Section 6
ENVIRONMENTAL ASSESSMENT

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1. INTRODUCTION

The organophosphorous insecticide fenitrothion is included in the second round of chemicals selected for review under the National Registration Authority's Existing Chemicals Review Program. From the environmental perspective, fenitrothion was accorded high priority for review because of its toxicity to birds and aquatic invertebrates, properties that have triggered reviews in the USA and Canada.

Organophosphorous insecticides exert their effects by inhibiting the activity of an enzyme known as acetylcholinesterase that is important in the transmission of nerve impulses. Fenitrothion belongs to a group of organophosphorous compounds known as the phosphorothioates that do not inhibit acetylcholinesterase directly. They rely for their effect on metabolic transformation in target tissue to their oxon form, which is intrinsically less stable and has greater activity, generally by several orders of magnitude.

Fenitrothion is used to control summer insect pests, particularly locusts and wingless grasshoppers, in vegetables, fruit, pastures and cereals. It is currently the Australian Plague Locust Commission’s chemical of choice for controlling locusts. Winter insect pests of southern pastures are also controlled using fenitrothion. Fenitrothion also has important uses in grain storage and poultry sheds.

Overseas, fenitrothion is mainly used to control chewing and sucking insects on rice, cereals, fruits, vegetables, stored grains, cotton and in forest areas. It also finds use for control of flies, mosquitoes and cockroaches in public health programmes and/or for household use. Restrictions to certain uses have been introduced in some overseas jurisdictions, as outlined in section 5 of this report.

This assessment report is based on material provided by Sumitomo Chemical Company Limited, with data gaps filled by reference to the review conducted under the International Programme on Chemical Safety (IPCS, 1992). Information on local use patterns has been obtained from user groups, in particular the Australian Plague Locust Commission (APLC), which also provided some details of its research program. Additional information was also obtained through Environment Australia’s role as one of the APLC commissioners. Selected papers published in the scientific literature since completion of the IPCS review have been included as appropriate.

2. CHEMICAL IDENTITY

Refer to Section 2, Volume I for chemistry details.

3. PHYSICO-CHEMICAL PROPERTIES

Refer to Section 2, Volume I for chemistry details.

4. FORMULATION OF END-USE PRODUCT

Refer to Section 2, Volume I for chemistry details.

5. PREVIOUS REGULATORY ACTION AND REVIEWS

5.1 Canada

Concerns over use in forestry led Environment Canada to review possible impacts on insect pollinators and pollination, forest songbirds, and aquatic organisms (Ernst *et al*, 1989). Population decreases in honey bees and wild bees were linked to fenitrothion use, and adverse economic consequences to blueberry production were demonstrated. Understanding of avian risks remained incomplete, but available evidence indicated considerable risk to protected migratory songbirds. Population reductions were noted for aquatic invertebrates, but occurred sporadically and were small in scale, with populations generally recovering within season. The question of fish population reductions associated with fenitrothion spraying was not entirely answered, but it was considered axiomatic that they must have been less than the small and sporadic reductions observed in aquatic invertebrate populations.

Further consideration of the large scale forestry uses, involving single aerial applications at 280 g/ha or two applications 4-6 days apart at 140-210 g/ha for control of spruce budworm, hemlock looper, and miscellaneous minor pests, led to the conclusion that existing use patterns were environmentally unacceptable because of identified or potential impacts on terrestrial arthropods, pollinators, aquatic invertebrates, amphibians, fish and songbirds. Four regulatory options were proposed in the discussion document (Agriculture Canada, 1993).

The final regulatory decision was that the main uses for control of spruce budworm and hemlock looper would be phased out by 31 December 1998, but that use against minor pests or for minor uses such as seed orchards would be retained. A lower maximum rate (210 g/ha) was prescribed for single aerial applications, with restriction to light aircraft unless equipped with electronic guidance systems, and introduction of buffer zones (400 m upwind and 100 m downwind) to protect aquatic habitats (Agriculture Canada, 1995). Sumitomo has advised that the registrations were withdrawn voluntarily, and that this should be clearly stated as such without additional judgement added.

5.2 USA

The United States Environmental Protection Agency issued its Reregistration Eligibility Decision for fenitrothion in July 1995 (US EPA, 1995). Uses on ornamentals (greenhouse and outdoors, including trees) and ant and cockroach baits were considered for reregistration. All products proposed for outdoor use were required to be labelled for restricted use only because of high acute toxicity to birds and aquatic invertebrates and the observation of chronic effects in avian reproductive testing. Apart from the baits, for which ecological impact is negligible, only high pressure handwand spot applications were determined to be eligible for reregistration, with a maximum rate of 350 g/ha and no more than three applications per year. Situations identified as having the greatest potential for non-target exposure, namely Christmas tree plantations, basal bark treatment and ornamental broadcast treatments, were voluntarily withdrawn by the manufacturer.

5.3 International Programme on Chemical Safety

In contrast to the regulatory outcomes described above, the IPCS review (IPCS, 1992) concluded that, despite its high toxicity for non-target arthropods, fenitrothion has been extensively used for pest control with few, or no, adverse effects on populations in the environment. It was recommended that application rates of fenitrothion should be limited, to avoid adverse effects on non-target arthropods, and that the insecticide should never be sprayed over water bodies or streams.

5.4 Australia

Following a recommendation from the Commonwealth Environment Minister, the APLC commissioned an independent review of its activities in 1993 to explore the environmental issues arising from its locust control operations (Bunn *et al*, 1993). The main recommendation from the review was that environmental monitoring should become a more integral part of APLC operations, with a focus on persistence of toxic residues of fenitrothion, including metabolites, particularly in water and locusts. More formal and rigorous monitoring of non-target effects was recommended, with observation of feeding behaviour in sprayed areas as well as routine searches for sick or dead animals, including around nearby bodies of water for avian and aquatic casualties. Monitoring activities should be a major responsibility of an environmental officer to be employed by the APLC. Field studies of fenitrothion impacts on aquatic communities, vegetation-associated invertebrates and soil and litter invertebrates were also recommended, together with routine vertebrate surveys. The use of caged yabbies was suggested as one approach to monitoring aquatic non-target effects. Regarding control methods, research into new approaches that would further reduce environmental impacts was recommended, with specific mention of the fungal pathogen *Metarhizium*, and further development of geographic information systems that could be used to predict locations of possible egg-beds.

The APLC (Hooper, 1994) provided an initial response to these recommendations in January 1994, noting that there had been an increased focus on environmental monitoring in recent years following the necessary focus on operational matters in the early days of the APLC, but that recent budgetary constraints would diminish the resources that could be committed to such activities and prevented the appointment of an environmental officer. Responding to the residues issue, the APLC referred to published work (Miyamoto *et al*, 1978) that shows increased mammalian toxicity in oxygen analogues but a generally lower toxicity of metabolites, which are invariably of shorter persistence, to insects and aquatic life. The published conclusions were not supported by data, however, and this was being sought from Sumitomo. Programs to routinely sample arthropod fauna of sprayed targets were being developed, and post-application non-target monitoring of sprayed areas and nearby water was to be formalised by modifying Target Control Sheets to include such aspects. The feasibility of using yabbies as monitors and of conducting vertebrate survey work was to be evaluated. Preliminary evaluations of the fungal pathogen *Metarhizium* had been undertaken.

The review recommendations were reconsidered by the APLC in 1996 (Hooper, 1996). On the residue/metabolite question, recent findings of rapid degradation in Spanish irrigation ditches, with only low levels of toxic metabolites detected, were noted (this work is evaluated in sections 6.2.5.2-3 of this report). The work of Miyamoto *et al* (1978) was again referred to, but no confirmatory data were presented. In local testing, the half-life of fenitrothion was found to be 3 days in sunlit tap water and 6.4 days in sunlit lake water, with persistence increasing markedly when light was excluded. Local results are consistent with overseas data (see section 6.2.2.1).

Residues of fenitrothion in a 15 cm water body 700 m downwind of a sprayed target were said to be below 2 µg/L based on APLC field work, and the fenitrothion content of sprayed locusts was said to fall in the range of 1-7 mg/kg (0.4-3.6 mg/kg on spur-throated locusts weighing 1.4-2.4 g sprayed at 508-762 g/ha, and 0.6-7.4 mg/kg on Australian plague locust nymphs sprayed at 267-381 g/ha). Note that residues at the higher end of this range have only been recorded on adult Australian plague locusts and not on nymphs (see section 6.2.5.4). Fenitrothion residues within sprayed areas were said to fall in the range 7-25 ppm on vegetation and be 70% lower on soil. Residues in soil, water or vegetation contained only fenitrothion, with no metabolites found (limit of detection about 1 µg/kg). Residues in target areas immediately after treatment at 267-381 g/ha were 0.4-2 mg/kg on soil and 1-40 mg/kg on grass, declining to 0.1-0.8 mg/kg at 500 m downwind. It may be seen that there is some inconsistency in the information presented. Further comment on residues from APLC operations may be found at section 6.2.5.4.

The APLC confirmed that Target Control Sheets had been updated to prompt staff to report information on adverse environmental effects (affected and dead wildlife, and whether creeks or dams had been searched) and undertook to make further amendments to request reporting of whether birds or other animals were seen feeding on sprayed locusts, and whether this had any adverse effect. In relation to field studies, the APLC undertook to prepare the results of the pitfall trapping program (see section 7.1.3.4) for publication and reported that research programs were under development to monitor possible aquatic contamination, and impacts on terrestrial invertebrates and vertebrates. The appointment of an environmental officer to oversee the environmental program was announced. Preliminary testing with the cladoceran *Daphnia obtusa* was reported, but it was claimed that the work needed to be repeated because the result (48 h LC50 = 1.5 µg/L) was lower than reported in the literature (this aspect will be returned to in section 7.1.2.5).

