-180 mg/L $CaCO_3$, alkalinity of 110-130 mg/L $CaCO_3$ and pH of 7.9-8.3. A proportional diluter was calibrated to provide 50% dilutions between adjacent nominal concentrations, and based on preliminary testing, nominal concentrations for the study were 0.029, 0.058, 0.12, 0.23 and 0.47 µg/L. In addition, a dilution water control and solvent control (acetone at 24 µL/L) were maintained. Test vessels had a constant volume of 1.8 L dilution water and all treatments and controls were maintained in quadruplicate. Test solutions were delivered at an approximate rate of 6 volume replacements per 24 hours. The test was conducted at around 20^{o}C with a 16:8 hour light:dark photoperiod.

The test was initiated with the distribution of daphnids (<24 h old) to each test concentration (10 per replicate). Adult survival and measurements of offspring production were made on days 1, 2, 4 and three times per week from day 7 to 21. Offspring were removed, counted and discarded. At test termination, surviving daphnids in each treatment level and controls were determined and lengths measured.

The test solution temperature was measured daily in one replicate of each level, and continuously monitored in another replicate of the solvent control throughout the study. Dissolved oxygen was measured every weekday in one replicate vessel per treatment. Total hardness, alkalinity and pH of the test solutions were monitored weekly in one replicate vessel per treatment. Dissolved oxygen and pH were also measured once a week in all replicate vessels. Water samples were analysed for actual test concentrations on days 0, 4, 7, 14 and 21. Additionally, the concentration of fenamiphos in the highest treatment level was confirmed by HPLC.

Data were statistically analysed according to standard procedures. The 21 day EC50 was determined by nonlinear interpolation and the 95% confidence limits were calculated by binomial probability.

Findings:

Biological performance of the two control groups was statistically similar indicating there was no adverse effect of the solvent used in the study. There was no apparent effect of the test substance on water quality parameters with hardness, alkalinity, pH and dissolved oxygen concentrations being at or around control values throughout the study.

Throughout the 21 day exposure period, there was no visible sign of insoluble material in any test solution. Based on analyses, the mean measured treatment levels in the study were 0.032, 0.066, 0.12, 0.24 and 0.49 µg/L.

After 7 days, no mortality was observed at any concentration or in the controls. However, by day 14, 92% mortality was found at the highest test concentration, and after 21 days, all daphnids exposed to the highest mean measured test concentration were dead. Therefore, reproductive results obtained from this group were therefore not subject to statistical analysis. The following table summarises the day 21 results.

Table A2.18: Effects of Fenamiphos on *Daphnia magna* in a 21 day Chronic Reproduction Study

Measured Concentration [µg ac/L]	Control	Solvent control	0.032	0.066	0.12	0.24	0.49
Parent survival at 21 days (%)	98	93	90	95	93	93	0*
Mean young/surviving female	46	53	49	63	68	54	-
Mean body weight (mg)	4.5	4.7	4.5	4.5	4.5	4.2*	-

* - statistically different than the pooled control at the 95% confidence level.

Control daphnids had begun to release offspring by day 7. While the raw figures aren't provided, the authors state that the time required for release of first brood offspring by daphnids in any of the exposure solutions was not adversely affected by the concentration tested.

After 21 days exposure, growth as determined by body length (no weight measurements were taken) was the most sensitive indicator of toxicity. Mean body length in the second highest test concentration, 0.24 µg/L, was deemed statistically significantly different from the pooled control mean length.

Conclusions:

The 21 day EC50 was calculated to be 0.36 µg/L (95% CI 0.24-0.49 µg/L). The dose/response curve is noted as being very steep with no significant mortality found in the next lowest treatment group.

Based on growth data, the NOEC of this study was 0.12 µg/L with a LOEC of 0.24 µg/L and a calculated MATC of 0.17 µg/L.

Algae and Aquatic Plants

One study each for technical fenamiphos and the main metabolites, M01 and M02, were provided to the APVMA for one algal species with the following results:

Table A2.19. Algae/Aquatic Plant Toxicity Results for Fenamiphos and its Main Metabolites

Test species	Test duration	Biomass (mg ac/L)	Growth rate (mg ac/L)	Reference
Fenamiphos technical		E_bC50/NOEC	E_rC50/NOEC	
Green algae (*S. subspicatus*)	96 h	3.5/0.32	11.0/1.0	Heimbach, 1987a
M01				
Green algae (*S. subspicatus*)	96 h	>100/10	>100/100	Heimbach, 1987b
M02				
Green algae (*S. subspicatus*)	96 h	25.0/10	45.7/18	Heimbach, 1987c

Test Material: **Report:**
Fenamiphos technical Heimbach, 1987a
Fenamiphos sulfoxide (M01) Heimbach, 1987b
Fenamiphos sulfone (M02) Heimbach, 1987c
Guidelines: OECD TG 201
GLP: Yes

Test system:

Fenamiphos (92.2% purity) and its two metabolites, M01 and M02, were tested in alga growth inhibition tests using the green algae *Scenedesmus subspicatus* in a static, 96 h test. The initial concentration of algal cells was $1X10^4$ cells/mL. Nominal formulation concentrations, based on the results of pre-tests were:

Table A2.20: Nominal Exposure Concentrations

Fenamiphos (mg/L)	0	0.56	1.0	1.8	3.2	10	
M01 (mg/L)	0	56	100				
M02 (mg/L)	0	3.2	10	18	32	56	100

In addition, for the fenamiphos technical test, two lower concentrations of 0.32 and 0.18 mg/L were used, but these results were not considered for the EC50 calculation.

Three replicates per concentration and control were used, and flasks were incubated at around 23°C. Algal cells were kept in suspension through intermittently turning off the incubator flasks. Samples were taken at 24, 48 and 72 hours. Cell counts were made indirectly by photometric evaluation of extinction/turbidity. The pH values were taken at time 0 then at 24 h intervals until the end of the test. Temperature measurements are provided for 96 h only.

No analytical determination of test concentrations was performed. The EC50 for growth of biomass and growth rate were calculated using a probit analysis by the method of "maximum likelihood".

Findings:

During the tests, pH was acceptable and there was no impact of any of the test substances on this parameter. Test temperature remained within acceptable limits for the studies.

The following results were found for inhibition of biomass growth (based on cell counts), and algae growth rate (based on the area under the growth curve, AUC).

Table A2.21: Inhibition (%) of biomass growth at 96 hours.

Fenamiphos (mg/L)	0	0.56	1.0	1.8	3.2	10	
Cell count (10^4/mL)	89.24	53.98	55.82	37.60	26.89	9.39	
% Inhibition	-	39.5	37.4	57.9	69.9	89.5	
M01 (mg/L)	0	56	100				
Cell count (10^4/mL)	181	163	168				
% Inhibition	-	9.9	7.2				
M02 (mg/L)	0	3.2	10	18	32	56	100
Cell count (10^4/mL)	234	255	199	183	73.2	4.11	2.29
% Inhibition	-	-9.0	15.0	21.8	68.7	98.2	99.0

Table A2.22: Inhibition (%) of algae growth rate (based on AUC) at 96 hours.

Fenamiphos (mg/L)	0	0.56	1.0	1.8	3.2	10	
% of control	100	88.8	89.6	80.8	73.3	49.9	
M01 (mg/L)	0	56	100				
% of control	100	98.6	98.0				
M02 (mg/L)	0	3.2	10	18	32	56	100
% of control	100	99.3	97.0	95.5	78.7	25.9	15.2

Conclusions:

The following results were calculated:

Compound	Biomass (mg/L)		Growth rate (mg/L)	
	E_bC50	NOEC	E_rC50	NOEC
Fenamiphos	3.5	0.32	11.0	1.0
M01	>100	10	>100	100
M02	25.0	10	45.7	18

Sediment Organisms

In support of the review of fenamiphos in Australia, one study was provided each for technical fenamiphos and its M01 metabolite addressing toxicity to the sediment dwelling midge, *Chironomus riparius*.

Test Material: **Fenamiphos technical**
Report: Hendel, 2001c
Guidelines: OECD TG 219 (Proposed at the time of testing)
GLP: yes

Test system:

The influence of fenamiphos (95.5% purity) was tested on the development and emergence of larvae of the sediment dwelling midge *Chironomus riparius* in a water-sediment system over a 28 day exposure period. Artificial test sediment was used consisting of 74% fine quartz sand, 5% peat and 20% kaolin with around 1% calcium carbonate to adjust the final pH to around 6. The sediment covered the bottom of the test containers to a depth of 1.5 cm and test water was added so as to not disrupt the sediment, to a depth of 6.0 cm (total of 0.38 L once test material was added). The water layer was gently aerated through the test, and precautions were taken to avoid evaporation of water. The test systems were prepared 7 days prior to test initiation with the test organisms added the day before the test substance.

Based on a range finding study, nominal test concentrations were 0.01, 0.02, 0.04, 0.08, 0.16 and 0.32 mg/L. The test substance was dissolved in dimethylformamide (DMF) and a solvent control (0.038 mL DMF) was maintained. Aliquots of application solution were applied just below the water surface with a pipette and gently mixed. For biological evaluations, three replicates were prepared for each test concentration, each containing 20 midge larvae. For chemical analysis of the active ingredient, additional parallel replicates were prepared for analytical purposes only (control and solvent control, 1 replicate; 0.01, 0.08 and 0.32 mg/L test concentrations, 2 replicates).

The test containers were exposed to a temperature of around 20^{o}C with a 16:8 hour light:dark photoperiod. Test vessels were observed at least three times per week for behavioural differences. The sex, time and number of emerged or not fully emerged adults were recorded daily during the period of emergence. One day prior to commencing the study and later on once per week, samples of the water column of the additional containers for water parameter measurements of each test concentration were taken, and the pH, temperature and dissolved oxygen of these samples was measured.

At the termination of the study, data on emergence and date of emergence (development rate) were analysed statistically to establish the EC15 and EC50.

Findings:

There were no noteworthy differences between the controls and treatment groups for water quality parameters throughout the test. Total hardness of the water at the start and end of the study was 249.2 and 284.8 mg/L $CaCO_3$ respectively while alkalinity at the start and end was 195.8 and 213.6 mg/L $CaCO_3$ respectively.

Overlying water concentrations (measured for the 0.01, 0.08 and 0.32 mg/L exposure levels) at day 0 ranged from 89.6-101% of nominal indicating the correct doses had been made. By day 7, no fenamiphos was detected in the overlying water or pore water at 0.01 mg/L. At day 7, around 22 and 28% of nominal levels remained in the overlying water of the 0.08 and 0.32 mg/L levels respectively with <1% found in the pore water. By day 28, negligible amounts of fenamiphos remained in either pore water or overlying water for these concentrations.

Emergence began on day 14 and finished on day 21 in the control and day 22 in the solvent control. Based on a total of 60 larvae per treatment, a total of 96.7% and 85% emergence was found of the control and solvent control respectively. Statistical analyses revealed these differences were not significant, and the control values were pooled for further comparison. The following table summarises emergence and development findings from the study.

Table A2.23: Emergence and mean development time and rate from 28 day exposure to fenamiphos.

		Control	Solvent control 0.01	0.02	
Emergence	Males	28	34	25	16
	Females	30	17	31	22
	Total	58	51	56	38
	Percent	96.7	85	93.4	63.4
Mean development time (d)		16.98	16.2	17.41	19.48
Mean development rate (/d)		0.059	0.062	0.058	0.052

No emergence was found in treatment levels greater than 0.02 mg/L. At 0.02 mg/L emergence did not commence until day 16 and ended at day 26. While development times were longer for the exposed midges where emergence was found, and the development rate for the 0.02 mg/L test was smaller than controls, these were not deemed significantly different from the controls.

Conclusions:

Based on probit analysis, and using emergence rate data (pooled sex), the EC15 was determined to 0.014 mg/L (95% confidence limits of 0.012-0.016 mg/L). The EC50 was determined to be 0.02 mg/L, although, it must be more realistically considered to be between 0.02 and 0.04 mg/L. Due to

no emergence at concentrations 0.04-0.32 mg/L, the NOEC for the development rate was 0.02 mg/L. This indicates a very steep dose-response curve for these organisms under the test conditions.

Test Material: **M01**
Report: Dorgerloh and Sommer, 2002
Guidelines: OECD TG 219 (Proposed at the time of testing)
GLP: yes

Test system:
The influence of the fenamiphos sulfoxide metabolite M01 was tested on the development and emergence of larvae of the sediment dwelling midge *Chironomus riparius* in a water-sediment system over a 28 day exposure period. Test set up, artificial sediment and methodology are as described in Hendel (2001) above for the test with the parent product.

The nominal test concentrations were 0.01, 0.018, 0.032, 0.058 and 0.1 mg pure metabolite/L. No solvent was used. For chemical analysis of the active ingredient, additional parallel replicates were prepared for analytical purposes only (control and solvent control, 1 replicate; 0.01, 0.032 and 0.1 mg/L test concentrations, 2 replicates).

Findings:

There were no noteworthy differences between the controls and treatment groups for water quality parameters throughout the test. Total hardness of the water at the start and end of the study was 302.6 and 284.8 mg/L $CaCO_3$ respectively while alkalinity at the start and end was 178.0 and 231.4 mg/L $CaCO_3$ respectively.

Overlying water concentrations (measured for the 0.01, 0.032 and 0.10 mg/L exposure levels) at day 0 ranged from 64.2-86.2% of nominal. Significant levels remained in the overlying water (38.5-58.7% at day 7 and 22.0-33.8% at day 28). Much lower levels were found in pore water with generally <1.5% of the dose being found in this medium.

Emergence began on day 14 and finished on day 21 in the control and day 22 in the solvent control. Based on a total of 60 larvae per treatment, a total of 93.3% emergence was found in the control. The following table summarises emergence and development findings from the study.

Table A2.24: Emergence and mean development time and rate from 28 day exposure to fenamiphos.

		Control	0.01	0.018	0.032	0.058	0.1
Emergence	Males	23	29	26	39	30	12
	Females	33	29	32	18	25	11
	Total	56	58	58	57	55	23
	Percent	93.3	96.7	69.7	95.0	91.7	38.3
Mean development time (d)		17.22	17.62	17.19	17.00	17.50	19.08
Mean development rate (/d)		0.058	0.057	0.058	0.059	0.057	0.052

There was no difference in time of emergence commencing in the control and treatment groups with the exception of the highest test level where it was two days later than the control.

There was no difference in development time in the control and the test concentrations up to 0.058 mg/L. At the highest test concentration, the mean development time was 11% higher compared to the control findings. Abnormal behaviour of larvae, pupae or midges throughout the study were observed only in the two highest test concentrations, although other than mortality or failing to emerge, it is unclear what these abnormal behaviours were.

Conclusions:

Based on probit analysis, and using emergence rate data (pooled sex), the EC15 was determined to 0.074 mg/L (95% confidence limits of 0.06-0.093 mg/L). The EC50 was determined to be 0.095 mg/L. Based on development rate, the NOEC was 0.10, the highest level tested as the 11% longer development time compared to control midges at this concentration was not considered statistically significantly different. However, the NOEC for the study must be determined to be 0.058 mg/L based on effects on emergence.

Mesocosm studies

Test Material:	Fenamiphos, (NEMACUR® 35.2% EC Formulation)
Report:	Kennedy *et al*, 1991
Guidelines:	US EPA Guideline 72-7
GLP:	yes

Test system:

The study was performed at the University of North Texas Water Research Field Station in Denton County Texas. Ponds used in the study were 30 m length and 16 m wide with all sides gently sloping (2:1 ratio) to a maximum depth of 2 m. Each was lined with clay. Topsoil was added to a depth of around 15 cm to provide a habitat for benthic organisms and a substrate for macrophyte roots. A total of 14 mesocosms were used and designated as control (3 replicates), no fish control (2 replicates) and three treatment level ponds (3 replicates per treatment level).

The test systems were dosed twice, with seven days between treatments. The first dosing was on 29 June 1990. Nominal treatment levels were 1.0, 3.5 and 12.5 µg/L. Levels were designed to simulate two runoff events that may occur after application. The high water solubility of the test substance results in little adsorption and the test product was applied in solution below the water surface rather than as soil slurry.

Ponds were divided into littoral (shallow) and pelagic (open) sampling zones for water quality and biological measurements. For most biological parameters, one littoral and one pelagic composite sample per pond were collected for analysis at each sampling point. Samples from all zones were composited prior to analysis with 3 replicates for each parameter collected.

Extensive biological/chemical measurements were made periodically during the 14 weeks prior to treatment to characterise the mesocosms so that a data base on the structure and function of the systems was available. During the treatment and post-treatment period, *in situ* measurements of dissolved oxygen, temperature and pH were made weekly. Biological parameters were measured every two weeks during pesticide treatment and after treatment except for sampling of periphyton chlorophyll *a* and periphyton biomass, which were sampled monthly for the 12 weeks following final application. Water concentrations were determined before and after each application, and every two weeks after the last application. In addition, during the two weeks of application, randomly selected water samples were collected at 1, 8, 24, 48 and 96 h, and at one week after application, to determine the dissipation and half-life of NEMACUR®. Sediment residues were measured each week of application and then monthly until 12 weeks post-treatment.

Biological parameters measured included phytoplankton (chlorophyll *a* and pheophytin *a*; total plankton biomass), periphyton (biomass and photosynthetic pigments); macrophytes, including judgements on the health of the macrophyte community; ecosystem metabolism (dissolved oxygen to indicate levels of primary production or community respiration); zooplankton (occurrence and spatial distribution); macroinvertebrates (artificial substrate samplers, trap sampling, visual assessment of pond organisms, grab sampling); and fish. The mesocosms were stocked with mature bluegill sunfish (*Lepomis macrochirus*) with a total of 15 females and 15 males per pond giving a

combined weight of around 2.1 kg (1.8-2.4 kg). Fish mortality was assessed daily and any fish found dead up until the time of first pesticide application were replaced. Fish were harvested from the mesocosms over an 11 day period (1-11 October 1990) and measured length and weight.

One-way ANOVA tests were used to test the null hypothesis of no differences between measured biological parameters in control and treatment ponds. Biological counts were log-transformed to normalise the data. If there was a difference between treatments a Dunnets Test was performed to identify differences among the means.

Findings:

Results of water residue measurements indicated the correct doses were received by the mesocosms. The following results of water residue analysis were found:

Table A2.25: Average water residue Concentrations (ppb) following application

Week of	1 ppb			3.5 ppb			12.5 ppb		
Application	Fen	M01	M02	Fen	M01	M02	Fen	M01	M02
1st app	1.12	0.22	<0.10	3.51	0.68	<0.10	9.56	2.00	<0.10
2nd app	0.98	0.53	<0.10	5.39	2.48	<0.10	9.49	3.46	<0.10
4	0.30	0.78	<0.10	0.75	2.28	<0.10	4.60	12.05	0.25
6	0.72	1.87	0.75	0.58	1.58	0.42	1.80	8.32	0.33
8	0.13	0.55	<0.10	0.40	1.52	<0.10	1.49	7.88	0.23
10	<0.10	0.43	<0.10	0.15	0.91	0.11	0.70	6.01	0.40
12	<0.10	0.15	<0.10	0.14	0.44	<0.10	0.66	3.80	0.13
14	<0.10	0.25	<0.10	0.12	0.56	<0.10	0.36	3.42	0.24

No movement was detected from water to sediment. The LOQ for sediment analyses was 10 µg/kg, and based on the amount of chemical applied to each mesocosm to obtain the desired application rate, a theoretical loading of 15, 52 and 185 µg/kg in sediment was achievable if all applied chemical was distributed among the top 15 cm sediment (assuming density of 1.5 kg/m^3). The top 1 cm of sediment was sampled, and at no time was either fenamiphos or M01 detected up to the LOQ in sediments from any treatment mesocosm. M02 was found at a mean level of 10.9 µg/kg after 14 weeks in the high test concentration mesocosms.

The half-life of NEMACUR® in the water column was estimated based on residue values measured after the first application and was calculated to be 93 hours.

The physicochemical results suggest slight differences after treatment between control ponds and the treatment ponds for phosphates, turbidity, nitrite and ammonia. However, no temporal trends were established that would suggest the effects were associated with dosing. There was no apparent consistent reduction in dissolved oxygen levels related to treatment rates. During the study an overall increase in pH was observed with one peak evident at week 10. There was no apparent effect of treatment on pH levels. The overall pH increase is associated with the development of the primary producer community.

The ponds supported a diverse phytoplankton, zooplankton and macroinvertebrate community. NEMACUR® had no quantifiable direct effects on the primary producer community. Planktonic algal production (biomass, chlorophyll *a* analysis) and taxonomic composition were similar in control and treatment ponds. There were no measurable effects on the periphyton photosynthetic pigments and biomass that could be related to treatment.

Effects on zooplankton population effects were noted, principally, a decrease in the Rotifera populations and an increase in Copepoda populations in the high rate ponds. The changes in Copepoda populations were considered indirect rather than a direct effect of toxicity, resulting from reduced predation by fish in the high rate ponds. Similarly, the lower Rotifera populations were probably a response to increased competition and predation as Copepoda populations increased.

Few effects were noticed on aquatic insects at the low and mid treatment levels. For invertebrate populations collected on artificial substrate samplers, there were no statistical probabilities calculated that would suggest separation of the control benthic communities from the treatment communities. Emergence trap results supported the observation that there no differences between control and treatments prior to dosing. Following dosing, by study week 4 (2 weeks after the last application), emergence composition in the high dose ponds was dominated by chaoborids, and was diverging from observations in other ponds, although still not statistically significant. By week 8, emergence in the control and two lower treatment ponds was dominated by Chironominae and Tanypodinae. Emergence in the high dose ponds was dominated by Chaboridae and macroinvertebrate community structure was considered statistically significantly different from the other ponds. This was possibly a response to fish predation pressures in these ponds. Emergence percent similarity between the ponds at the end of the study was similar between all treatment ponds.

Macroinvertebrate taxa collected were classified into functional feeding groups (a somewhat subjective procedure). The system was dominated by collector-gathers. Statistical differences that were found between feeding group proportions could be related to impacts on invertebrate groups. For example, significant increases observed during weeks 3, 4 and 10 in the numbers of scrappers during the study is probably due to the higher populations of snails in the treatment ponds. Significant reductions in the number of herbivore-piercers observed during weeks 2, 6, 8 and 14 are stated as being due to the effect of treatment on the caddisfly family Hydroptilidae. This apparent toxic effect was not explored further.

No acute effects were observed on adult fish in the low or middle treatment ponds. However, the highest treatment rate resulted in acute effects on both adults and young fish within 24 hours after application. From the three replicates of each treatment and control, a mean number of 10,766 fish were harvested from the control ponds compared to 15,829 in the low treatment ponds, 15,112 in the medium treatment ponds and only 4,115 in the high treatment ponds. There were no statistically significant differences between the low and medium dose groups and the control for numbers or weights of fish. Average fish weights (total biomass) for the control, low and medium treatment groups were in the order of 5.7, 6.2 and 5.2 kg respectively. By comparison, a statistically significantly reduced mean pond weight of fish in the high dose ponds was 2.7 kg. A number of significant differences were measured in the number and weight of fish size classes collected from the highest treatment rate ponds that could be related to either direct pesticide effects (decreases in size class populations) or indirect effects (increases in size class average weights).

The fish harvested were also examined for abnormalities. No physical abnormalities were observed in any of the fish collected.

Conclusions:

The physicochemical parameters of the water were generally unaffected by any treatment level. Turbidity in the treatment ponds was lower than that observed in the control ponds and is thought to be related to NEMACUR® formulation.

Specific effects on aquatic organisms were noted over the range of test concentrations. Based on the laboratory 96 h LC50 to the test fish, bluegill sunfish were highly sensitive to the chemical at the highest test concentration. There were few apparent direct effects on the total numbers of

zooplankton. Decreases in the number of Rotifera were noted at the highest dose rate. However, this effect was thought to be a result of copepod predation on the rotifer community. Few effects were noticed on certain taxa (mayflies; caddisflies) at the highest test concentration. Direct mortality of fish was noted at the highest treatment level; however, no statistically significant effects were observed at the low and medium test levels. Based on these results, a NOEC for this study was the nominal 3.5 ppb test concentration.

Test Material:	Fenamiphos, (NEMACUR® 35.2% EC Formulation)
Report:	Kennedy *et al*, 2000
Guidelines:	N/A
GLP:	N/A

Test system:

This study was undertaken to re-evaluate the effects on NEMACUR® treatment on zooplankton and macroinvertebrate communities observed in the study performed by Kennedy *et al* (1991) described above and used statistical tools beyond the ANOVA techniques originally used to analyse the data.

The new statistical method used in this study was principal time response curves (PTRC) analysis. Principal response curves are used to obtain an overview of the effect of treatments on species abundance across time. To determine which treatment levels were significantly different from control populations for individual sampling dates, a Monte-Carlo permutation test (1000 replications) was performed for each sampling date.