A progress report on the APLC's environmental program (Story, 1997) was included in the 1997 research review report. Following delays associated with obtaining research permits and demonstrating proficiency in retro-orbital bleeding, permanent monitoring sites were being established at Willandra National Park (near Hillston, NSW) and the Muncoonie Lakes system (near Birdsville, Queensland) for monitoring of small mammal, bird and reptile populations. Field work to determine red blood cell acetylcholinesterase activity in native mammals was to continue through the 1997-98 campaign season. A literature review on potential ecological impacts of fenitrothion was underway and would be used as the basis for further work to determine the significance of any variations in areas such as territory defence, home range utilisation, reproductive success and mobility. Bird populations had been monitored near Griffith during the previous season, with bird species, numbers and activity recorded in preliminary surveys conducted at dawn, midday and dusk along predetermined transects in target and non-target areas. Work had also commenced in developing a database of sensitive areas such as organic farms, aquaculture enterprises and locations of threatened, vulnerable and endangered species.

APLC operations were reviewed in 1997 by a team convened by the Primary Industries and Energy Portfolio (Hoare *et al*, 1997). The team considered that the APLC brings significant benefits in terms of reduced risks to the environment than would occur in its absence, but that these benefits were not widely recognised. APLC operations were occurring in a climate of increased community awareness of environmental issues, including the perception that aerial application of pesticides is undesirable, and difficulties in site access were becoming more frequent due to landholder objections. The team recommended that operational strategies should be refined to "work around" organic enterprises pending availability of non-chemical control methods. The fungus *Metarhizium flavoviride* was identified as one such option for the medium term, and should receive priority for evaluation. The team considered that the APLC faces a major challenge in reducing the risks inevitably associated with pesticide use, and recommended that research into environmental effects of locust control, and alternatives to conventional insecticides, must be given a high priority, with external funding sources to be sought for expansion of activities.

APLC research activities were reviewed independently as part of the above review (Gregg, 1997). Further research into the fungal pathogen *Metarhizium* was recommended, and it was noted that this may become the only control agent usable in areas where organic farming is widely practiced. Environmental research was identified as the one area where progress may not have matched expectations, with a lack of staff continuity identified as a contributing factor. The environmental program was described as very broad, perhaps too broad to expect one person to cover it.

6. ENVIRONMENTAL EXPOSURE

6.1 Environmental Release

6.1.1 Volume

The main dispersive use of fenitrothion is for control of Australian plague locusts. Volumes used are variable. For example, no control was required in the 1994-95 season, but use can be heavy with a maximum of 130 tonnes consumed by the APLC during the 1992-93 outbreaks. A further 81 tonnes was used by State departments and landholders in South Australia and NSW during that season. The APLC has advised that increasing reliance on the APLC has seen a dramatic decline in the use of EC formulations of fenitrothion by State authorities since 1979. NSW Agriculture has confirmed this trend, advising that the average area sprayed over the last 3 years, which have seen relatively low locust pressure, is 1200 ha, requiring some 900 L of emulsifiable concentrate. Earlier plague years had required as much as 30000 L.

Only limited information is available on volumes of fenitrothion used in other applications. Wholesalers and retailers in Tasmania, where fenitrothion is particularly important for the control of corbies on pasture, have indicated that some 20000 L was sold in 1991/92, but that this has reduced to 2600-3000 L in 1996/97 and 3200-4000 L in 1997/98. Use is projected to reach as high as 6000 L in 1998/99 because of higher pest pressure.

Annual global production capacity has been estimated at 15000-20000 tonnes but current production volumes are not available (IPCS, 1992).

6.1.2 Application and use pattern

The uses of fenitrothion in Australia fall into three broad categories: structural and storage applications, winter applications to control pasture pests, and spring/summer applications in a broad range of crops to control insect pests, primarily locusts and grasshoppers but also sitona weevil in lucerne. There is also a minor household use as an outside fogger in Western Australia.

6.1.2.1 Structural and storage applications

Application occurs as a 1 g/L spray, with 1 L covering around 20 m^2 of grain storage or 7 m^2 of poultry housing. Spray solutions are also applied to hides to control beetles. Environmental exposure from these indoor applications is expected to be low given the situations of use and the limited persistence of fenitrothion.

A major grain industry association made a submission to the review, indicating that use of residual grain protectants has seen a major reduction in recent years, but that these chemicals remain important tools to the industry. The diluted chemical is applied to grain as a coarse spray as it is received into storage, within the confines of grain storage facilities and usually below ground level. Leaks and spills are contained in sumps which may be pumped out or soaked up with absorbent rolls. The potential for non-target exposure is minimal given application in secure, confined spaces.

On-farm hygiene treatment of grain bins and equipment such as harvesters uses knapsack or other portable spraying equipment and takes place once per year, usually in November in preparation for harvesting and receiving grain.

Application to poultry housing occurs in the 7-10 day period between batches of broilers, after removal of litter and cleaning of the shed. Two sprays 4-6 days apart are commonly applied. A variety of equipment may be used to apply insecticide to the walls and floors and as a perimeter band outside the shed wall, usually boom sprayers but also air-blast orchard sprayers for walls. Occasionally, part of the litter will be retained and treated in the same manner. Poultry are introduced after the spray has dried (typically a few days) with no further treatment until the next batch, typically some 40-50 days later. Some environmental exposure will arise under this use pattern when litter is used as fertiliser (see section 8).

6.1.2.2 Winter applications in pasture

Application may occur between April and July in temperate southern States for control of such pests as underground grass grub (800-1000 g/ha), cockchafers (500-700 g/ha) or oxycanus grass grub (1300 g/ha). The Tasmanian Department of Primary Industries and Fisheries (DPIF) has nominated fenitrothion as essential for control of corbie (800-1000 g/ha), winter corbie (1300 g/ha) and pasture cockchafer (700 g/ha). Ground based or aerial equipment may be used, the latter allowing treatment of hilly or rocky terrain unsuitable for ground spraying, but seldom used over the last decade because of cost factors. Most applications are made to high value pasture carrying cattle (mostly dairy) by ground boomspray. Application is made when opening rains have stimulated feeding activity or where pests are causing damage, with specific instructions to spray when rain is imminent for control of blackheaded pasture cockchafer, which only comes to the surface to feed after rain. There may be scope to reduce the high application rates by carefully assessment earlier in the season to determine whether pest pressure in pasture reaches economic thresholds, allowing treatment while grubs are less developed and more susceptible.

It is claimed by the DPIF that all of Tasmania's 900 000 ha of pasture is subject to attack by corbies and cockchafers on an annual basis, but current sales figures (2.6-4 tonnes, possibly increasing to 6 tonnes in the current season) would only be sufficient to treat a small proportion (up to about 1%) of this area. This is consistent with earlier published findings from the Tasmanian Department of Agriculture (Pauley and Miller, 1993). These authors distinguished between prevalence, which may exceed 50% of total improved pasture but does not normally result in any significant damage, and infestation with associated pasture damage. Estimated annual levels of infestation by blackheaded cockchafers, common corbies and winter corbies were 60 000, 36 000, and 6 000 ha, respectively. The study did not examine possible longer term pasture impacts, but analysis of short-term economic losses revealed that benefits could only be expected from spraying to control winter corbies and blackheaded cockchafers in poor to average seasons, with only marginal economic value in good seasons. Common corbie infestations were estimated to result in only minor economic losses in all but the worst seasons.

Winter use of fenitrothion in southern pastures appears to occur predominantly in Tasmania because of the problems with corbies and winter corbies, for which the only alternative registered treatment is chlorfenvinphos. Fenitrothion is recommended for use against blackheaded pasture cockchafers, underground grass grubs and oxycanus grass grubs in the Seymour/Alexandria district of Victoria. Fenitrothion is the only chemical registered for control of oxycanus grass grubs in NSW, but it is understood that little would be used against this occasional pest, and that chlorpyrifos would be a more likely alternative for other pasture pests in NSW because of its wider spectrum of use. Use against blackheaded pasture cockchafer has largely been discontinued in South Australia because of unreliable performance and the availability of synthetic pyrethroids as registered treatments.

6.1.2.3 Spring/summer applications for locust control

Labels for ULV and EC formulations indicate that ground based or aerial applications of fenitrothion may be made to control migratory locust and spur-throated locust (380-550 g/ha), wingless grasshopper (300-320 g/ha) and Australian plague locust (325-510 g/ha). Higher applications (510-770 g/ha) have been approved under permit for control of spur throated locust in maize and grain sorghum. Applications occur when insects attack or reach potentially damaging levels. The maximum number of applications in cereal crops is restricted to three during the growing cycle.

The APLC conducts control operations across the arid, primarily pastoral, country of NSW, Victoria, South Australia and Queensland, targeting larger bands and swarms that can be detected from an altitude of 300-400 m. Fenitrothion is the only chemical used. Control areas cover about 2 million km^2 of the Murray-Darling and Lake Eyre basins, but only small proportions of the total area are affected by locusts, and only about 5% of infested areas are sprayed. The same area is unlikely to be sprayed more than once, either within or between seasons, but the probability increases in southern areas where a spring infestation could develop from an autumn invasion.

The principal species of concern is the Australian plague locust (*Chortoicetes terminifera*) for which general rates of application have been reduced to 270 g/ha, with a maximum rate of 380 g/ha where factors such as tall dense vegetation would otherwise compromise performance. Most outbreaks originate in the Channel Country of south-west Queensland and adjacent areas of SA, NSW and the Northern Territory. If undetected, swarms may move into agricultural areas of NSW, SA, Victoria and Queensland.