Findings:

PTRC analysis for pelagic zone zooplankton communities in the high dose ponds were significantly different from control ponds during all but 10 and 14 weeks after dosing commenced and are stated as probably being a result of both direct chemical effects and indirect influences that occurred because of reduced fish predation rates on plankton populations. As noted in the original report, recently spawned fish and some adult fish were killed in the high dose ponds after treatment resulting in reduced predation pressures on the zooplankton community. This interaction was captured in the PTRC analysis where zooplankton communities in the high dose ponds closely followed the no fish control (NFC) group community beginning two weeks after dosing began. Although not statistically significant zooplankton populations in the medium dose ponds showed a deviation from control ponds in samples taken during week 3 after dosing. This deviation was transient and not evident in week 4 littoral zooplankton communities or after week 4 in the pelagic zone. The impact of fish on zooplankton communities was obvious in both littoral and pelagic zones of the ponds. Beginning 2 weeks before dosing NFC pond zooplankton communities were statistically significantly different from control in both zones. These community differences were maintained throughout the study in the NFC ponds except for the last sampling date in the littoral zone.

PTRC analysis for the littoral macroinvertebrate community showed statistically significant deviation from the control in the high dose pond samples collected 4 and 6 weeks after dosing began. The PTRC of the pelagic macroinvertebrate community revealed no visual dose response relationships. Although there were treatment levels that were significantly different from the control at individual time points, none represent a dose response relation (low dose, week 10; medium and high dose, week 14).

Conclusions:

The zooplankton community inhabiting the pelagic zone showed consistent differences from the control at the highest treatment level. Transitory effects on zooplankton populations were indicated at the medium dose level. No other differences were consisted with a dose response.

Transitory effects on the littoral macroinvertebrate community were detected in week 4 and 6 at the highest dose level. On the basis of the PTRC analysis, this community was considered to be recovered in samples taken 8 weeks after dosing began.

Conclusions for Aquatic Toxicity

Several older (pre-1990) fish toxicity results (including one salt-water species) were reviewed for fenamiphos and four main metabolites, M01, M02 (1 species each), M12 and M13 (two species each). In addition, one more recent study (2001) was provided for technical fenamiphos. For the parent compound, results were relatively uniform with LC50 values ranging from 8.4-14.3 ppb (one LC50 of 58.4 ppb was found for rainbow trout). These results indicate fenamiphos is highly to very highly toxic to fish. When tested as a granular formulation, results for two species also showed LC50 values of 22.6-84.4 ppb, also indicative of high toxicity. Dose/response curves were steep. One longer term study was provided (rainbow trout, early life stage) with fenamiphos technical as the test substance. Based on significantly reduced larval growth following 60 days post-hatch exposure, the LOEC was estimated to be 7.4 ppb with a NOEC of 3.8 ppb, confirming fenamiphos as being highly toxic to fish.

The metabolites were substantially less toxic to fish than the parent compound. Based on 1 species and 1 test, M02 was the most toxic of the tested metabolites (LC50 1,200 ppb (moderately toxic) while M01 was also moderately toxic with an LC50 of 2,600 ppb (1 species, 1 test). M12 and M13 were practically non-toxic with NOECs >100,000 (2 species each, 1 test).

Very few data were provided for toxicity of fenamiphos or metabolites to aquatic invertebrates. One standard study with *Daphnia magna* for technical fenamiphos resulted in an LC50 of 1.9 ppb (NOEC <1 ppb) suggesting the substance is very highly toxic to aquatic invertebrates. M01 and M02 were also very highly toxic to aquatic invertebrates based on one study each to *Daphnia magna* where LC50s of 15 and 3.2 ppb were found respectively. M12 and M13 were much less toxic, again based on one study each to *Daphnia magna* with M12 resulting in an LC50 of around 100,000 ppb (practically non-toxic), and M13 with an LC50 around 20,200 ppb (slightly toxic). A non-standard screening study comparing toxicity of M24 to fenamiphos showed this substance to be practically non-toxic to two species, *Daphnia magna* and a mosquito (*A. aegypti*) with LC50s >100,000 ppb for both. One study testing chronic toxicity of fenamiphos technical to *Daphnia magna* was provided. Based on mortality, the EC50 was calculated to be 0.36 ppb. The dose/response curve was very steep with no significant mortality found at the next lowest treatment level of 0.24 ppb. Growth, as determined by mean body weight, was the most sensitive end-point and resulted in a NOEC of 0.12 ppb. These results confirm fenamiphos as being highly toxic to aquatic invertebrates.

Only one study each was provided testing toxicity of fenamiphos, M01 and M02 to algae/aquatic plants, and for all, only one algal species was tested (green algae, *S. subspicatus*). Fenamiphos was moderately toxic to this species (E_bC50 3,500 ppb). M02 was slightly toxic (EC50 25,000 ppb) while M01 was practically non-toxic (EC 50 >100,000 ppb).

One study each was provided testing toxicity of fenamiphos and M01 to the sediment dwelling midge, *Chironomus riparius*. For fenamiphos, the EC50 was determined to be 20 ppb, although it must be more realistically considered to be between 20 and 40 ppb (very highly toxic). Due to no

emergence at concentrations 40-320 ppb, the NOEC for the development rate was also 20 ppb. This indicates a very steep dose-response curve for these organisms under the test conditions. In the M01 study, the EC50 was determined to be 95 ppb (highly to very highly toxic). The NOEC for the study was determined to be 58 ppb based on effects on emergence.
A mesocosm study was undertaken assessing toxicity of fenamiphos (applied as a 35.2% EC formulation). The test systems were dosed twice, with seven days between treatments. Nominal treatment levels were 1.0, 3.5 and 12.5 µg/L. Control mesocosms were maintained either with no chemical treatment, or no fish loading. The mesocosms were stocked with mature bluegill sunfish (*Lepomis macrochirus*) with a total of 15 females and 15 males per pond. Specific effects on aquatic organisms were noted over the range of test concentrations. There were few apparent direct effects on the total numbers of zooplankton. Decreases in the number of Rotifera were noted at the highest dose rate. However, this effect was thought to be a result of copepod predation (due to lower predation on copepods resulting from fish mortality) on the rotifer community. Few effects were noticed on certain taxa (mayflies; caddisflies) at the highest test concentration. Direct mortality of fish was noted at the highest treatment level; however, no statistically significant effects were observed at the low and medium test levels. Based on these results, a NOEC for this study was the nominal 3.5 ppb test concentration.

Terrestrial Toxicity

Non-Target Invertebrates

Bees

Two studies were submitted to the APVMA for review with the following results:

Table A2.26. Summary of Toxicity to Bees for Fenamiphos

Test species	Test duration	LD50 (µg ac/bee)	Reference
Fenamiphos technical			
Honey bee (A. mellifera)	48 h oral	0.46	Kleiner, 1995
Honey bee (A. mellifera)	48 h contact	0.28	Kleiner, 1995
Bumble bee (B. terrestris)	72 h contact	1.59 (NOEC 0.7)	Kling, 2001

Test Material: Fenamiphos technical
Report: Kleiner, 1995
Guidelines: EPPO Guideline No. 170
GLP: Yes

Test system:

The study was undertaken to evaluate the acute oral toxicity and contact of fenamiphos (95.3% purity) administered to the honey bee (*Apis mellifera*). Test concentrations were as follows (µg/bee).

Oral toxicity: 0.2, 0.24, 0.28, 0.32, 0.36, 0.4, 0.8

Contact toxicity: 0.1, 0.15, 0.2, 0.25, 0.3, 0.35, 0.4, 0.45, 0.5

For both, a control (sucrose for the oral component; acetone for the contact component) and a positive control (dimethoate from 0.2-0.4 µg/bee in the oral test and 0.0313-1.0 µg/bee in the contact test) were maintained. Test levels for the oral toxicity component were determined based on available test substance in the diet, assumed to be distributed evenly amongst bees.

Test cages consisted of disposable cardboard cages with ventilation holes. Each cage contained 10 bees with 3 replicates per concentration. Temperature was maintained at around 25°C with relative humidity of 61-74% and an 8 h per day photoperiod was used. The test duration was 48 hours.

Assessments of mortality and behaviour were assessed at 24 and 48 hours. The validity criterion for this study was a maximum 15% mortality in the control group. Determination of the LD50 was carried out by non-linear regression analysis (dose-response relationship).

Findings:

Mortality in the control was 0% for both oral and contact tests. Mortality in the fenamiphos treatments at 48 hours (%) was recorded as follows:

Table 2.27: % Mortality to honey bees in a 48 h acute oral and contact toxicity test.

Oral toxicity:	0.2	0.24	0.28	0.32	0.36	0.4	0.8		
48 h mortality (%)	20	10	13	17	20	33	97		
Contact toxicity:	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5
48 h mortality (%)	0	7	7	17	77	70	97	97	90

The majority of observed mortality had occurred after the first 24 hours. In the positive control 97% mortality was observed at 0.4 µg/bee in the oral toxicity test, and 90 and 100% mortality at 0.5 and 1.0 µg/bee respectively in the contact test.

Bees affected by fenamiphos showed restlessness, irritation, uncontrollable motions and dorsal position before dying in the test variant. Surviving bees exhibited no abnormal behaviour.

Conclusion:

The LD50 from the oral toxicity test was calculated to be 0.46 µg/bee (95% CI 0.40-0.52 µg/bee) compared to a dimethoate 48 h LD50 of 0.26 µg/bee.

The LD50 from the contact toxicity test was calculated to be 0.28 µg/bee (95% CI 0.27-0.30 µg/bee) compared to a dimethoate 48 h LD50 of 0.30 µg/bee.

Test Material: Fenamiphos technical
Report: Kling, 2001.
Guidelines: EPPO Guideline No. 170
GLP: Yes

Test system:

Fenamiphos (96.2% purity) was tested for acute contact toxicity to the bumble bee (*Bombus terrestris*) in a 72 h test. Based on the results of a range-finding study, the test substance was tested at 0.35, 0.70, 1.40, 2.80 and 5.60 µg/bee. Bees in the control group were treated with acetone and dimethoate was used as a toxic standard at a nominal test concentration of 5 µg/bee.

Test cages consisted of white plastic vessels with perforated lids for ventilation. Anaesthetised bees were topically treated with the test substance to the ventral part of the thorax and distributed to the test cages (10 bees per cage, 3 cages per treatment).

During the experimental phase the test animals were kept under constant darkness. Observations were made under red light. The temperature was 25-26°C and relative humidity from 44-60%. The number of dead bees was recorded after 2, 4, 24, 48 and 72 hours. In the case of symptoms of poisoning the behavioural differences between the bumble-bees of the control group and those of the test substance treatment were noted at each observation interval.

The average mortality of the three replicates per concentration was calculated after correction for control mortality. The validity criterion for this study was a maximum 15% mortality in the control group after 48 h.

Findings:

No mortality was recorded in the control group after 72 hours. In the toxic standard test, mortality was 96.7% after 72 h (90% after 24 h). By comparison, after 72 hours, mortality of 6.7, 3.3, 40.0, 93.9 and 100% was found in the 0.35, 0.70, 1.40, 2.80 and 5.60 µg fenamiphos/bee treatment levels respectively. Most of this mortality had been found after the first 24 hours.

The test report states that treated bumble-bees did not differ in behaviour from the control bees at any time during the study.

Conclusion:

The 72 h acute contact LD50 for bumble-bees exposed to fenamiphos was determined to be 1.59 µg/bee (95% CI 1.33-1.84 µg/bee). While not confirmed in the test report, the NOEC for this study is 0.7 µg/bee based on mortality.