Operations have also been conducted recently against spur-throated locust (*Austracris guttulosa*) with rates of 380-510 g/ha found to be effective. The rate reductions achieved for Australian plague locust appear not to be feasible for this pest, which moves through more heavily vegetated country. Spur-throated locusts are generally targeted as adult swarms as nymphs rarely form the dense marching bands typical of other locusts. The APLC control area is bounded by Charleville, Roma, Dalby, Narrabri and Bourke. Spur-throated locusts rarely need to be controlled as nymphs suffer high rates of mortality if ephemeral grasses essential to development dry off when no rain falls after hatching, as is common in drier areas to the south of the main egg-laying areas in northern Australia. However, a large outbreak occurred following successful breeding during the summer of 1995-96, with over 300 000 ha sprayed by landholders, mostly from the air. The recent portfolio review (Hoare *et al*, 1997) notes that, in contrast to APLC operations, landholders used maximum allowable rates of registered chemicals, are likely to have resorted to unregistered chemicals over at least 20% of the sprayed area, undertook control actions even where thresholds were well below those observed by the APLC, and sprayed in unsuitable meteorological conditions because of pressures on aircraft availability. Subsequent preventative control by State authorities and the APLC targetting high density overwintering swarms was highly effective, such that little spraying by landholders was required over the next summer cropping season.

Control may also need to be exercised from time to time over migratory locust (*Locusta migratoria*) and the Queensland Department of Natural Resources has conducted spraying to control small outbreaks of this pest near Clermont (West Central Coast) and Westmar (Darling Downs West) during the current season.

Aircraft fitted with two Micronair AU5000 rotary atomisers are used with a 10 m flying height, track spacing of 100 m, flow rate of 7 L/min/aircraft and Micronair blade angle of 50^o generating fine droplets with a volume median diameter typically in the 80-90 µm range. This differs markedly from normal crop spraying, with the wide swath and relatively high release allowing treatment of large areas in a rapid response situation. Deposition is uneven, but movement through treated areas effectively averages the exposure of individual locusts.

The APLC requires a minimum downwind buffer of 1.5 km for sensitive areas such as water bodies, to be increased when winds exceed 5 m/s. A large buffer is used because the method used to apply fenitrothion, currently the only chemical used operationally, is inherently susceptible to drift, as indicated by locust mortality 500 m downwind of spray release.

Further information on the magnitude and persistence of residues arising from APLC operations is contained in section 6.2.5.4. Reported wildlife incidents are described at section 7.1.1.6.

State agricultural authorities also conduct aerial operations where locusts are likely to affect agriculture within the State. For example, South Australia recently conducted large scale operations in the Flinders Ranges and mid-North in order to forestall southward migration of swarms through cereal, pastoral and horticultural areas. South Australian authorities have advised that APLC practices were closely followed, the main distinction being that smaller targets were occasionally sprayed in South Australia. Little fenitrothion has been applied by NSW Agriculture in recent years because of the success of the APLC’s control efforts in the pastoral areas of Queensland and western NSW. Use by NSW Agriculture generally occurs using boomspray, with some spot treatment and mister application. Aircraft are seldom used by NSW Agriculture because operations are mainly conducted in more heavily populated intensive agricultural areas.

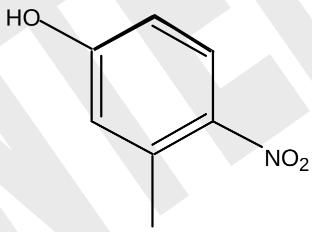
Landholder or local authority control of locust and grasshopper infestations in broadacre crops normally entails application around the perimeter, using misters to target those areas where locusts have congregated, including in surrounding vegetation. For orchard crops, growers target the underlying vegetation using a ground-directed spray, with no direct treatment of trees. For vegetable crops, only the surrounds would be treated. Small ground-directed boom sprays, either around the perimeter or between the rows, are used to control wingless grasshopper infestations in vineyards. Normal crop protection equipment may not be readily available in some of the more remote pastoral country, where graziers are believed to use hand guns or firefighting equipment without proper calibration. In contrast to the APLC, which relies on fenitrothion because of a relatively favourable environmental profile, inexperienced landholders may use a range of registered chemicals, some of which would appear to present much higher non-target risks than fenitrothion. Application rates tend to be higher because of a desire for rapid knockdown, and high demand for application equipment during outbreaks means that chemicals may be applied in unsuitable meteorological conditions.

6.2 Environmental Chemistry and Fate

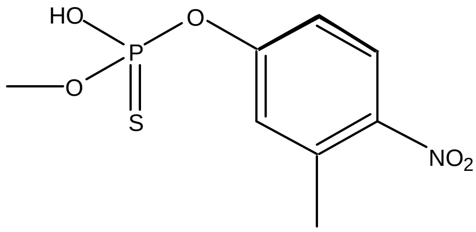
Descriptions follow of the testing that has been conducted to define the environmental fate of fenitrothion. Information has been taken from a range of sources, as outlined in the introduction to this report. Some of the older tests were conducted more than two decades ago, but results are generally consistent. Except where specifically noted, it would appear that tests have been conducted satisfactorily according to accepted international guidelines such as those of the US EPA (Hitch, 1982, and subsequent revisions) and OECD.

6.2.1 Hydrolysis

The hydrolysis of fenitrothion, uniformly radiolabelled throughout the aromatic ring, was studied at a concentration of 1 mg/L in sterile buffers for 30 days at 25^{o}C, using two-dimensional TLC for tentative identification and HPLC for confirmation of chemical identities. Analytical recoveries of radiocarbon were quantitative (97.1-103.8%) but extrapolated half-lives should be regarded with caution as they exceeded the duration of the study, being 100-101 days at pH 9, increasing to 180-186 days at pH 7 and 191-200 days at pH 5. Alkaline hydrolysis formed 3-methyl-4-nitrophenol as main product (about 15% after 30 days) while demethylation of a methoxy group to form desmethyl fenitrothion was predominant at neutral and acidic pH (Ito *et al*, 1988).



3-methyl-4-nitrophenol



desmethyl fenitrothion

Results confirm earlier studies conducted for 32 days across a broader pH range (2.0-11.5) using the same concentration of fenitrothion, radiolabelled in the aromatic ring. Again, two hydrolytic processes were found to be operating, neutral and base catalysed. The neutral reaction, involving demethylation, prevailed below pH 7, and the base catalysed hydrolysis to 3-methyl-4-nitrophenol was dominant above pH 10. At intermediate pH, both processes occurred. Half-lives at 15^{o}C ranged from 200 days at pH 9 to 630 days at pH 5, decreasing to 17-61 days at 30^{o}C and 4-8 days at 45^{o}C. Rate constants determined in filtered sterile river and seawater were consistent with those obtained in buffered solution (Mikami *et al*, 1984a).

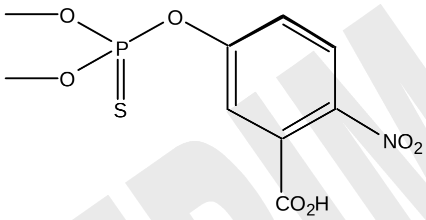
6.2.2 Photolysis

Fenitrothion photolyses readily in aqueous solution but more slowly on soil surfaces, as outlined below.

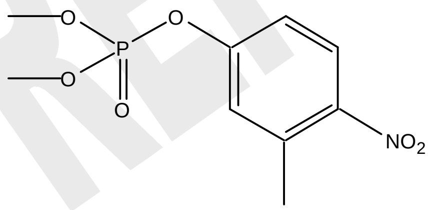
6.2.2.1 Water

Fenitrothion, radiolabelled at the aromatic methyl group, was dissolved in distilled water (14 mg/L) and exposed to Japanese autumn sunlight in a quartz flask for a total of 28 hours. Product mixtures were separated by TLC after freeze drying, with individual components quantitated by LSC. Analytical recoveries were essentially quantitative. A complex mixture of photoproducts formed, from which five were identified as carboxy-fenitrothion, fenitrooxon, *S*-methyl fenitrothion, 3-methyl-4-nitrophenol and 3-carboxy-4-nitrophenol, all increasing in concentration through the study.

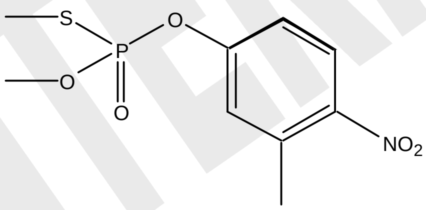
Approximately half the initial dose of fenitrothion was found to have degraded at the 11 hour sampling. Respective yields after 28 hours were 17.0, 3.3, 3.9, 3.9 and 3.1%, accompanied by 20% unchanged fenitrothion and about 25% each of unknown metabolites and baseline residues. Minimal degradation occurred in dark controls, with 98% unchanged fenitrothion recovered after 28 hours (Ohkawa *et al*, 1974).



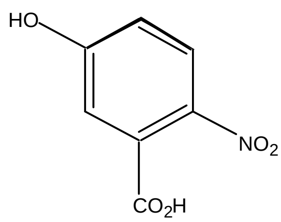
carboxy-fenitrothion



fenitrooxon



S-methyl fenitrothion



3-carboxy-4-nitrophenol

Aquatic photolysis was further studied using sterile solutions of fenitrothion, radiolabelled in the aromatic ring, in distilled water, river water pH 7.4, seawater pH 7.8, and buffers pH 3, 7 and 9. Carbon dioxide free air was continuously supplied over the surface, with volatiles collected in polyurethane plugs followed by sodium hydroxide traps. Sunlit irradiation in quartz flasks was conducted for 32 days (8 hours/day) in Japan during September and October at concentrations of 1 and 10 mg/L.

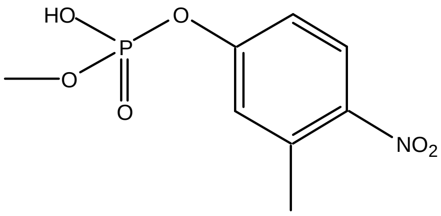
Analysis by TLC indicated that degradation was complex, with more than 50 products detected from which 20 were identified. Photodegradation pathways included oxidation of phosphorothioate to phosphate, oxidation of aryl methyl to carboxyl and subsequent dimerisation, reduction of nitro to amino, cleavage of P-O-alkyl and P-O-aryl linkages, isomerisation, cyclisation to benzisoxazole derivatives and subsequent rearrangement to azepine derivatives, and photomineralisation. Chemical structures for the identified photoproducts are available in the published literature (IPCS, 1992) and will not be reproduced in this document as yields were generally low and declining, with formation of $^{14}CO_2$ and unextractable residues as terminal degradation products. Significant photoproducts were carboxy-fenitrothion and its dimer, the latter of more importance at alkaline pH, and both in decline by the end of the test. Cumulative evolution of volatiles, predominantly $^{14}CO_2$, ranged between 21 and 45% of applied, and unextractable residues increased steadily to between 29 and 52%. The rate of degradation was independent of pH and concentration, with half-lives in the order of a day (Mikami *et al*, 1984a).

A more recent study used 1 mg/L solutions of ring-radiolabelled fenitrothion in sterile buffer (pH 5) with xenon lamp irradiation (λ > 290 nm) at 25°C for 30 days on a 10/14 hour light/dark cycle. Products were tentatively identified by TLC, with structural confirmation by HPLC. Analytical recoveries were 88-103%, declining through the study because of losses of dissolved CO_2 during workup. Photodegradation pathways included oxidation of aryl methyl to carboxyl and subsequent dimerisation, oxidation of phosphorothioate to phosphate, cleavage of P-O-alkyl and P-O-aryl linkages, isomerisation, and photomineralisation. The main photoproduct, carboxy-fenitrothion, reached levels in the order of 10% of applied after 14 days before declining. No persistent photoproducts formed, and evolution of $^{14}CO_2$ reached 41-42%, with 31-32% unextractable residues by study end. The estimated half-life under sunlight was about 2 days (Katagi *et al*, 1988).

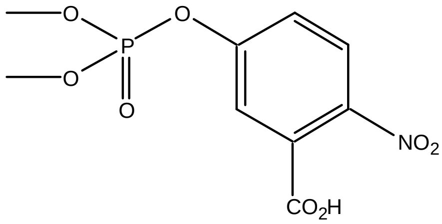
6.1.2.2 Soil

Fenitrothion was lost from the surface of two silty loam soils through volatilisation and photolysis when exposed to Japanese autumn sunlight as soil thin layer plates for 12 days following application at 10 µg/cm^2. Recoveries using methanol/water extraction followed by TLC declined to below 40% of applied during the study, with only traces (1-3%) residual fenitrothion. It appears soil plates were maintained in the open air and that losses were largely due to volatilisation. Two photoproducts were identified, fenitrooxon and 3-methyl-4-nitrophenol. The former peaked at 3.6-9.4% on the first day before declining, while the latter increased steadily to about 22-24% of applied before declining slowly after a week (Mikami *et al*, 1984a).

Similar results were obtained from a study on sandy loam, treated at 23.4 µg/cm^2 and irradiated for 30 days at 25°C with a xenon lamp (λ > 290 nm) having similar spectral characteristics to sunlight. Closed systems equipped with traps (KOH, H_2SO_4 and ethylene glycol) and foam plugs were used. Analysis of soil extracts, residual soil and trapping solutions using LSC or combustion analysis as appropriate revealed that fenitrothion decayed according to pseudo first order kinetics with a projected half-life of 85 days, compared with 182 days in dark controls. Fenitrooxon formed at levels in the order of 1% of applied, and was present at 1.6% on day 30. Desmethyl fenitrooxon exhibited similar behaviour. 3-Methyl-4-nitrophenol reached 3.3% on day 14 before declining to 2.4% by day 30. Cumulative $^{14}CO_2$ evolution reached 4.3%, with negligible recovery of other volatiles under the test conditions. Small amounts (each < 1%) of desmethyl fenitrothion, *S*-methyl fenitrothion, carboxy-fenitrothion and carboxy-fenitrooxon were also formed. Analytical recoveries declined to about 93% over the course of the study (Dykes and Carpenter, 1988).



desmethyl fenitrooxon



carboxy-fenitrooxon

6.1.2.3 Plant surfaces

Fenitrothion (carrying an aromatic methyl radiolabel) was rapidly lost from the surface of bean leaves exposed under unshaded and unprotected conditions to autumn sunlight. Analysis by TLC revealed the formation of small amounts of carboxy-fenitrothion, fenitrooxon, 3-methyl-4-nitrophenol and 3-carboxy-4-nitrophenol, none of which persisted. More than half the applied radiocarbon (6.8 µg/cm^2) was lost within 3 days (Ohkawa *et al*, 1974). Again, it appears that volatilisation is the main loss process operating in the open air.

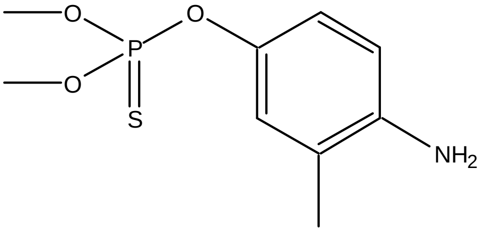
6.2.3 Metabolism

Two short and two long term aerobic tests were conducted in a range of Japanese and US soils. Anaerobic metabolism was also studied under flooded conditions. Fenitrothion degrades through microbial activity in aerobic soils with typical half-lives in the order of 2-4 weeks. Oxidation and demethylation are prominent, together with transformations of the aromatic methyl group. Reduction of the nitro to an amino group and subsequent acylation also occur, particularly under anaerobic or aquatic conditions where the half-life is less than a day. Anaerobic incubation leads predominantly to formation of unextractable residues rather than carbon dioxide. Considerable mineralisation occurs in aerobic soils, with as much as much as 70% of applied liberated as carbon dioxide within 2 weeks, and residues are also incorporated into soil organic matter.

6.2.3.1 Short term studies in four Japanese soils

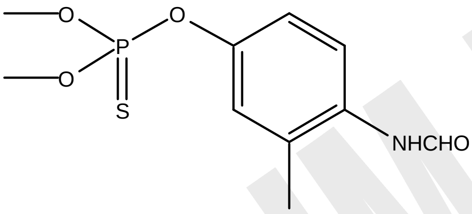
An emulsion of fenitrothion, radiolabelled at the aromatic methyl group, was added to four soils (silty loam, pH 5.2, 11% organic carbon; silty loam, pH 6.4, 1.4% organic carbon; sandy loam, pH 5.6, 0.9% organic carbon; and sand, pH 7.6, 0.1% organic carbon) to a level of 10 mg/kg and incubated at 25^{o}C for 60 days. Analysis by TLC with quantitation by LSC revealed that degradation produced 3-methyl-4-nitrophenol and $^{14}CO_2$ as main products, the former reaching levels of 10-20% of applied during the first 30 days before declining, and the latter amounting to 11.6-39.3% of applied over 60 days. Half-lives for fenitrothion ranged between 12 and 28 days.

Under submerged conditions, maintained for a week in the dark before addition of the test substance, degradation followed a reductive pathway with the formation of aminofenitrothion as main product (more than 65% after 1 week in the second silty loam) accompanied by smaller amounts (< 10%) of 3-methyl-4-nitrophenol and $^{14}CO_2$. Half-lives were very short at 4 days in two soils (the second silty loam and the sandy loam) collected from submerged locations, but comparable with aerobic data (12 and 20 days) in the other two soils.

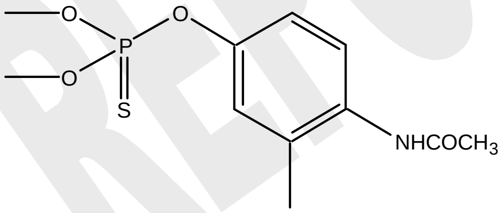


aminofenitrothion

Fungi and bacteria from the two silty loams were separately cultured in nutrient media. Aerobic incubation of these cultures with fenitrothion at 30°C caused a rapid degradation (> 70% within 3 days in the bacterial culture, and > 80% within 10 days in the fungal culture). Fenitrothion was stable in control cultures containing streptomycin and cycloheximide. The main product formed in each case was aminofenitrothion, accompanied by formylaminofenitrothion, acetylaminofenitrothion, desmethyl fenitrothion and 3-methyl-4-nitrophenol. The acylated products were more prominent in bacterial culture, and the cleavage products in fungal culture (Takimoto *et al*, 1976).