Other Arthropods

Several studies were provided assessing toxicity of fenamiphos and its major metabolites to various non-target arthropods with the following results:

Table A2.28. Summary of Toxicity to Terrestrial Arthropods for Fenamiphos and Metabolites

Test species	Test system	LR50 (g ac/ha)	Reference
Fenamiphos (CS240 Formulation)			
Aphid parasitoid (*A. rhopalosiphi*)	48 h mortality	0.152	Vinall, 2001
Aphid parasitoid (*A. rhopalosiphi*) – extended laboratory study	Adult mortality (48 h)	14.68	Schuld, 2000
	Reproduction	NOEC >14.2	
Predaceous mite (*T. pyri*)	Adult mortality (7 d)	1.69	van Stratum, 2002
	Reproduction	NOEC 1.0	
Predaceous mite (*T. pyri*) – extended laboratory study	Adult mortality (7 d)	14.1	Adelberger, 2002
	Reproduction	NOEC >14.2	
Green lacewing (*C. carnea*) – extended laboratory study	Adult mortality (12 d)	34.05	Kemmeter, 2000
	Reproduction	NOEC >51.6	
Carabid beetle (*P. cupreus*) – extended laboratory study	Adult mortality (22 d)	226	Neumann, 2001
	Feeding rate	NOEC 516	
Predatory bug (*M. pygmaeus)*	Adult mortality (14 d)	1.3	Jackel, 2002
Collembola (*F. candida*) – extended laboratory study	Adult mortality (28 d)	4.07 mg/kg dw	Friedrich, 2001a
	Reproduction (EC50)	1.14 mg/kg dw	
M01			
Collembola (*F. candida*) – extended laboratory study	Adult mortality (28 d)	8.91 mg/kg dw	Meister, 2001a
	Reproduction(EC50)	4.55 mg/kg dw	
M02			
Collembola (*F. candida*) – extended laboratory study	Adult mortality (28 d)	4.5 mg/kg dw	Meister, 2001b
	Reproduction(EC50)	5.1 mg/kg dw	
M12			
Collembola (*F. candida*) – extended laboratory study	Results not provided in report. Results for M13 below are used as a surrogate.		Friedrich, 2001b
M13			
Collembola (*F. candida*) – extended laboratory study	Adult mortality (28 d)	441 mg/kg dw	Friedrich, 2001c
	Reproduction(EC50)	21.6 mg/kg dw	

Test Material: Fenamiphos, CS240 formulation
Report: Vinall, 2001
Guidelines: Mead-Briggs *et al*, 2000
GLP: Yes

Test system:

The study was undertaken to determine the effect of the capsule suspension (CS) formulation Fenamiphos CS 240 (232.1 g ac/L, measured) on the aphid parasitoid *Aphidius rhopalosiphi* in the laboratory. The test article was diluted in deionised water (200 L/ha) and applied to glass plates at rates equivalent to 0.023, 0.058, 0.146, 0.371 and 0.928 g/ha based on the nominal active ingredient (maximum of 4 mL product/ha). A control treatment of deionised water (200 mL/ha) and dimethoate at a nominal rate of 0.1 g/ha (applied in 200 L/ha) were also included in the experiment.

Treatments were applied to glass plates, and once dry, these were used to form the floor and ceiling of shallow arenas. Ten adult wasps including a minimum of 5 females were placed in each arena (3 replicates per treatment). The test was conducted at around 20^{o}C and 64-87% relative humidity with ambient lighting for a 16 h photoperiod.

The conditions of the wasps were recorded at 2, 24 and 48 h after their introduction. Moribund wasps were counted as dead. Mortality was corrected for control mortality, and $\log_{10}$ transformed mortality data were evaluated by Probit analysis to determine the LR50. The test was deemed valid if control mortality did not exceed 13.5% (4/30 wasps).

Findings:

Control mortality was 3% after 48 hours compared to 100% mortality in the dimethoate control. In terms of correct mortality, the fenamiphos exposed groups had mortality of 0, 7, 25, 100 and 100% in the 0.023, 0.058, 0.146, 0.371 and 0.928 g/ha groups respectively.

No observations appear relating to sub-lethal effects.

Conclusion:

The results of the Probit analysis on the data resulted in a calculated LR50 for Fenamiphos CS 240 of 0.152 g ac/ha (95% CI 0.084-0.312 g ac/ha).

Test Material:	**Fenamiphos, CS240 formulation**
Report:	Schuld, 2000
Guidelines:	Polgar (1988); Mead-Briggs (2000), Barrett *et al* (1994)
GLP:	Yes

Test system:

The study was undertaken to determine the effect of the formulation Fenamiphos CS 240 (258.2 g ac/L, measured) on the aphid parasitoid *Aphidius rhopalosiphi* in an extended laboratory study. The product was diluted in water and applied to tomato leaves at nominal rates of 4.2, 10, 24, 55 and 130 mL product/ha. Based on these nominal application rates, the equivalent applications of fenamiphos were 1.08, 2.58, 6.20, 14.20 and 33.57 g ac/ha. When dry, the treated leaves formed the floor of the treatment arenas. 10 wasps of equal sex ratio were placed into each replicate (4 per treatment). Water was applied as a control and dimethoate (12 g/ha applied in 200 L/ha water) was used as a toxic standard.

Assessments of direct treatment effects were made after 0.5, 2, 24 and 48 hours. Then to assess any impact on fecundity of surviving individuals, 15 females from the control groups and the three lowest treatment groups were taken and confined individually over aphid-infested (untreated) barley plants for a further 24 h. The fertility test of the 14.2 g/ha treatment group was conducted with 6 females, and no fecundity assessment was undertaken with the highest treatment group due to mortality being >50%. The numbers of parasitised aphids that developed was recorded 11 days later.

Experimental conditions included a temperature around 20°C, relative humidity of 50-85%, continuous light for the 48 h exposure component and 16:8 hour light:dark photoperiod for the reproduction component. The test was considered valid if mean mortality in the control group did not exceed 10%, and in the toxic standard group, was not <50%.

For the exposure part of the test, mortality was corrected for control mortality and the LR50 determined by Probit analysis. For the reproduction component, the mean number of offspring/female was determined by averaging replicate values to enable calculation of the reproduction factor. These were analysed statistically for comparison with control values.

Findings:

During the 48 h exposure period, no mortality was found in the control and 100% mortality was found in the dimethoate control indicating the test system was satisfactory. Based on dead and moribund organisms, mortality (%) in the 1.08, 2.58, 6.20, 14.20 and 33.57 g ac/ha levels was 5, 5, 10, 45 and 97.5% respectively with levels at the two highest test rates being significantly different to control values.

The following findings were recorded for the reproduction component of the study:

Table A2.29: Reproduction rate of *Aphidius Rhopalosiphi*.

Application rate (g ac/ha):	0	1.08	2.58	6.20	14.20
Number of females	15	15	15	15	6
Number of mummies	351	273	298	210	136
Mummies/female	23.40	18.20	19.87	14.00	22.67
Reproduction factor[1]	-	0.78	0.85	0.60	0.97

1) Relative to the control

Between groups exposed to the test substance at all tested concentrations in comparison to the control group, no statistically significant differences were observed.

Conclusion:

The 48 h LR50 was calculated to be 56.85 mL product/ha, equivalent to 14.68 g ac/ha, with 95% confidence limits of 11.66-17.37 g ac/ha.
No statistically significant effects on the reproduction capacity of *Aphidius rhopalosiphi* were observed up to 14.2 g ac/ha.

Test Material: **Fenamiphos, CS240 formulation**
Report: van Stratum, 2002
Guidelines: Blumel *et al* (2000); Bakker *et al* (1992); Overmeer (1988); Barrett *et al* (1994)
GLP: Yes

Test system:

The study was undertaken to determine the effect of the formulation Fenamiphos CS 240 (236.2 g ac/L, measured) on the predaceous mite, *Typhlodromus pyri* in a laboratory study. The product was diluted in water (200 L/ha) and applied to glass mortality units (coffin cells) and glass reproduction units at five nominal concentrations of 0.25, 0.5, 1.0, 2.0 and 4.0 g ac/ha. After drying of the residues, the coffin cells were assembled. The control was treated with deionised water. Dimethoate at a rate of 96 mg/ha was used as a toxic standard.

The test organisms (1 day old protonymphs) were confined to the residues in the cells (20 mites per cell with 4 cells per treatment level) and mortality was assessed after a 7 day exposure period. All surviving individuals of the water control and test item rates up to 1.0 g/ha were transferred to treated open glass arenas on the day of the mortality assessment (<50% corrected mortality at higher rates). Reproduction for these treatments was determined during 7 days in total.

Climatic conditions through the test included a temperature around 25^{o}C, 60-90% relative humidity and a 16:8 h light:dark photoperiod.

The test was considered valid if control mortality did not exceed 20% and was not <50% in the toxic standard; and if mean reproduction in deionised water control was at least 4 eggs/female in seven days.

The LR50 was calculated using probit analysis while reproduction data were analysed statistically using standard procedures.

Findings:

Mortality in the deionised water control was 8% with corrected mortality in the reference test being 69%. Corrected mortality in the fenamiphos treatment groups of 0.25 and 0.5 g ac/ha were 6 and 4% respectively and were not statistically different from the control. In the 1, 2 and 4 g ac/ha groups, corrected mortality did differ significantly from the control and were recorded as 20, 55 and 97% respectively.

The mean total number of eggs/female during the 7 day period of reproductive observation was 7.5. Reproduction relative to the control in the 0.25, 0.50 and 1.0 g ac/ha treatment groups were 99, 85 and 77% respectively, and despite an apparent dose related reduction in reproduction, these values were deemed to not be significantly different from the control.

Conclusion:

The 7 day LR50 was calculated to be 1.69 g ac/ha, with 95% confidence limits of 1.5-1.9 g ac/ha. No statistically significant effects on the reproduction capacity of *T. pyri* were observed up to 1.0 g ac/ha.

Test Material:	**Fenamiphos, CS240 formulation**
Report:	Adelberger, 2002
Guidelines:	IOBC (Overmeer, 1988 and Oomen, 1988); Barrett *et al* (1994)
GLP:	Yes

Test system:

The extended laboratory study was conducted to assess the effects of the Fenamiphos CS 240 formulation (258.2 g ac/L measured) on mortality and reproduction of the predatory mite, *T. pyri*. The test formulation was diluted in 200 L water/ha and applied to dwarf bean leaves at nominal rates of 4.2, 10, 24, 55 and 130 mL product/ha. Based on these nominal application rates, the equivalent applications of fenamiphos were 1.08, 2.58, 6.20, 14.20 and 33.57 g ac/ha. The underside of the leaf was treated. After drying of residues, lead disks (3.8 cm diameter) were punched out and placed with treated side up on wet cotton pads in petri dishes. Ten healthy protonymphs were placed into each replicate unit (10 replicates per treatment). Water was applied as a control and dimethoate (12 g/ha applied in 200 L/ha water) was used as a toxic standard.

Assessments of mortality were made after 3 and 7 days. The fertility test was conducted in those treatments were corrected mortality did not exceed 50%. Fecundity assessments were carried out

10, 13 and 14 days after treatment by counting the number of eggs and juveniles present in each test unit and determining the number of eggs/female.

Experimental test conditions included a temperature around 25^{o}C, 55-80% relative humidity and a 16:8 h light:dark photoperiod. The test was considered valid if control mortality did not exceed 20% and was not <50% in the toxic standard; and if mean reproduction in deionised water control was at least 4 eggs/female in seven days.

The LR50 was calculated using probit analysis while reproduction data were analysed statistically using standard procedures.

Findings:

Mortality in the water control was 18% after 7 days compared to 88% in the toxic standard. By comparison, corrected mortality (dead and missing mites) was 3.7, -12.2, 7.3, 46.3 and 79.6% in the 1.08, 2.58, 6.20, 14.20 and 33.57 g ac/ha respectively. Mortality in the two highest test groups was considered statistically significantly different from the control.

Cumulative egg production in the control group was 7.8 eggs/female. Reproduction rates in the treated groups relative to the control were 84.6, 110.3, 106.4 and 83.3% in the 1.08, 2.58, 6.20 and 14.20 g ac/ha respectively. These were not considered statistically significantly different from the control.

Conclusion:

The 7 day LR50 was calculated to be 14.1 g ac/ha, with 95% confidence limits of 11.7-16.1 g ac/ha. No statistically significant effects on the reproduction capacity of *T. pyri* were observed up to 14.2 g ac/ha.

Test Material: **Fenamiphos, CS240 formulation**
Report: Kemmeter, 2000
Guidelines: Bigler (1988); Vogt *et al* (2000); Barrett *et al* (1994)
GLP: Yes

Test system:

The extended laboratory study was conducted to assess the effects of the Fenamiphos CS 240 formulation (258.2 g ac/L measured) on mortality and reproduction of the Green Lacewing, *Chrysoperla carnea* Steph. The test formulation was diluted in 200 L water/ha and applied to detached tomato leaves at nominal rates of 21, 42, 92, 200 and 420 mL product/ha. Based on these nominal application rates, the equivalent applications of fenamiphos were 5.4, 10.8, 23.8, 51.6 and 108.4 g ac/ha. Water was applied as a control and dimethoate (25 g/ha applied in 200 L/ha water) was used as a toxic standard. Application was carried out using a laboratory spraying cabin.

All treatment groups were conducted with 50 replicates each consisting of 1 larva, 2-3 days old, freshly applied on the tomato leaves. During assessment, they were fed with fresh eggs of the grain moth, and the number of dead larvae recorded. The pre-imaginal mortality was calculated after the emergence of the adults. Exposure was for 12 days.

For all treatment groups (except the highest rate) and the control group, the reproduction performance of the surviving adults was examined over a 7 day period two times for 24 h. The eggs from this period were counted and furthermore hatching success of the larvae was checked.

Experimental test conditions included a temperature around 24^{o}C, 55-85% relative humidity and a 16:8 h light:dark photoperiod. The test was considered valid if control mortality did not exceed 20%

and was not <50% in the toxic standard; and if mean reproduction in deionised water control was at least 15 eggs/female/day with a mean hatching rate in the control of at least 70%.