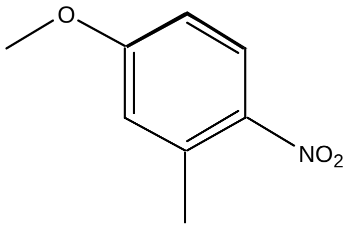
formylaminofenitrothion



acetylaminofenitrothion

6.2.3.2 Short term studies in US forest soils

Ring radiolabelled fenitrothion degraded rapidly via 3-methyl-4-nitrophenol in two forest soils, an organic soil (pH 3.5, 25.8% organic carbon) and a stony mineral soil (sandy loam, pH 5.2, 3.1% organic carbon). Soil samples were Soxhlet extracted (benzene/isopropanol) with extracts analysed by TLC/autoradiography followed by GC/radioactivity monitor, and residual soils by combustion. Residues recovered after 50 days of incubation at 30°C were fenitrothion (3-6%), 3-methyl-4-nitrophenol (5-7%) and the corresponding anisole (4%), $^{14}CO_2$ (35%) and unextractable soil residues (48-50%). Minimal degradation occurred in sterilised soils. The unextractable residues appeared to be mainly incorporated into soil organic matter through covalent bonds, with small amounts of fenitrothion or 3-methyl-4-nitrophenol loosely bound to the soil. The authors propose that 3-methyl-4-nitrophenol degrades further to a hydroquinone intermediate that reacts at radical sites in the organic matter or copolymerises with humic acids during their formation (Spillner *et al*, 1979).

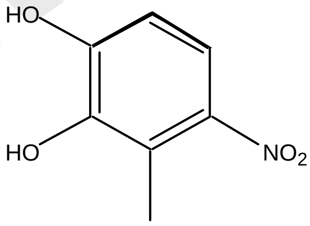


3-methyl-4-nitroanisole

6.2.3.3 Longer term studies in Japanese soils

Two soils from upland regions of Japan (sandy clay loam, pH 5.5 and loam, pH 4.4) were equilibrated in the laboratory for 2 weeks, fortified with 10 mg/kg fenitrothion (radiolabelled in the aromatic ring) and incubated at 25°C for 52 weeks, with samples analysed periodically using TLC, LSC, combustion analysis and autoradiography. Degradation was initially rapid, with a first half-life shorter than 7 days, and then proceeded more gradually. The slowing rate of decline is thought to reflect sorptive influences that protect against microbial attack. The main product formed initially was 3-methyl-4-nitrophenol, reaching about 30% of applied after 1-2 weeks before declining. Traces of fenitrooxon, acetylaminofenitrothion, desmethyl fenitrothion and desmethyl fenitrooxon were also detected. Cumulative $^{14}CO_2$ evolution exceeded 60% in the loam and 70% in the sandy clay loam. Significant amounts of radiolabel, in the order of 20-40% of applied, formed nonextractable residues, but these declined through the study after the first 2-4 weeks. When extracted soils containing these bound residues were mixed with equal amounts of fresh soil and incubated for 22 weeks, around 20% of the residues were liberated as $^{14}CO_2$.

Analogous studies with the metabolite 3-methyl-4-nitrophenol found a rapid degradation, from 10 mg/kg to less than 0.1 mg/kg within 4 weeks, with the simultaneous release of $^{14}CO_2$ (45-55%) and formation of bound residues (40-50%). Traces of an intermediate product, tentatively identified as 3-methyl-4-nitrocatechol, were also detected.



3-methyl-4-nitrocatechol

Two different soils (sandy clay loam and sandy loam, both pH 5.6) sourced from Japanese paddy fields were equilibrated under submerged conditions for four months before treatment with 10 mg/kg radiolabelled fenitrothion. The half-life was considerably less than 7 days under these reductive conditions, with less than 5% unchanged fenitrothion remaining after 2 weeks. The dominant metabolite was aminofenitrothion (more than 60% in one soil after 2 weeks) accompanied by smaller amounts of formylaminofenitrothion, acetylaminofenitrothion, desmethyl fenitrothion and desmethyl fenitrooxon. Soils were drained after 30 weeks, when $^{14}CO_2$ evolution had reached 31 and 15%, respectively. Terminal residues were $^{14}CO_2$ (40 and 23%) and unextractable residues (46 and 71%).

Evolution of $^{14}CO_2$ during the early part of the study suggests that conditions remained partly aerobic (Mikami *et al*, 1984b).

6.2.3.4 Longer term studies in US soil

Fenitrothion (1.115 mg/kg) degraded rapidly (half-life 2.0 days during the initial 7 days) when incubated at 25°C in sandy loam soil, pH 6.2. At the end of the study, a total of 71% of the initial radiolabel had been liberated as $^{14}CO_2$ (50% within 30 days) with a further 20% forming unextractable residues. 3-Methyl-4-nitrophenol was the main intermediate metabolite detected using TLC, at 20.5% of applied on day 3. Also detected were fenitrooxon (0.7% on day 1), desmethyl fenitrooxon (1% between days 1 and 5), 3-methyl-4-nitroanisole (0.5% on day 10) and formylaminofenitrothion (0.4% on day 10). Degradation slowed with time, the half-life extending to 10 days over the first two months of incubation, during which 99% of applied fenitrothion had degraded, and further to 36 days over the duration of the year long study (Cranor and Daly, 1989).

6.2.3.5 Anaerobic aquatic metabolism

This study used the same sandy loam as above, flooded with well water and aged in the dark for more than 30 days before amendment with glucose and treatment with 1 mg/kg fenitrothion, radiolabelled in the aromatic ring. Bacterial plate count analysis confirmed anaerobicity. Degradation products were tentatively identified by TLC and confirmed by HPLC. Fenitrothion degraded with a half-life of less than a day, with less than 1% of applied remaining after a month. Approximately 0.5% of $^{14}CO_2$ was liberated during 365 days at 25°C. Nonextractable residues increased to about 82% of applied after 153 days and remained high at 74% when the study was terminated. Metabolites were detected during the early stage of the study, with 3-methyl-4-nitrophenol peaking at 15% after 2 days, aminofenitrothion and acetylaminofenitrothion at 13% each after 3 days, and formylaminofenitrothion at 5% after 7 days. Desmethyl fenitrothion, desmethyl fenitrooxon and 3-methyl-4-nitroanisole were tentatively identified as minor metabolites (each less than 1.5%). The acylated metabolites remained at detectable levels through 273 days (Cranor and Daly, 1990).

6.2.4 Mobility

Standard batch adsorption (5 soils) and column leaching tests (7 soils) were conducted, as well as leaching tests with metabolites. Fenitrothion and metabolites adsorb moderately strongly to soils and do not leach significantly. Vapour transport is likely to be significant in view of the moderate vapour pressure, although volatilisation will be limited to a short period after application as fenitrothion does not persist on vegetation or soil surfaces. Fenitrothion appears relatively stable in air.

6.2.4.1 Adsorption/desorption in soils

Standard batch adsorption studies were conducted on four soils and a sediment (see table) equilibrated by shaking for 24 hours at 22°C with four volumes of aqueous solution (0.01-10 mg/L) of fenitrothion, radiolabelled in the ring. The richly organic sediment was equilibrated with eight volumes. Fenitrothion in the aqueous phase was determined by liquid scintillation, with the balance assumed to be adsorbed to the soil. Desorptions were conducted according to the same procedure.

Soil type	pH	Organic carbon (%)	Sand/silt/ clay (%)	Koc (ads)	Koc (des)
Silty clay loam	7.1	3.9	18/47/35	330	430
Silty clay	7.5	7.1	11/44/45	250	430
Sand	6.2	1.3	90/5/5	380	600
Sandy loam	5.2	3.1	56/38/6	1020	1600
Sediment	6.1	42	na	1960	1800

Adsorption results for the first three soils, taken from agricultural areas, place fenitrothion in the medium mobility class according to the McCall scale (McCall *et al*, 1980). The higher desorption coefficients are consistent with metabolism studies where fenitrothion became incorporated into organic matter. Coefficients increased further in two further desorptions on the silty clay loam, to 540 and 670. Fenitrothion is of low mobility in the remaining soil, taken from a forest area, and in the sediment. Coefficients increased through two further desorptions from the sediment, to 2330 and 3230.

Radiolabel was fully extractable from the supernatant, and contained 88% fenitrothion, 10% 3-methyl-4-nitrophenol and 1% of the corresponding anisole for the adsorption step. Desorbed solutions contained the same mixture but in different proportions (72:25:1). The report gives no indication of which soil these results were obtained from (Spillner and Neuberger, 1979).

6.2.4.2 Leaching of aged samples of fenitrothion

Leaching of fenitrothion (aromatic methyl radiolabel) and degradation products was studied on 2.5 x 20 cm columns of the same four Japanese soils as used for the short term soil metabolism study. Fenitrothion was aged for 2 months on soil samples before addition to the columns and elution with 100 mL water. Columns were then segmented, extracted with benzene, and analysed by TLC with quantitation by LSC. Little movement was apparent in the two silty loams and the sandy loam, but significant movement occurred in the sand, with 16% elution through the column from fresh samples, 6% from aerobically aged samples, and 40% (including 11% aminofenitrothion) from samples aged under submerged conditions (Takimoto *et al*, 1976).

6.2.4.3 Leaching of fresh samples of fenitrothion and metabolites

Mobility in soil of fenitrothion (labelled with ^{14}C at the aromatic methyl) and metabolites (3-methyl-4-nitrophenol, fenitrooxon, desmethyl fenitrothion) was also investigated by leaching tests on packed columns (3 x 25 cm) of clay loam (117 g, pH 5.3, 11.6% organic matter), sandy loam (163 g, pH 6.2, 2.3% organic matter) and sandy loam (118 g, pH 5.7, 6.2% organic matter). Test substances were incorporated into soils (24-33 g) to a level of 1 mg/kg and added to the tops of the equilibrated columns, which were then eluted at 3 mL/hour for 5 days, taking care to avoid water accumulation at the surface. Leachate was collected in 10 mL fractions, and effluxed air passed through a caustic trap. The leached column was divided into treated soil and sequential 5 cm segments. Liquid extracts were analysed by liquid scintillation, and soils by combustion.