The LR50 was calculated using probit analysis while reproduction data were analysed statistically using standard procedures.

Findings:

Control mortality was 4% after 12 days with 100% mortality in the toxic standard. Corrected mortality in the treatment groups were –2.08, 2.08, 20.83, 81.25 and 100% in the 5.4, 10.8, 23.8, 51.6 and 108.4 g ac/ha groups respectively, with only the two lowest tested concentrations not being significantly different from the control.

The mean number of eggs/female/day in the control group was 27.33. All treatment groups considered in the fecundity component of the study had a higher level of egg production with 30.14, 33.34, 37.74 and 50.38 eggs/female/day in the 5.4, 10.8, 23.8 and 51.6 g ac/ha groups respectively. Emergence of larvae in all these treatment groups and the control ranged between 94-96.5%. Therefore, no treatment related effect on the reproduction performance in these treatment groups was observed.

Conclusion:

The 12 day LR50 was calculated to be 34.05 g ac/ha, with 95% confidence limits of 28.9-38.96 g ac/ha.
No statistically significant effects on the reproduction capacity of *C. carnea* were observed up to 51.6 g ac/ha.

Test Material: **Fenamiphos, CS240 formulation**
Report: Neumann, 2001
Guidelines: BBA 23-2.1.8; Draft of the IOBC *Poecilus cupreus* ring testing group.
GLP: Yes

Test system:

The extended laboratory study was conducted to assess the effects of the Fenamiphos CS 240 formulation (258.2 g ac/L measured) on mortality and feeding rate of the carabid beetle, *Poecilus cupreus*. While the guidelines call for quartz sand to be used in the test, this test used natural soil. The test formulation was diluted in 400 L water/ha and applied at nominal rates of 200, 350, 630, 1100 and 2000 mL product/ha. Based on these nominal application rates, the equivalent applications of fenamiphos were 51.6, 90.4, 163, 284 and 516 g ac/ha. Water was applied as a control and pyrazophos (306 g/ha applied in 400 L/ha water) was used as a toxic standard.

Polystyrene boxes were used for test units, each containing 500 g natural soil. Deionised water was added to adjust to 40% water holding capacity. Five boxes were set per treatment group, and established 3 days prior to test initiation. Six beetles (3 male and 3 female) were assigned to each unit and deprived from food until treatment. Immediately prior to treatment, one punctured pupae of house fly per beetle was added to each unit. These were replaced with fresh fly pupae on test days 2, 4, 7, 10, 14, 17 and 22 – the feeding activity was recorded. Mortality and behavioural impairments were recorded at these same times, as well as 2, 4 and 6 hours after treatment. The test was terminated after 22 days.

Experimental test conditions included a temperature around 18-22^{o}C, 75-85% relative humidity and a 16:8 h light:dark photoperiod. Validity criteria are unclear from the test report.

The LR50 was calculated using probit analysis while other data were analysed statistically using standard procedures.

Findings:

In the first week, 13.3%, 73.3% and 90% of beetles in the 163, 284 and 516 g ac/ha groups respectively were noted as exhibiting signs of intoxication along with 63.3% in the toxic standard group. No surviving beetles in any group exhibited abnormal symptoms at any other time, and the symptoms were not described.

The majority of observed mortality occurred within the first week of exposure. In the control group, no mortality was recorded at the end of the study while 63.3% mortality was found in the toxic standard. By comparison, mortality at the end of the study in the 51.6, 90.4, 163, 284 and 516 g ac/ha treatment groups were 0, 0, 23.3, 76.6 and 93.3% respectively.

Control beetles ate on average 0.237 fly pupae/viable beetle/day. The feeding rate of beetles exposed to a spray application of fenamiphos was not statistically significantly different from the control beetles, although, it is noted that in relation to control feed consumption, beetles in the 284 and 516 g ac/ha consumed 73.1% and 63.5% as much food as the control beetles. By comparison, viable beetles in the toxic standard consumed 53.4% of control levels.

Conclusion:

The 22 day LR50 was calculated to be 877 mL product/ha (226 g ac/ha, with 95% confidence limits of 198-259 g ac/ha).

Test Material:	Fenamiphos, CS240 formulation
Report:	Jackel, 2002
Guidelines:	German guideline – unpublished
GLP:	Yes

Test system:

Toxicity of the Fenamiphos CS 240 formulation (236.2 g/L fenamiphos, measured) was assessed to predatory bugs *Macrolophus pygmaeus* in a multi rate test at concentrations of 4.2, 10, 24, 55 and 130 mL product/ha. Based on these nominal application rates, the equivalent applications of fenamiphos were 1.08, 2.58, 6.20, 14.20 and 33.57 g ac/ha. Dimethoate (36 g/ha) was used as a toxic standard, and deionised water as a negative control.

The test arena was a bean leaf in a petri dish, on top of cotton used to provide the leaf with water. After the spray residue had dried, food and one larva per leaf (20 larvae per treatment) was put on. The test considered both mortality, and development of surviving animals to adulthood.

The mortality rate was assessed on days 1, 3, 7, 10 and 14. The test was carried out in a climatic chamber a temperature around 25^{o}C, 60-90% relative humidity and a 16:8 h light:dark photoperiod.

The LR50 was calculated by probit analysis. The test was considered valid because <20% mortality was found in the control group after 14 days.

Findings:

Mortality after 14 days in the control group was 17.6% (5.9% after 7 days) while 100% mortality was found in the toxic standard after 3 days indicating the test system worked.

Compared to the control, the following corrected mortalities were recorded in the treatment groups at days 7 and 14:

Table A2.30: Day 7 and 14 corrected mortality (%)

Treatment rate (g ac/ha)	1.08	2.58	6.20	14.20	33.57
% corrected mortality, day 7	5.9	22.2	40.0	35.0	64.7
% corrected mortality, day 14	52.9	55.6	65.0	75.0	94.1

Statistical analysis are not described in the report, however, the above results would indicate that even at the lowest tested rate, adverse effects based on mortality were significant.

By day 14, 92.9% of surviving adults in the control group had developed to adult status. This compared with 80%-100% in the treated groups, although the sample size was greatly reduced compared to control numbers due to mortality.

Conclusion:

The 14 day LR50 was calculated to be 5.54 mL product/ha (1.3 g ac/ha, with wide 95% confidence limits of 0.08-22.9 g ac/ha).

Test Material:	**Report:**
Fenamiphos CS240 formulation	Friedrich, 2001a
Fenamiphos sulfone (M01)	Meister, 2001a
Fenamiphos sulfone (M02)	Meister, 2001b
Fenamiphos sulfoxide phenol (M12)	Friedrich, 2001b
Fenamiphos sulfone phenol (M13)	Friedrich, 2001c
Guidelines:	ISO 11267:1999
GLP:	Yes

Test system:

Effects on reproduction of fenamiphos as its CS 240 formulation (260 g/L measured), and four metabolites as their pure substances, were tested in separate experiments to the collembola (*Folsomia candida*). The tests were conducted in artificial test soil with 69.5% fine quartz sand, 10% sphagnum peat, 20% kaolin and around 0.5% calcium carbonate to adjust the pH value to around 6. The water holding capacity was a maximum of 65.2 to 68% dw in all soils except that used to test the M02 metabolite, where the maximum water holding capacity was reported as 41% dry weight. The reason for this is unclear given all soils was prepared with the same components in the same ratios. In all tests, the water content of the soil was around half the maximum water holding capacity.

Test vessels consisted of glass beakers covered with a glass lid. 10 animals, 10-12 days old, were distributed with 5 replicates per test group and an additional 1-2 vessels not loaded with springtails for measurement purposes. During the test, the soil (30 g wet weight per test vessel) was kept at around 50% maximum water holding capacity (adjusted as necessary once per week), with a target temperature of around 20^{o}C and a 16:8 hour light:dark photoperiod. The test duration was 4 weeks. Test vessels were aerated twice per week by removing the lid. Organisms were fed granulated dry yeast.

The test substance was applied in various ways. For the fenamiphos experiment, it was applied in the deionised water used to bring the soil up to its desired moisture content. For the M01 and M02 experiments, the test substances were dissolved in acetone and added to a sub-sample of the quartz sand used to make the artificial soil. For the M12 and M13 metabolites, they were mixed (solid form at room temperature) with the quartz sand component of the artificial test soil.

In all tests, a control and a toxic control using the active substance, phenmedipham in the product Betosip (around 160 g/L) was used at maximum rates of 200 mg product/kg dw soil in the M01 and M02 studies, and 400 mg product/kg dw soil in the other studies. In the tests with M01 and M02, a solvent control (acetone) was also run. The following nominal concentrations were tested:

Table A2.31: Exposure Concentrations

Fenamiphos (mg/kg dw)	0	0.313	0.625	1.25	2.5	5	10
M01 (mg/kg dw)	0	Solvent	0.5	1	2	4	8
M02 (mg/kg dw)	0	Control	3.75	7.5	15	30	60
M12 (mg/kg dw)	0	10	32	100	316	1000	
M13 (mg/kg dw)	0	10	32	100	316	1000	

At the start of the test, physicochemical parameters of the artificial soil were measured. After 4 weeks, the number of adult and juvenile springtails per test vessel was counted, and physico-chemical parameters (water content and pH) of the soil determined.

Validity criteria for the test included no more than 20% adult mortality in the control group, at least 100 juvenile springtails per test vessel in the control group with a coefficient of variation (mean number of juveniles) of no more than 30%.

For the fenamiphos results, parental mortality results were analysed using the U-test with statistical analysis of reproduction values tested with the Dunnett test (both with $p \leq 0.05$, one sided). The EC50 with respect to the number of juveniles (reproduction rate) was calculated by Probit analysis. This was the same for M12 and M13, except statistical analysis of reproduction values were also analysed with the U-test.

The U-test was used for reproduction data from the M01 and M02 tests with mortality data analysed using Fisher's Exact Test. The LC50 was calculated by Probit analysis and the EC50 by Moving Average analysis.

Findings:

Validity criteria are reported as being met for all studies. While this can be ascertained from reviewing the data for fenamiphos, M01, M02 and M13, it must be assumed as the case for M12 where the data have not been provided (see table below).

The following data are reported:

Table A2.32: Effects of Fenamiphos and Metabolites on Adult Mortality and Reproduction of Springtails.

Fenamiphos (mg/kg dw)	0	0.313	0.625	1.25	2.5	5	10
Adult mortality (%)	0	2	2	8	24*	56*	90*
No. Juveniles (mean/level)	213.2	215.2	115.2	84.4	63	24	8.2
% Reduction of reproduction	-	-0.9	46*	60.4*	70.5*	88.7*	96.2*
M01 (mg/kg dw)	0	Solvent	0.5	1	2	4	8
Adult mortality (%)	8	4	8	6	16	16	60*
No. Juveniles (mean/level)	1101 (pooled)		1142	1260	1188	553*	14*
% Reduction of reproduction	-		103.8	114.5	107.9	50.2*	10.3*
M02 (mg/kg dw)	0	Solvent	3.75	7.5	15	30	60
Adult mortality (%)	18	18	18	100*	100*	100*	100*

No. Juveniles (mean/level)	426	526	402	10*	0*	0*	0*
% Reduction of reproduction		124.1	94.5	2.3*	0*	0*	0*
M12 (mg/kg dw)	0	10	32	100	316	1000	
Adult mortality (%)	4	4	10	12	36*	80*	
No. Juveniles (mean/level)	198.2	202.6	88.6	74.6	47	0	
% Reduction of reproduction		-2.2	55.3	62.4	76.3	100	
M13 (mg/kg dw)	0	10	32	100	316	1000	
Adult mortality (%)	4	4	10	12	36*	80*	
No. Juveniles (mean/level)	198.2	202.6	88.6	74.6	47	0	
% Reduction of reproduction		-2.2	55.3	62.4	76.3	100	

* = Statistically significantly different from the control.

The results reported for the M13 study are identical to those reported for the M12 study. In fact, it appears those reported for M13 are correct, and the results reported for M12 (fenamiphos sulfoxide phenol) have not been updated considering table headings provided in the test report. At this stage, the results obtained for M13 are considered an acceptable surrogate for M12. However, the need for the actual M12 results may be needed, and will depend on the risk assessment.

Conclusion:

The following results were calculated, and reported in nominal concentrations:

	Adult Mortality (mg/kg dw)			Reproduction (mg/kg dw)		
	LC50 (95% CI)	LOEC	NOEC	EC50	LOEC	NOEC
Fenamiphos	4.07 (2.71-6.84)	2.5	1.25	1.14 (0.55-2.04)	0.63	0.31
M01	8.91 (5.51-14.4)	8.0	4.0	4.55 (not calculated)	4.0	2.0
M02	4.5 (not reported)	7.5	3.75	5.1 (not reported)	7.5	3.75
M12[1]	Refer to results for M13 below.					
M13	441.3 (223.7-1405)	316	100	21.6 (not calculated)	32	10

1) Results as calculated for M13 – used as surrogate values for M12.

Earthworms

Several studies were provided assessing toxicity of fenamiphos and its major metabolites to earthworms with the following results:

Table A2.33: Summary of Toxicity to Earthworms from Fenamiphos and Metabolites

Test substance	Duration	LC50 (mg/kg)	NOEC (mg/kg)	Reference
Acute studies				
Fenamiphos	14 d	888	0.032	Meisner, 2000
M01	14 d	>1000	0.10	Meisner, 2001a
M02	14 d	>1000	<10	Meisner, 2001b
M12	14 d	>1000	32	Meisner, 2001c
M13	14 d	>1000	316	Meisner, 2001d
Chronic studies				
Fenamiphos+M01+M02	56 d	NOEC <0.12 mg/kg fenamiphos + 0.17 mg/kg M01 + 0.02 mg/kg M02		Lechelt-Kunze, 2002
Fenamiphos EC 400	56 d	-	<6 kg ac/ha[1]	Heimbach, 1994
Fenamiphos EC 400	Field test	-	<10 kg ac/ha[1]	Heimbach, 1986

1) Significant sub-lethal effects (including changes in species population and profiles in the field test) at these, the lowest concentrations tested.

Test Material:	**Report:**
Fenamiphos technical	Meisner, 2000
Fenamiphos sulfone (M01)	Meisner, 2001a
Fenamiphos sulfone (M02)	Meisner, 2001b
Fenamiphos sulfoxide phenol (M12)	Meisner, 2001c
Fenamiphos sulfone phenol (M13)	Meisner, 2001d
Guidelines:	OECD TG 207
GLP:	Yes

Test system:

Acute toxicity of fenamiphos (95.5% purity) and four metabolites were tested in separate experiments to earthworms (*Eisenia fetida*) in a series of 14 day studies. The tests were conducted in artificial test soil with 69% fine quartz sand, 10% dried finely ground peat, 20% kaolin and around 1% calcium carbonate to adjust the pH value to around 6.

Each test container contained 500 g dw test soil (around 625 g wet weight). Test containers were 1.5 L preserving jars, covered with glass lids. Adult worms used in the study were >2 months old.

Fenamiphos technical was tested at 12 concentrations, 0.032, 0.1, 0.32, 1.0, 3.2, 10, 32, 100, 178, 316, 562 and 1000 mg/kg dw test soil. Nominal formulation concentrations for the metabolites were:

Table A2.34: Exposure Concentrations

M01 (mg/kg dw)	0	0.1	1.0	10	32	100	316	1000
M02 (mg/kg dw)	0			10	32	100	316	1000
M12 (mg/kg dw)	0			10	32	100	316	1000
M13 (mg/kg dw)	0			10	32	100	316	1000

When adding the test substance, 50 mL deionised water was added to each test container so that the water content in the test soil was around 26% at the time of introducing the worms. Seven days after the start of the study, the number of surviving worms was determined. After 14 days, the weight, abnormal behaviour, observed symptoms and survival were determined.
Ten worms were placed in each test container (four replicates per test level) with average worm weights at the beginning of the studies of 0.32 to 0.34 g. Test conditions were around 20^{o}C, 70-90% relative humidity and constant light. Worms were not fed during the study.

If possible, the LC50 and 95% confidence limits were calculated using probit-analysis after the "Maximum-Likelihood" Method. Weight alterations were statistically evaluated by the U-Test (p = 0.05, two sided).

Findings:

Test concentrations were not measured. However, homogeneous distribution of the test substances was shown in separate studies using ^{14}C-labelled active ingredients.

There were no remarkable findings related to soil pH or moisture content in any of the studies, and all remained at or around target levels.

In the fenamiphos study, mortality of 0% was found in the control. Mortality of 0-5% was found up to test concentrations of 316 mg/kg dw soil. At the two highest test concentrations of 562 and 1000 mg/kg dw soil, mean mortality was 25 and 65% respectively. Significantly different weight

alterations by comparison with the control (+15%) occurred in all test concentrations except the lowest concentration of 0.032 mg/kg dw soil. From 0.1 mg/kg to 3.2 mg/kg, worms still gained weight (2-6%), but these were deemed statistically significantly different from the mean control level. At all other test concentrations worms lost weight with –5% at 10 mg/kg dw soil to –52% at the highest tested rate of 1000 mg/kg dw soil. No other observations relating to worm health and behaviour in the fenamiphos study are made.

Table A2.35: Survival/Weight Alteration of Earthworms after 14 Days Acute Exposure Study

M01 (mg/kg dw)	0	0.1	1.0	10	32	100	316	1000
Mortality (%)	0	0	0	0	0	0	0	10
Weight change (%)	+1	-1	-7*	-21*	-31*	-40*	-46*	-49*
M02 (mg/kg dw)	0			10	32	100	316	1000
Mortality (%)	0			0	3	0	5	28
Weight change (%)	-1			-32*	-40*	-43*	-47*	-50*
M12 (mg/kg dw)	0			10	32	100	316	1000
Mortality (%)	0			0	0	0	5	10
Weight change (%)	+11			+13	+10	+3*	-28*	-46*
M13 (mg/kg dw)	0			10	32	100	316	1000
Mortality (%)	0			0	0	0	0	0
Weight change (%)	+6			+6	+4	+5	0	-5*

* = Significantly different from control group

In the M01 study, worms in all test concentrations except the control and 0.1 mg/kg test level were noted as becoming cramped. In the M02 study, worms at all test concentrations (but not the control) were noted as becoming cramped.

Conclusions:

The following results were calculated, and reported in nominal concentrations:

	14 d LC50 (mg/kg dw)	NOEC (mg/kg dw)	LOEC (mg/kg dw)
Fenamiphos	888 (95% CI 668-1181)	0.032	0.1
M01	>1000	0.10	1.0
M02	>1000	<10	10
M12	>1000	32	100
M13	>1000	316	1000

Test Material: Fenamiphos technical; M01; M02
Report: Lechelt-Kunze, 2002
Guidelines: ISO/DIS 11268-2 (1996); BBA Part VI, 2-2.
GLP: Yes

Test system:

The influence of fenamiphos together with its metabolites M01 and M02 on reproduction of earthworms (*Eisenia fetida*) was tested in a 56 day experiment. Adult worms (4 replicates per treatment, 10 worms per replicate) were exposed to an artificial soil, 74% quartz sand; 5% dried, finely ground peat; 20% kaolin; 1% dried, finely ground cattle manure and around 1% calcium carbonate to adjust the pH to around 6.

The test containers were 1.2 L plastic boxes, 16.5 cm length, 12 cm wide and 6 cm high. Moistened soil was acclimatised for 1 day under test conditions before introducing earthworms. Worms were transferred to test boxes three hours before application and at the start of the study they had a mean weight of 0.29 g.

The test substances were added together in acetone to form a stock solution. Each test box contained 500 g dw soil (600 g wet weight), and the test was conducted at a single concentration of 0.12 mg fenamiphos + 0.17 mg M01 + 0.02 mg M02/kg dw soil. The concentration was prepared by mixing the solution into the test substrate thoroughly. Test conditions were around 20^{o}C, 70-90% relative humidity and 16:8 h light:dark. Cattle manure was used as food, and added weekly to the test boxes. Each time, the food was evenly distributed on the soil surface and the amount of food consumed was estimated. Soil moisture was assessed weekly and adjusted as necessary.

Worms were weighed individually at the start of the study. On day 28, the number of surviving worms were enumerated and weighed. After an additional 4 weeks, the study was terminated and test boxes transferred to a water bath (50-60^{o}C). After about 10 minutes, earthworms started to crawl out of the soil. They were counted. No further worms were observed at the surface of the test boxes after about another 30 minutes.

The weight alterations of the adult test organisms and the number of juveniles at the end of the study were statistically evaluated by the U-Test (probability level $p = 0.05$, one sided).

Findings:

Validity criteria of the test guideline were met (no more than 10% mortality and >30 juveniles/10 adults in untreated control). In both variants (treated and untreated), no mortality of adult earthworms occurred. However, there was a statistically significant effect on adult worm weights. After 4 weeks, mean weight gain in the control group (mean of all replicates) was 79.2% of initial weights. By comparison, the mean weight gain in the treatment group was 49.9%.

Treated and untreated variants showed no differences with respect to the reproductive performance (average 12.7 juveniles/adult in both variants).

Conclusions:

The combined tested concentrations of fenamiphos, M01 and M02 had no influence on earthworm reproduction, although there was an apparent effect on weight gain of adult worms.

Test Material:	Fenamiphos as EC 400 formulation
Report:	Heimbach, 1994
Guidelines:	ISO/DIS 11268-2 (1993); BBA Part VI, 2-2.
GLP:	Yes

Test system:

The influence of fenamiphos formulated as NEMACUR EC 400 on reproduction of earthworms (*Eisenia fetida*) was tested in a 56 day experiment. Adult worms (4 replicates per treatment, 10 worms per replicate) were exposed to an artificial soil, 69% quartz sand; 10% dried, finely ground peat; 20% kaolin; 1% dried, finely ground cattle manure and around 1% calcium carbonate to adjust the pH to around 6.

The test containers were 1.2 L plastic boxes, 16.5 cm length, 12 cm wide and 6 cm high. Moistened soil was acclimatised for 1 day under test conditions before introducing earthworms. Worms were transferred to test boxes 6-8 hours before application and at the start of the study they had a mean weight of 0.39 g.

The test substances were added together in acetone to form a stock solution. Each test box contained 500 g dw soil (775 g wet weight). The test was conducted at three nominal application rates of 6, 10 and 40 kg ac/ha, applied as a surface spray using a laboratory sprayer. Test conditions were around 20^{o}C, 70-90% relative humidity and 16:8 h light:dark. Cattle manure was used as food, and added several to the test boxes. After 4 weeks, the evaporated water was replaced by spraying 30 mL water on the top of the substrate of each box after adding food.

Worms were weighed individually at the start of the study. On day 28, the number of surviving worms were enumerated and weighed. After an additional 4 weeks, the study was terminated and test boxes transferred to a water bath (50-60^{o}C). After about 10 minutes, earthworms started to crawl out of the soil. They were counted. No further worms were observed at the surface of the test boxes after about another 30 minutes.

The weight alterations of the adult test organisms and the number and biomass of juveniles at the end of the study were statistically evaluated by the U-Test (probability level $p = 0.05$, one sided).

Findings:

No mortality was observed in adult earthworms at any treatment level or in the control. However, there were statistically significant effects on weight alterations of adult worms at all treatment levels. In the control, mean weight gain in adult worms (mean of all four replicates) was 58% of initial weight. By comparison, worms lost weight in all replicates at all test levels with mean weight losses of 22, 27 and 41% at the 6, 10 and 40 kg/ha treatment rates respectively.

Additionally, there were significant effects on reproduction of worms. After 56 days exposure, the mean number of juveniles per adult in the control group was 20.4 worms. This compared to a mean 2.6 juveniles per adult in the 6 and 10 kg/ha group (13% of control), and 0.6 juveniles per adult in the 40 kg/ha group (3% of control). Also, the weight of the juveniles was significantly affected with worms mean juvenile weights in the 6, 10 and 40 kg/ha groups being 28, 25 and 3% respectively of mean juvenile weights in the control group.

Conclusions:

While no mortality of adult worms was observed, all application rates decreased the body weights of adults significantly. The numbers and biomass of offspring were significantly reduced at all application rates.

Earthworm Field Data

Test Material:	Fenamiphos as NEMACUR EC 400 formulation
Report:	Heimbach, 1986
Guidelines:	US EPA 70-1 Special Tests.
GLP:	Yes

Test system:

The test was designed to determine the effect of fenamiphos (applied as NEMACUR EC 400) on earthworm populations under field conditions. For this purpose, the effect on the abundance was determined in grassland due to the high numbers of animals (up to 800/m^2). The test field had been a pasture for many years near the Hoefchen Experimental Station, Germany. An area of 30 m X 30 m was used for the test. Nine 10 X 10 m plots were laid out. The pasture was mulched 8 times during the year with mulching dates selected in such a manner that mulching was performed shortly before application of the product.

A spray boom was used to provide an even application of the product under conditions relevant to actual use. Application rates of 10 and 40 kg ac/ha were used. A total of 2 plots were treated at each rate with a further 2 plots used as a control. Only one application per plot was used.