Mobility of fenitrothion depended on organic matter content of the soil. Thus more than 20% of applied leached through the sandy loam with 2.3% organic matter, but essentially no radiolabel was recovered from leachates from the other two columns. The main component in the leachate was 3-methyl-4-nitrophenol, accompanied by smaller amounts of desmethyl fenitrothion. Fenitrothion and fenitrooxon were at very low levels, and evolution of volatiles (CO_2) amounted to about 1-2%.

Similar results were obtained for the metabolites as for parent fenitrothion in clay loam soil, and for 3-methyl-4-nitrophenol and fenitrooxon in the sandy loam with 6.2% organic matter. Again, the phenol was prevalent in leachate from the oxon, indicating the latter metabolite to be susceptible to hydrolytic degradation in the same way as fenitrothion. Desmethyl fenitrothion was more mobile than fenitrothion in the organic rich sandy loam, with significant recoveries from all soil segments, more than 20% recovered from leachate, and volatiles (CO_2) exceeding 5%. Around 5-10% of radiolabel was volatilised as CO_2 from metabolites applied to the sandy loam with 2.3% organic matter. Again, desmethyl fenitrothion was most mobile with significant recoveries of radiolabel from all soil segments and more than 20% recovered from leachate (Mikami *et al*, 1984c).

6.2.4.4 Volatilisation

The estimated Henry's law constant, based on vapour pressure of 18 mPa and water solubility of 14 mg/L, is 0.36 Pa.m^3/mole. The moderate Henry's law constant indicates that volatilisation from water may be significant, and this prediction is supported by findings of rapid losses from estuarine waters in Catalonia (Lacorte & Barceló, 1994). Particularly fast volatilisation (half-life 18 minutes) has been reported from surface slicks (Ernst *et al*, 1989). Degradation processes would generally be expected to be competitive with volatilisation given the lability of fenitrothion, and likely to be dominant in soils where fenitrothion is moderately strongly adsorbed and therefore less volatile.

Overseas reviews have reached different conclusions concerning the volatility of fenitrothion. The RED document (US EPA, 1994) reports a vapour pressure of about 0.7 mPa at 20^{o}C, noting that data requirements for stability in air were waived because of the very low vapour pressure. A 21 day laboratory volatility study from soil is also reported, in which 0.13-2.2% of applied was lost to volatilisation and the vapour pressure at 50% field capacity was initially 0.77 mPa but declined to 0.29 mPa over the course of the study.

The Canadian discussion document (Agriculture Canada, 1993) reports a vapour pressure of 128.5 mPa, noting that this indicates a moderate to high volatility under field conditions. The document concludes that fenitrothion has the potential to volatilise from soil, particularly moist soil, and that volatilisation from the surface microlayer is the major means of dissipation for fenitrothion sprayed on natural waters (see sections 6.2.5.2-3 for field observations supporting this conclusion). Phototransformation of fenitrothion in air is considered slow.

6.2.5 Field Dissipation

Fenitrothion would not be expected to persist in the field based on the laboratory results, and this prediction is supported by results from terrestrial and aquatic field trials conducted in Australia and overseas.

The aquatic half-life in Canadian forest trials was 1-3 days, decreasing to less than a day in Spanish rice crop waters and irrigation ditches. Aquatic dissipation mainly occurs through photolysis.

APLC research finds aquatic half-lives of 3-6 days and foliar half-lives of 2-5 days. Because of the wide swath used, ground deposits are heterogeneous with a saw-tooth pattern. Mean spray deposits are about 20 mg/kg on vegetation in target areas, ranging up to about 50 mg/kg. Residues in 15 cm water at 500 m downwind are predicted by computer modelling to be in the order of 2-3 µg/L, consistent with field measurements in an unspecified depth of 4.5 µg/L at 500 m downwind and 2.0 µg/L at 700 m. At least 90% of fenitrothion leaving the aircraft is believed to be deposited within 500 m downwind.

Residues on locusts appear to fall in the 1-10 mg/kg range, but residues as high as 100 mg/kg have been reported, and similarly high levels have been recorded in the stomachs of birds that had been feeding on contaminated locusts (see section 7.1.1.6).

6.2.5.1 Spruce forest

Analysis of ethereal extracts using glc found that residues of fenitrothion following aerial spraying of white spruce forest at 280 g/ha ranged between 9 and 25.5 µg/L in pond waters and were lower at 4.6-6.7 µg/L in a flowing stream. Residues dissipated to below 0.03 µg/L within 40 days, with a half-life in the order of 1-3 days. Rain after spraying delivered additional increments to surface waters. Residues in the surface 10 cm soil layer remained below 100 µg/kg and had dissipated within 45 days (Sundaram, 1974).

6.2.5.2 Estuarine waters

Fenitrothion dissipated rapidly following winter spray application at a nominal 20 and 200 µg/L to Spanish irrigation ditches. Two hours after application, residues determined by GC-ms in the water (depth of sampling not specified) had declined to 6% of nominal at the higher and 30% at the lower concentration. These high initial losses are thought to reflect volatilisation. Metabolites 3-methyl-4-nitrophenol, fenitrooxon and *S*-methyl fenitrothion could be detected during the first 4 days at the higher rate, the first two predominant at 0.6 and 0.4 µg/L on the day of treatment. Metabolites were only detected on the day of treatment at the lower rate. Overall half-lives including the initial rapid volatilisation and the subsequent slower metabolism through microbial activity and photolysis were about 12 hours (Lacorte and Barceló, 1994).

6.2.5.3 Rice crop waters

Fenitrothion residues were monitored in a irrigation ditch near a treated rice field by sampling from the 5-20 cm depth and analysing using immunoassay and chromatographic techniques. A formulation containing 50% fenitrothion was sprayed by helicopter at 148 mL/ha during summer. Initial residues in the rice water as determined by immunoassay were 119 µg/L. Residues in the irrigation ditch declined from an initial 45 µg/L with half-lives of 19 hours (immunoassay) or 11 hours (chromatography). Volatilisation and photolysis were thought to be the main processes through which fenitrothion dissipated from the water (Oubiña *et al*, 1996).

6.2.5.4 APLC operations

Some details of the persistence of fenitrothion under Australian field conditions are contained in the APLC's 1994-95 Annual Report. In general, APLC work has not been published, and experimental details are limited. A half-life of 19 hours is reported for vegetation in grass plots sprayed with fenitrothion ULV. The half-life in tap water exposed to sunlight was 2.5 days, but fenitrothion was much more stable in the dark with 88% recovered after 17 days.

Deposits on grass following application of fenitrothion by the APLC have been measured at 5-50 mg/kg, consisting only of fenitrothion with no metabolites detected (limit of detection about 1 µg/kg). Outdoor trials found half-lives of less than 2 days on grass and less than 5 days on sorghum leaf and grain heads.

The failure to detect metabolites is unexpected given the composition of fenitrothion. Material used by the APLC contains a maximum of 0.7% *S*-methyl fenitrothion. If total residues are 50 ppm, *S*-methyl fenitrothion should be present at levels up to 350 ppb, and should readily have been detected with a detection limit of 1 ppb.

Residues in duplicate water samples of about 0.4 and 1 mg/L have been recorded in target areas following application at 380 g/ha, and 0.21 and 0.33 mg/L following application at 270 g/ha. The depth of water in these studies is not specified. Residues declined downwind, to about 0.1 and 0.4 mg/L at 200 m for the higher rate, and 0.12 and 0.28 mg/L at the lower rate. Half-lives in sunlit lake water have been measured at 6.4 days.

The pattern of fenitrothion deposited downwind from two target blocks in the Coonamble area was reported to the 1996 Research Committee meeting. Wind speed was 3-6 km/h and grass samples were taken at 50 m intervals to 200 m and 100 m intervals to 1 km downwind of the first spray run.

The mean fenitrothion deposit on grass samples downwind of the first block declined to around 20 mg/kg at 100 m and further to 0.5-4 mg/kg at 400 m. Similar results were obtained from the second block. Based on these results, it is suggested that at least 90% of fenitrothion leaving the aircraft is deposited within 500 m downwind.

Deposition on locusts is reported by the APLC to leave residues of 1-7 mg/kg (0.4-3.6 mg/kg on spur-throated locusts weighing 1.4-2.4 g sprayed at 508-762 g/ha, 0.6-5.3 mg/kg on Australian plague locust nymphs sprayed at 267-381 g/ha, and 7.4 mg/kg on adults sprayed at 267 g/ha). Residues from Western Australian operations (Crisp, 1992) have been reported to fall in the 0.2-4.1 mg/kg range in the 5 days following spraying, with residues highest on the fifth day. At another site, residues in locusts increased from 3.5 mg/kg immediately post-spraying to 16 mg/kg at the 1 day sampling. The maximum levels at a third site occurred 3 days after spraying. Residues at this site were very high at 56-100 mg/kg. The author comments that locusts were difficult to sample.

More recent work reported to the 1997 meeting involved the taking of grass samples at 25 m intervals along a spray run that crossed bands of late instar Australian plague locust nymphs, allowing comparison of insecticide deposition and locust mortality. This was supported by contact studies in which caged unsprayed nymphs were exposed to contaminated grass samples. Oil sensitive papers were also deployed to monitor airborne droplets, but gave inconclusive results.

Deposition on grass was highly variable with distinct peaks and troughs, reflecting the 100 m spacing between spray runs. Vegetation ranged from sparse (20 cm high) to dense (up to 50 cm high) but mean spray deposits were fairly uniform (17.7-24 mg/kg). Locusts showed more than 95% mortality within 24 hours in the spray blocks, where residues on grass ranged from 12 to 49.4 mg/kg. Unsprayed locusts confined with samples of contaminated grass suffered similar rates of mortality. Grass samples taken 24 hours after application were similarly lethal to unsprayed locusts. The relatively rapid kills obtained, and similar kill rates from low and high residues, including aged deposits, suggest that application rates can be reduced well below the 267 g/ha used in general operations and in this trial, and further large scale trials are planned to investigate the feasibility of using a lower rate of 230 g/ha.