For several days after application, the surface of each plot was thoroughly searched for dead earthworms. Attention was also paid to worms with behaviour changes or injuries. Earthworm abundances were determined 6 weeks after application (6 July 1982), at the end of the season in autumn (7-13 October 1982) and again in spring 1983, about a year after application. The "formalin method" was used. From each plot, 2-5 samples were obtained from the inner 6 X 6 m core. An area of 50 X 50 cm was marked off, the grass cut, and depending on the leaching behaviour, 5-9 L of 0.2% formalin solution poured over it. The worms that were crawled out were fixed in 5% formalin solution for identification.

Findings:

Live earthworms exhibited no behavioural changes or other symptoms. Following application, the search of plot surfaces revealed a total of 37, 58 and 71 live worms in the control, 10 and 40 kg/ha treatment plots respectively. No dead worms were found in the control or 10 kg/ha plots, while 21 dead worms were found in the 40 kg/ha plots.

A total of 7 different species were found in the test field. There were large variations in number between sampling sites even within one plot. Tanylobous species found were *Lumbricus terrestris*, *L. rubellus* and *L. castaneus*. Only *L. terrestris* was found in sufficient quantities to enable statistical comparisons on the species level with totals of other species combined for statistical analyses. Epilobous species found were *Allolobophora caliginosa, A. rosea, A. chlorotica* and *A. terr. longa*. Only *A. caliginosa* and *A. chlorotica* were found in sufficient quantities to enable statistical comparisons on the species level with totals of other species combined for statistical analyses.

The results showed in part a change in earthworm abundance resulting from fenamiphos application. The following tables provide a summary of the changes in abundance in terms of either earthworm numbers or biomass compared to control values. The results of statistical comparison (U-test) are also provided.

Table A2.36: Change in Abundance (Numbers) Following Application of Fenamiphos

Sampling time	6 weeks after appl.		Autumn 1982		Spring 1983	
Application rate (kg ac/ha)	10	40	10	40	10	40
Lumbricus terrestris	+23	-21	+1	-21	+27	-37
Other tanylobous species	+71	+76	-44*	-21	+19	+14
Total tanylobous species	+54*	+41	-37	-20	+21	+3
Allolobophora calinginosa	-66*	-86*	-25	-60*	-4	-36
Allolobophora chlorotica	-47	-81*	-66*	-63*	-42	-63*
Total epilobous species	-65*	-85*	-33	-55*	-14	-40
TOTAL	-25	-43*	-35*	-38*	+4	-17

* = Statistically significantly different from control according to the U-test at $p = 0.05$

Table A2.37: Change in Abundance (Biomass) Following Application of Fenamiphos

Sampling time	6 weeks after appl.		Autumn 1982		Spring 1983	
Application rate (kg ac/ha)	10	40	10	40	10	40
Lumbricus terrestris	-20	-55	-10	-24	+27	-32
Other tanylobous species	+26	+42	-39	+11	+25	+41
Total tanylobous species	-13	-40	-18	-16	+25	-18
Allolobophora calinginosa	-81*	-92*	-4	-54*	+29	-11
Allolobophora chlorotica	-55	-91*	-68*	-68*	-43	-57
Total epilobous species	-77*	-90*	-8	-12	+11	-9
TOTAL	-32	-55*	-15	-14	+22	-16

* = Statistically significantly different from control according to the U-test at $p = 0.05$

After 6 weeks, the 10 kg/ha treated areas showed a marked reduction in the number of the most frequent species *A. caliginosa* with an even more marked reduction (81%) in the biomass of this species. This loss was also found in the total of the epilobous species in number (65%) and weight (77%). With respect to total of all species there was no difference in comparison to the control.

In the areas treated with 40 kg/ha, the more than 80% reduction in number and 90% reduction in biomass of the epilobous species resulted in a considerable reduction in the total of all earthworm species 6 weeks after application.

The effect of treatment on earthworm abundance was observed into autumn (3 months after application). The 44% reduction in "other tanylobous species" found in the 10 kg/ha plots can probably be disregarded as it was not supported by biomass results of the earthworms, or by the data at the higher application rate, or by the data for these species at the earlier sampling time. However, the 66% reduction in numbers of *A. chlorotica* at this rate was reflected in biomass results (68% reduction). The 40 kg/ha treatment still had a marked effect on the two most abundant epilobous species.

A year after application (spring, 1983), no effect on earthworm fauna was found except for a statistically significant reduction (63%) in the number of *A. chlorotica* on plots treated at 40 kg/ha. This is not supported by biomass measurements, and did not have an effect on the total number of epilobous species or the total of all species.

Conclusions:

The tests indicate that some earthworm species were negatively affected by fenamiphos applications at 10 and 40 kg/ha. A marked difference in comparison to control values was found for epilobous species, particularly at 40 kg/ha.

Soil Micro-Organisms

One study was provided considering effects on fenamiphos to soil respiration/ mineralisation activity. Several studies were provided considering effects of fenamiphos and its metabolites on the nitrogen cycle of soil. The results are summarised as follows:

Table A2.38: Summary of toxicity of fenamiphos and metabolites to soil micro-organisms

Soil respiration/mineralisation activity			
Fenamiphos		No adverse effects up to 133 mg/kg dw (2 soil types)	Anderson, 1986a
Soil nitrogen cycle			
Fenamiphos		No adverse effects up to 133 mg/kg dw (2 soil types)	Anderson, 1989b
M01	70.19 mg/kg	No permanent adverse effects based on single application rates to a single soil. Some temporary increase in nitrate	Anderson, 2001a
M02	73.69 mg/kg		Anderson, 2001b

M12	37.47 mg/kg	production may occur at these levels.	Anderson, 2001a
M13	40.93 mg/kg		Anderson, 2001b

Test Material: **Fenamiphos, technical**
Report: Anderson, 1986a
Guidelines: Draft (1981) BBA guideline for testing the influence of crop protection compounds on the soil microflora with regard to the carbon and nitrogen cycle.
GLP: No

Test system:

The effect of fenamiphos on the influence of soil respiration and microbial mineralisation of lucerne-grass green meal was tested. Two soils were used, a loamy sand with low organic carbon (0.84%), and a sandy silt soil with higher organic carbon (2.60%). The soils had a pH of 5.3-5.4. They were sieved (2 mm) prior to use. The sifted soil was thoroughly mixed with ground quartz sand (10 g/kg dw soil, control) or quartz sand and fenamiphos (13.36 or 133 mg ac/kg soil dw). After treatment, the samples were split into two equal quantities. The first part was mixed with powdered lucerne-grass green meal (5 g/kg dw soil), and the second remained unamended.

Samples of 100 g dw were filled into breeding chambers. Samples were kept in the dark at around 20°C and 45-55% water capacity. The CO_2 set free from soil was passed through 40 mL 0.5 N NaOH with around 60 mL/min air, free of CO_2. The quantity of bound CO_2 was determined by titration with 0.1 N HCl from pH 8.3 to 3.8.

Findings:

The soil respiration (release of CO_2 from unamended soils) was reported as follows:

Table A2.39: Soil Respiration rate (mg CO_2/100 g dw soil), Unamended Soils Exposed to Fenamiphos up to 6 Weeks.

Week of incubation	Concentration	1	2	3	4	5	6
Loamy sand	0	13.8	14.2	12.4	8.8		
	13.3 mg/kg dw	19.6*	14.5	14.2	11.3		
	133 mg/kg dw	21.7*	13.8	14.6*	9.9		
Sandy silt	0	22.3	17.7	17.7	18.5	14.8	13
	13.3 mg/kg dw	32.0*	18.6	21.1	20.8	17	13.8
	133 mg/kg dw	35.3*	18.2	22.7*	22.1*	17.6*	14.1

* Statistically significantly different from the control.

There was no adverse impact on soil respiration rates in the unamended soils. In both soils, some increase in CO_2 production was observed in the treated soils compared to the controls. However, these increases were relatively low and disappeared during the course of the study.

Table A2.40: Soil Respiration rate (mg CO_2/100 g dw soil), from Amended Soils Exposed to Fenamiphos up to 6 Weeks.

Week of incubation	Concentration	1	2	3	4	5	6
Loamy sand	0	242.9	67	38.3	30.1		
	13.3 mg/kg dw	260.8	66.6	38.9	27.3		
	133 mg/kg dw	250.4	63.1	36.2	27.3		
Sandy silt	0	224.2	65.9	43.2	41.7	21.7	28.8
	13.3 mg/kg dw	230.7*	69.9*	48.3*	42.3	22	31.8
	133 mg/kg dw	250.3*	68.1	48.9*	37.0*	21.1	27.1

* Statistically significantly different from the control.

There was no adverse impact on the mineralisation of lucerne-grass green meal in either soils. In the loam sand, mineralisation rates in both treatment levels were statistically comparable to the control at all times during the study. In the sandy silt soil, there was a statistically significant increase in mineralisation rates at both treatment levels with one statistically significant decrease in the highest exposure group at week 4. However, all these differences were relatively small and during the last two weeks of the exposure, no further differences between treatments and control rates were observed.

Conclusion:

Based on this study, fenamiphos is not expected to adversely affect soil respiration rates or mineralisation activity of soil bacteria up to the maximum tested level of 133 mg/kg dw soil.

In addition to the above test on soil respiration/mineralisation rates, 5 studies using fenamiphos technical and four metabolites were performed assessing the impact of fenamiphos treatment to soil nitrogen.

Test Material: **Fenamiphos, technical**
Report: Anderson, 1986b
Guidelines: Draft (1981) BBA guideline for testing the influence of crop protection compounds on the soil microflora with regard to the carbon and nitrogen cycle.
GLP: No

Test system:

The influence of fenamiphos on soil ammonification and nitrification of soil nitrogen as well as nitrification of added ammonium was tested. Soils and preparation methods are as described in Anderson (1986a) above. Following treatment of the soil and splitting into two parts, one part was mixed with powdered ammonium sulphate (1000 mg/kg). Samples of 50 g were filled in to test vessels.

Immediately after treatment and after 7, 14, 21, 28, 42 and 56 days the humid soil samples were filled into 1 L beakers and thoroughly mixed. Samples corresponding to 10 g dw were extracted with KCl. The soil extracts were liberated from soil particles by filtration and were tested on their content of ammonium-N and nitrate-N plus nitrite-N and nitrite-N.

Findings:

There was no adverse impact on the ammonification and subsequent nitrification of soil nitrogen in both soils at both test rates. Ammonium levels in the soils were generally comparable with control levels throughout the study. Nitrate-N levels in both soils were statistically significantly higher at all days after day 0, and by the end of the study, these levels were some 50% higher in the treated soils than the control soil in the loamy sand. A similar, although not as pronounced pattern was seen in the sandy silt. After 56 days, nitrate-N levels in the treated soils were around 15% higher than the control soil. The authors suggest the stimulation of nitrate formation of the treated soils was probably due to the killing and subsequent mineralisation of some soil microorganisms.

There was no negative influence on the conversion of ammonium to nitrate based on results of soils with added ammonium. In the loamy sand soil, at the end of the study, there were no statistically significant differences in levels of nitrate-N for either treatment level compared to the controls. In the sandy silt soil, nitrite-N levels were statistically significantly higher in both treated soils compared with the control but the differences in absolute terms were still small (<5%). There was an apparent delay of nitrate formation in the loamy sand soil with statistically significantly lower levels of nitrate-N up until the day 42 measurement in the highest test rate. The difference at day 7 was 20% lower nitrate-N than in the control soil, with <10% difference at days 14, 21 and 28.

Conclusion:

Based on this study, fenamiphos is not expected to adversely affect the soil nitrogen cycle up to the maximum tested level of 133 mg/kg dw soil.

Test Material:	**Report:**
Fenamiphos sulfone (M01)	Anderson, 2001a
Fenamiphos sulfone (M02)	Anderson, 2001b
Fenamiphos sulfoxide phenol (M12)	Anderson, 2000a
Fenamiphos sulfone phenol (M13)	Anderson, 2000b
Guidelines:	BBA TG Part VI, 1-1; ISO/DIS 1036-6:1992; OECD TG 216
GLP:	Yes

Test system:

The above metabolites of fenamiphos were tested for their influence on nitrogen mineralisation in an agricultural soil. For the M01 and M02 test, a silty sand soil with 0.6% OC and biomass of 190 mg C/kg/dw was used. For the M12 and M13 test, a loamy sand soil with 0.5% OC and biomass of 189-208 mg C/kg/dw was used. The amount of metabolite used in the study was determined by multiplying a field rate of fenamiphos of 10 kg ac/ha by 5 and converting the resulting number into the molar equivalent of metabolite. To calculate the amount to be applied per kg dw soil, a depth of 5 cm and soil density of 1.5 g/cm^3 was assumed. The resulting single treatment rates for the four metabolites were 70.19, 73.69, 37.47 and 40.93 mg/kg dw soil for the M01, M02, M12 and M13 metabolites respectively.

Sieved soil (2 mm) was treated with either 10 g ground quartz sand/kg dw (control) or a mixture of quartz sand (10 g/kg dw soil) and the tested metabolite to provide the test concentration. The samples were mixed with pulverised lucerne-grass green meal (5000 mg/kg dw). After mixing, soil samples equivalent to 250 g dw were poured into 500 mL brown glass bottles that were closed with parafilm. Three replicates were prepared per treatment, and the soil was incubated in the dark at around 20^{o}C and 40% water capacity.

Soils were sampled at 0, 7 (not for M13), 14, 28 and 42 days for all metabolites, with an additional sampling time of 56 days for the M01 and M02 tests. The soil was extracted with KCl and analysed for their content of ammonium-N and nitrate-N plus nitrite-N and nitrite-N.

Findings:

In all experiments, a temporary increase in nitrate levels was found in treated soils. These increases generally persisted throughout the incubation period, but the differences at the end of the study were usually within acceptable levels. The following table summarises the differences in nitrate levels compared to control levels, in (rounded) percentage terms for days 14, 28, 42 and 56 if relevant:

Table A2.41: Differences in Nitrate Levels (%) in Treated Soil Compared to Control Levels

Day	14	28	42	56
M01	+98*	+30*	+16.5*	+11.5*
M02	+170*	+53*	+33*	+24*
M12	+103*	+33*	+13.3*	
M13	+120*	+31*	+7.5	

* = Statistically significantly different from the control.

While there is no explanation for the consistent observation of the temporary increase in nitrate levels for all metabolites, the authors state its possible that this stimulation is the result of killing and subsequent mineralisation of some soil microorganisms. It would appear that such effects are

transient with no difference in nitrate levels >25% of control values after 42-56 days for any of the metabolites tested.

Conclusion:

Based on these studies, the M01, M02, M12 and M13 metabolites are not expected to adversely affect the soil nitrogen cycle up to the maximum tested levels. However, some temporary increase in nitrate production can be expected at these levels.

Test Material: **Fenamiphos Technical**
Report: Caspers and Muller, 1999.
Guidelines: Primarily following OECD TG 209
GLP: Yes

Test system:

Toxicity of technical fenamiphos (96% pure) was tested to bacteria in an activated sludge test measuring respiratory rate. In order to check the sensitivity of the activated sludge, 3,5-dichlorophenol was used as a reference substance.

Activated sludge (mixed population of different microorganisms) was obtained from the aeration tank of a wastewater plant treating predominantly domestic sewage in Germany. The pH of the suspension before application was 6.7.

Fenamiphos was tested at concentrations of 560, 1000, 1800, 3200 and 5600 mg/L. A physicochemical oxygen consumption control was maintained (to allow differentiation between oxygen consumption from physicochemical processes as opposed to biological processes) with fenamiphos at 10,000 mg/L. Application was made by direct weighing and the test concentration of the activated sludge was 320 mg/L. The test temperature was around 20^{o}C with an incubation time of 3 hours under permanent aeration.

Findings:

No oxygen consumption due to physicochemical processes was ascertained. A dose-response was found for inhibition of respiration with the high application rates tested. Based on the mean of two control incubation flasks, the control respiration was 30.5 mg O_2/L/h. Compared to this rate, inhibition of respiration in the 560, 1000, 1800, 3200 and 5600 mg/L was 35.4, 43.3, 45.9, 52.1 and 65.6% respectively.

The EC50 was calculated by probit analysis and determined to be 2030 mg/L. 95% confidence limits were not reported. The sensitivity of the activated sludge was confirmed with an EC50 of 10 mg/L for the toxic reference substance.

Conclusion:

Based on the 3 hour EC50 determined from this study, fenamiphos is unlikely to be toxic to sewage bacteria.

Non-Target Vegetation

Test Material: Fenamiphos CS 240 Formulation
Report: Meisner, 2001e
Guidelines: Following proposal for updating of OECD TG 208
GLP: Yes

Test system:

Fenamiphos as its CS 240 formulation (236.2 g ac/L measured) was tested on non-target plants in a screening level seedling emergence study. The test formulation was applied with a water application rate of 1000 L/ha, and spray treatments were applied in an automatic spray chamber adjusted to pressure of 3 bar, height of spray boom of 45 cm, 8003E nozzle and target application rates of 1000, 2000, 5000, 10,000 and 15,000 g ac/ha.

The test used 11 plant species consisting of 6 dicots from 6 different plant families, and 5 monocots from one plant family as follows:

Dicotyledonae		Monocotyledonae	
Plant family	Species	Plant family	Species
malvaceae	*Abutilon theophrasti*	gramineae	*Alopecurus myosuroides*
amaranthaceae	*Amaranthus retroflexus*	gramineae	*Avena fatua*
chenopodiaceae	*Beta vulgaris*	gramineae	*Echinochloa curs-galli*
rubiaceae	*Galium aparine*	gramineae	*Setaria viridis*
convolvulaceae	*Ipomoea herderacea*	gramineae	*Zea mays*
cruciferae	*Sinapis alba*		

Seeds of all plant species were planted together into soil (sandy loam, 2.5-3% OM) in greenhouse pots of 420 cm^2 surface. Typically, 10 seeds of each species were sown 24 hours prior to application of the test substance. The soil allowed good germination.

The plants were maintained at a day/night temperature of 22/15^oC respectively with relative humidity set at 50% and a 14:10 h light:dark (day:night) photoperiod. Plants were sown, sprayed with the test material and directly placed under the specified growing conditions. The final evaluation was done 21 days after treatment initiation.

Evaluation of phytotoxicity was done by visual observation using a rating scale of 0-100% where 100% represents complete destruction of above ground parts. No analysis of other parameters was made (e.g., germination, shoot height/weight etc).

Findings:

Based on the visual observation approach, compared to control plants, no effect of any treatment level was found for any plant species with ratings of "0%" assigned to all species at all rates.

Conclusions:

In this pre-emergence test, all plant species showed no phytotoxic effects up to the highest application rate of 15,000 g ac/ha.

Conclusions for Terrestrial Toxicity

Fenamiphos was toxic to bees through both the oral and contact routes with LD50 values for honeybees of 0.46 and 0.28 µg/bee respectively. A further contact toxicity test with bumble bees resulted in an LD50 of 1.59 µg/bee.

Several studies were provided considering toxicity to non-target arthropods when exposed through spray application. Results were variable. The aphid parasitoid (*A. rhopalosiphi*) was most susceptible based on exposure to glass plates with an LR50 of 0.152 g ac/ha. Under more extended laboratory conditions (predominantly testing effects on both adult mortality and reproduction with exposure on tomato leaves), toxicity was less pronounced than using worst-case laboratory exposure conditions (glass plates). Available data for the aphid parasitoid (*A. rhopalosiphi*), predaceous mite (*T. pyri*), green lacewing (*C. carnea*) showed LR50's (based on adult mortality)

between 14.1 and 34 g ac/ha. Reproductive effects were only assessed at rates where adult mortality was not significantly affected, and resulted in NOECs of 14.2-51.6 g ac/ha. The carabid beetle (*P. cupreus*) was less sensitive and resulted in a LR50 of 226 g ac/ha with a NOEC (based on feeding rate) of 516 g ac/ha. Collembola (*F. candida*) was the only species exposed through the soil and resulted in an LC50 (adult mortality) of 4.07 mg/kg dw and a NOEC (reproduction) of 1.14 mg/kg dw. This species was also exposed to the metabolites M01, M02, M12 and M13. M01 and M02 had toxicity similar in magnitude to the parent compound (LC50s of 8.91 and 4.5 mg/kg dw respectively). Results for M12 were not provided, however, M13 was significantly less toxic with an LC50 of 441 mg/kg dw.

Acute toxicity of fenamiphos, M01, M02, M12 and M13 to earthworms was tested. The only definitive result for mortality obtained was for the parent fenamiphos with a 14 d LC50 of 888 mg/kg dw (moderately toxic). Corresponding 14 d LC50s for all other compounds was >1000 mg/kg dw. Despite this apparent lack of toxicity based on mortality, when exposed to fenamiphos, significantly different weight alterations by comparison with the control (+15%) occurred in all test concentrations except the lowest concentration of 0.032 mg/kg dw soil. This resulted in a NOEC of 0.032 mg/kg dw. In the M01 study, worms in all test concentrations except the lowest test level were noted as becoming cramped. In the M02 study, worms at all test concentrations (but not the control) were noted as becoming cramped. Again, based on weight comparisons, the NOECs for M01 and M02 were 0.01 and <10 mg/kg dw (the lowest rate tested) respectively. For M12 and M13, NOECs were 100 and 315 mg/kg dw respectively.

Chronic toxicity of fenamiphos to earthworms was tested in two separate experiments (one soil incorporated and one surface applied) and one field study (as a surface spray). When exposed through the soil, the tested concentrations of fenamiphos (0.12 mg/kg dw), M01 (0.17 mg/kg dw) and M02 (0.02 mg/kg dw) had no influence on earthworm reproduction, although there was an apparent effect on weight gain of adult worms. When worms were exposed in a 56 d laboratory study to three different spray application rates (6, 10 and 40 kg/ha), no mortality of adult worms was observed but all application rates decreased the body weights of adults significantly (87-97%). The numbers and biomass of offspring were significantly reduced at all application rates (72-97%). In the field study, some earthworm species were negatively affected by fenamiphos applications at 10 and 40 kg/ha. A marked difference in comparison to control values was found for epilobous species, particularly at 40 kg/ha. Effects were noted up to 3 months after application, but by the following year, no negative effects on earthworm fauna were observed.

Based one study for fenamiphos impacts on soil respiration, fenamiphos is not expected to adversely affect soil respiration rates or mineralisation activity of soil bacteria up to the maximum tested level of 133 mg/kg dw soil. In addition, 5 studies using fenamiphos technical, M01, M02, M12 and M13 were performed assessing the impact of fenamiphos treatment to soil nitrogen. Fenamiphos is not expected to adversely affect the soil nitrogen cycle up to the maximum tested level of 133 mg/kg dw soil. The single treatment rates for the four metabolites were 70.19, 73.69, 37.47 and 40.93 mg/kg dw soil for the M01, M02, M12 and M13 metabolites respectively. The results showed they are not expected to adversely affect the soil nitrogen cycle up to the maximum tested levels. However, some temporary increase in nitrate production may occur at these levels.

Fenamiphos as its CS 240 formulation (236.2 g ac/L measured) was tested on non-target plants in a screening level seedling emergence study. All plant species (11 species consisting of 6 dicots from 6 different plant families, and 5 monocots from one plant family) tested showed no phytotoxic effects up to the highest application rate of 15,000 g ac/ha.

Glossary

ac	Active constituent
APVMA	Australian Pesticides and Veterinary Medicines Authority
AR	Applied radioactivity
BCF	Bioconcentration Factor
ChE	cholinesterase
CS	Capsulated suspension formulation
DAT	Days after treatment
DSEWPaC	Department of the Sustainability, Environment, and Water, Population and Communities Resources (previously the Department of the Environment, Water, Heritage and the Arts and Heritage)
DT_{50}	Time for 50% of the substance to dissipate
EbC_{50}	The concentration of a test substance resulting in a 50% inhibition of biomass in an algal test
EC	Emulsifiable concentrate formulation
$EC\chi$	The concentration of a test substance resulting in an effect on χ% of the test species.
ErC_{50}	The concentration of a test substance resulting in a 50% inhibition of growth rate in an algal test
FC	Field capacity
GLP	Good Laboratory Practice
HPLC	High pressure liquid chromatography
ISO	International Organization for Standardization
Kd	Soil sorption constant
kg	Kilogram
Koc	Soil sorption/desorption coefficient, normalised to organic carbon content
LC_{50}	Concentration (for example, in water, food or soil) resulting in a 50% mortality of the test organism.
LD_{50}	Dose (oral) resulting in a 50% mortality of the test organism
LOC	Level of concern
LOD	Limit of detection
LOEC	Lowest Observed Effect Concentration i.e. the test concentration at which some effect occurs
LOEL	Lowest Observable Effect Limit
LOQ	Limit of quantification
LSC	Liquid scintillation counter
MATC	Maximum acceptable toxicant concentration
NFC	No fish control
NOEC	No Observed Effect Concentration i.e. the test concentration at which no effect is observed
NOEL	No Observed Effect Level
OECD	Organisation for Economic Co-operation and Development
OP	Organophosphorus pesticide
PEC	Predicted environmental concentration
PTRC	Principal time response curves
RQ	Risk quotient
TLC	Thin layer chromatography
US EPA	United States Environmental Protection Agency
USGS	US Geological Survey
UV	ultraviolet
WHC	Water holding content

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