Sumitomo has advised that the mean residue during 1996-1997 in pasture samples taken by the APLC immediately after treatment at 508 g/ha was 67.6 mg/kg, equivalent to residues of 37.3 mg/kg for treatment at 280 g/ha.

Studies at Griffith during October 1996 examined two different methods (pilot judgement and a DGPS navigational system) for achieving a 100 m spacing between spray runs. The actual track spacing based on visual judgement by the pilot was only 80%, resulting in increased flying time and 14.5% higher insecticide application. Experienced aerial operators commented that increased spray runs would commonly be used to ensure adequate coverage in the absence of DGPS equipment. The use of DGPS equipment clearly allows greater precision and economy of application, and such equipment has now been fitted to one of the APLC's contract aircraft on a trial basis.

Drift from APLC operations has been modelled using the FSCBG (Forest Service, Cramer, Barry and Grimm) model. The model predicts that ground deposits are heterogeneous with a saw-tooth pattern, consistent with field observations. The model predicts residues on vegetation of 0.8-64.3 mg/kg from an application of 292 g/ha, declining to 3.8 mg/kg at 500 m, 0.71 mg/kg at 100 m, 0.31 mg/kg at 1500 m, and 0.07 mg/kg at 2000 m downwind. Predicted residues are lower by a factor of about 3 when wind speed is reduced from 6 to 3 m/s. Predicted residues in 15 cm water at the same sampling points with a wind speed of 6 m/s are 2.98, 0.67, 0.30 and 0.17 µg/L, declining to 2.38, 0.59, 0.27 and 0.16 µg/L at 3 m/s. Predicted residues are in reasonable agreement with measurements of 4.5 µg/L at 500 m and 2.0 µg/L at 700 m downwind in one trial, and 0.6 µg/L at 570 m in another.

6.2.6 Accumulation and Bioaccumulation

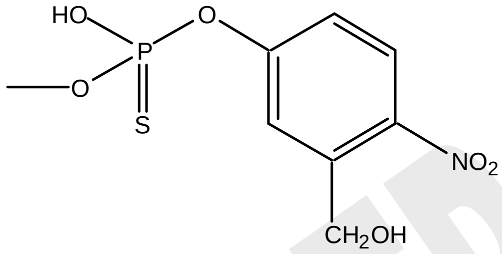
No specific studies have been conducted, but accumulation in soils from season to season is not expected from infrequent applications (the maximum frequency allowed is three applications per cereal crop) given the metabolism demonstrated in laboratory studies and the rapid dissipation observed in the field. Fenitrothion bioconcentrates to moderate levels in fish and other aquatic life. Steady state is soon achieved, and residues depurate rapidly in clean water.

6.2.6.1 Trout and minnows

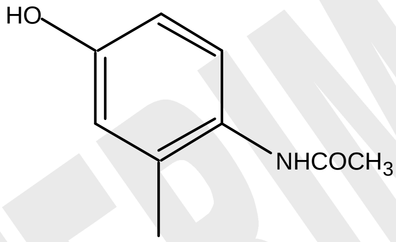
Bioconcentration factors in rainbow trout and southern top-mouthed minnows exposed under flow-through conditions to 20 or 100 µg/L fenitrothion (aromatic methyl radiolabel) were about 200-250. Steady state was reached in 1-3 days, and residues depurated by three orders of magnitude within 5 days when fish were transferred to clean water. Metabolism in fish formed fenitrooxon, desmethyl fenitrothion, desmethyl fenitrooxon, and 3-methyl-4-nitrophenol and its glucuronide, all of which were readily eliminated and could be detected in the water (Takimoto and Miyamoto, 1976).

6.2.6.2 Bluegill sunfish

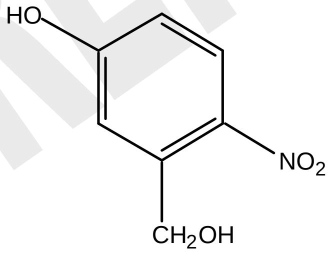
The calculated bioconcentration factor in bluegill sunfish exposed under flow-through conditions for 28 days to 43 µg/L fenitrothion (49 µg/L ^{14}C) was 30 (118 for total ^{14}C). Steady state was reached in 1-3 days and the depuration half-life was less than a day. Metabolism in bluegills followed the same pathways as in trout and minnows. After 28 days of exposure, some 21-29% of radioactivity in the fish was fenitrothion, accompanied by 29-40% desmethyl fenitrothion, 11-15% 3-methyl-4-nitrophenol-β-glucuronide, and 9-23% unknowns (Ohshima *et al*, 1988).



hydroxymethyl-desmethyl fenitrothion



3-methyl-4-acetylaminophenol



hydroxymethyl-4-nitrophenol

Further investigation revealed the unknown metabolites to be 3-methyl-4-nitrophenol (as sulfate conjugate) 3-methyl-4-acetylaminophenol (as sulfate and glucuronide conjugates), 3-hydroxymethyl-4-nitrophenol (as glucuronide) and hydroxymethyl-desmethyl fenitrothion (Ohshima and Mikami, 1990).

6.2.6.3 Killifish

Bioconcentration factors in killifish exposed for 7 days under flow-through conditions to 7.6 µg/L fenitrothion reached 132-136 (GC determination) after 1-3 days of exposure before declining. In contrast, fenitrooxon continued to accumulate in killifish through 7 days, but only to low levels (bioconcentration factors below 3). Respective half-lives for depuration were 6.3 and 2.3 hours. Bioconcentration was consistent with octanol/water partition coefficients, measured at about 2000 for fenitrothion and 60 for the oxon (Tsuda *et al*, 1997).

6.2.6.4 Red swamp crayfish

Fenitrothion residues determined by GC in muscle tissue from adult intermoult specimens of *Procambarus clarkii* exposed to a nominal 20 µg/L under static conditions with constant aeration increased to 220 µg/kg after 4 hours of exposure before declining to a steady state in the order of 50 µg/kg between 8 and 24 hours. Residues were lower than expected based on the octanol/water partition coefficient because of rapid biotransformation *in vivo* (Escartín and Porte, 1996a).

6.2.6.5 Algae

Accumulation of fenitrothion (aromatic methyl radiolabel) in algae was studied in static systems at a nominal 10 µg/L with green algae (*Chlorella vulgaris*), diatoms (*Nitzschia closterium*) and blue-green algae (*Anabaena flos-aquae*). Exposure concentrations determined by TLC and LSC remained fairly constant for the former two species with fenitrothion representing 93-99% of radiolabel in the water. Radioactivity increased to 387 µg/kg (56-84% fenitrothion) in green algae and 926 µg/kg (86-98% fenitrothion) in diatoms. With blue-green algae, fenitrothion in the water decreased rapidly to below 0.6 µg/L after 48 hours, while total radiolabel remained fairly constant. Similar trends prevailed in the organism, with production of more than ten metabolites including desmethyl fenitrothion, desmethyl fenitroxon, 3-methyl-4-nitrophenol and fenitrooxon. Bioaccumulation ratios were about 50 in green algae and 100 in diatoms, for total ^{14}C and fenitrothion. In blue-green algae, ratios were about 100 for total ^{14}C and 50 for fenitrothion. Depuration half-lives were less than an hour, increasing to 2.6 hours in blue-green algae (Kikuchi *et al,* 1984a).

6.2.7 Summary of Environmental Fate

Fenitrothion is not expected to persist in the environment as it is degraded by the following processes.

6.2.7.1 Hydrolysis

Two studies were presented. Testing in sterile buffers revealed that fenitrothion hydrolyses with a half-life in the order of 3 months at pH 9, increasing to about 6 months at pH 5. Base catalysed hydrolysis forms 3-methyl-4-nitrophenol, while demethylation of a methoxy group prevails under neutral and acidic conditions. Similar rates of hydrolysis were observed in sterile river and seawater.

6.2.7.2 Photolysis

Testing was conducted in aqueous solution (three studies) and on the surface of soils (two studies) and foliage, using artificial irradiation or natural autumn sunlight. Fenitrothion photolyses readily in aqueous solution but more slowly on soil surfaces. Degradation is hastened by microbial activity, and half-lives in sunlit water are typically less than a day. Photolysis formed a complex range of products through such transformations as oxidation of the thiophosphate and aromatic methyl groups, isomerisation to the *S*-methyl analogue, and cleavage to the phenol.

6.2.7.3 Metabolism

Two short and two long term aerobic tests were conducted in a range of Japanese and US soils. Anaerobic metabolism was also studied under flooded conditions. Fenitrothion degrades through microbial activity in aerobic soils with typical half-lives in the order of 2-4 weeks. Oxidation and demethylation are prominent, together with transformations of the aromatic methyl group. Reduction of the nitro to an amino group and subsequent acylation also occur, particularly under anaerobic or aquatic conditions where the half-life is less than a day. Anaerobic incubation leads predominantly to formation of unextractable residues rather than carbon dioxide. Considerable mineralisation occurs in aerobic soils, with as much as much as 70% of applied liberated as carbon dioxide within 2 weeks, and residues are also incorporated into soil organic matter.

6.2.7.4 Mobility

Standard batch adsorption (5 soils) and column leaching tests (7 soils) were conducted, as well as leaching tests with metabolites. Fenitrothion and metabolites adsorb moderately strongly to soils and do not leach significantly. Vapour transport is likely to be significant in view of the moderate vapour pressure, although volatilisation will be limited to a short period after application as fenitrothion does not persist on vegetation or soil surfaces. Fenitrothion appears relatively stable in air.

6.2.7.5 Field dissipation

Fenitrothion would not be expected to persist in the field based on the laboratory results, and this prediction is supported by results from terrestrial and aquatic field trials conducted in Australia and overseas.

The aquatic half-life in Canadian forest trials was 1-3 days, decreasing to less than a day in Spanish rice crop waters and irrigation ditches. Aquatic dissipation mainly occurs through photolysis.

APLC research finds aquatic half-lives of 3-6 days and foliar half-lives of 2-5 days. Because of the wide swath used, ground deposits are heterogeneous with a saw-tooth pattern. Mean spray deposits are about 20 mg/kg on vegetation in target areas, ranging up to about 50 mg/kg. Residues in 15 cm water at 500 m downwind are predicted by computer modelling to be in the order of 2-3 µg/L, consistent with field measurements in an unspecified depth of 4.5 µg/L at 500 m downwind and 2.0 µg/L at 700 m. At least 90% of fenitrothion leaving the aircraft is believed to be deposited within 500 m downwind.

Residues on locusts appear to fall in the 1-10 mg/kg range, but residues as high as 100 mg/kg have been reported, and similarly high levels have been recorded in the stomachs of birds that had been feeding on contaminated locusts (see section 7.1.1.6).

6.2.8 Accumulation and Bioaccumulation

No specific studies have been conducted, but accumulation in soils from season to season is not expected from infrequent applications (the maximum frequency allowed is three applications per cereal crop) given the metabolism demonstrated in laboratory studies and the rapid dissipation observed in the field. Fenitrothion bioconcentrates to moderate levels in fish and other aquatic life. Steady state is soon achieved, and residues depurate rapidly in clean water.

6.2.8.1 Conclusion

Fenitrothion will mainly become associated with the soil following use to control insect pests in cropping and pastoral situations, with a portion volatilising and dispersing. The insecticide is moderately strongly adsorbed to soils and degrades through microbial metabolism with typical half-lives of a few weeks under aerobic conditions. Residues entering water dissipate through photolysis and microbial metabolism with half-lives typically less than a day, as well as through uptake into biota to moderate levels, accompanied by metabolism.

7. ENVIRONMENTAL EFFECTS

Results for the following tests are available. Except where specifically noted, it would appear that tests have been conducted satisfactorily according to accepted international guidelines such as those of the US EPA (Hitch, 1982, and subsequent revisions) and OECD. Note that only limited test data were provided by the registrant, with no information for aquatic invertebrates despite their sensitivity. Further information is taken from the recent international review of fenitrothion (IPCS, 1992) and the subsequent scientific literature, and from various APLC reports.

Toxicity classifications used by the US EPA for inter-chemical comparison are adopted for birds and aquatic organisms. For terrestrial invertebrates, the classifications of Mensink *et al* (1995) are used, except for earthworm contact toxicity which is described using the criteria of Neuhauser *et al* (1985).

7.1 Avian Toxicity

Reports from acute, dietary and reproductive testing in quail and mallards have been submitted, and laboratory and field information for a large number of species has been obtained from the scientific literature. Fenitrothion is slightly to very highly toxic to birds by acute oral and dietary routes. Quail are sensitive and mallards relatively insensitive. Similar trends are apparent in reproductive testing, with the no observed effect concentration with respect to egg production in quail below 35 ppm, but no statistically significant impacts on reproductive parameters in mallards exposed to 107 ppm in feed. In general, it appears that small birds are more sensitive than larger birds to the toxic effects of fenitrothion.

Adult mortality has been reported from the field at rates above 280 g/ha, increasing markedly at rates above 560 g/ha. Cholinesterase activity is inhibited and mortality of juvenile birds has been reported at lower rates. Songbird impacts are commonly reported. The lower end of this range slightly exceeds the rate generally used by the APLC for control of Australian plague locust, and other rates for locust and grasshopper control fall within it, except for the high rates approved under Permit for control of spur-throated locusts in maize and grain sorghum. In contrast, application rates for control of subterranean pasture pests exceed this range, in some cases being more than double the upper limit.

Available field data from Scotland, Canada and Senegal indicate that a proportion of the bird population will receive a significant exposure to fenitrothion in sprayed areas, and that some birds will die and others suffer sub-lethal effects. Emigration from sprayed areas will also occur in response to a reduction in invertebrate food resources. This is best demonstrated by the detailed study of avian effects of fenitrothion used at relatively high rates for grasshopper control in semi-arid thornbush savannah in Senegal, involving weekly bird counts before and after application, carcass searches, and collection of sick and healthy specimens for cholinesterase analysis. One of the main species affected also occurs widely in Australian locust habitat and may be expected to be routinely exposed to fenitrothion during APLC operations. Sumitomo has advised that it should be clearly stated in this overview of avian toxicity that the rates used in the Senegal study (485 and 825 g/ha) were very much higher than the routine dose (267 g/ha) used by the APLC.

Detailed monitoring of avian effects from APLC operations has yet to occur, although a bird census was commenced in October 1996. Little information is available on avian behaviour during and after control operations, notwithstanding that locust plagues would be expected to attract birds. Only a few avian casualties have been collected, the most notable examples being fifteen dead black kites found dead near control operations in southwestern Queensland in 1992, with high residues (26-92 mg/kg) found in the stomachs of three specimens subjected to analysis.

7.1.1 Acute oral

Reported acute oral LD50s for six species (IPCS, 1992) range from 25 mg/kg (redwinged blackbird) to 1190 mg/kg (mallard). Fenitrothion is slightly to very highly toxic to birds by the acute oral route. The APLC has indicated that bobwhite quail and pigeons are also sensitive to fenitrothion with acute LD50s below 50 mg/kg, and suggests that higher metabolic rates and higher food consumption relative to body weight may account for the generally observed trend that small birds are more sensitive to fenitrothion.

Results from testing conducted in the early 1970s are tabulated below. They indicate fenitrothion to be highly toxic to pheasants, moderately toxic to quail, and practically nontoxic to mallards.

Test	Species	Result	Reference
Acute oral	Japanese quail	LD50 = 115 mg/kg (¢) LD50 = 140 mg/kg (™)	Kadota *et al*, 1974
Acute oral	Mallard duck	LD50 = 2550 mg/kg	Fletcher, 1971a
Acute oral	Ringneck pheasant	LD50 = 34.5 mg/kg	Fletcher, 1971b

Symptoms of intoxication in Japanese quail included irregular respiration and ataxia at lower doses (< 100 mg/kg) progressing to tremor, salivation and lacrimation within 10-30 minutes at higher doses. Death occurred within 48 hours, and survivors returned to normal after 2-5 days. The sub-acute LD50s from daily dosing for 2 weeks were 21.5 mg/kg for males and 13.7 mg/kg for females.

Symptoms preceding death in young adult mallards included lacrimation, nutation, partial immobility, regurgitation and clonic convulsions. All mortalities occurred within 2 days of dosing. There was a dose dependent depression in food consumption during the first week after dosing via gavage. No abnormal gross pathology was evident in survivors sacrificed at 21 days after dosing, but dead birds had an inconsistent dilation of cardiac vessels.

Symptoms in young adult ringneck pheasants included lacrimation, lethargy, tachypnea, loss of righting reflex and terminal wingbeat convulsions before death. There was a dose dependent depression in food consumption during the first week after dosing via gavage. No abnormal gross pathology was evident at post mortem.

Sumitomo has provided two further studies on avian toxicity. An acute oral study in mallards (Grimes and Jaber, 1988c) was confounded by the tendency of mallards to regurgitate the test article. The highest dosage at which only minimal regurgitation occurred was 259 mg/kg. An acute oral study in bobwhite quail (Grimes and Jaber, 1988d) returned an LD50 of 23 mg/kg.

7.1.2 Dietary

Dietary studies provided by the principal registrant involved 5 days of dietary exposure to 10 day old birds followed by 3 days with untreated feed. Results indicate high dietary toxicity to bobwhites and slight toxicity to mallards.

Test	Species	Result	Reference
Dietary	Bobwhite quail	LC50 = 126 ppm	Grimes and Jaber, 1988a
Dietary	Mallard duck	LC50 = 1773 ppm	Grimes and Jaber, 1988b

The onset of toxicity in bobwhites became apparent on day 4 at a dose of 78 ppm, and on the first morning following dosing at 625 ppm. Typical symptoms were lethargy, depression, wing droop, reduced reaction to external stimuli, lower limb weakness, prostrate posture, loss of righting reflex, loss of coordination, shallow and rapid respiration, and coma. Reduced feed consumption and attendant impacts on body weight were observed over this range of exposures.

In mallards, symptoms of intoxication included lethargy, depression, wing droop, reduced reaction to external stimuli, lower limb weakness, prostrate posture, loss of righting reflex, loss of coordination, lower limb rigidity and salivation. Symptoms had generally subsided by day 7. Food consumption was depressed at all concentrations.

A recent paper from the scientific literature reports a 5 day LC50 of 49.8 ppm in white-throated sparrows, indicating very high dietary toxicity to this species. Mortality was complete at 90 ppm. Cholinesterase activity was significantly depressed in survivors, and birds spent increased time foraging, except at the highest dose of 200 ppm where foraging time decreased. Dead birds weighed 30% less than survivors. Frequency of singing declined in all groups, including controls, during the exposure period. The dietary LC50 was considerably higher than the dietary exposure in the field, where residues in spruce budworm were measured at 0.7-1.2 ppm (wet weight) 3 hours after spraying at 210 g/ha (Forsyth and Martin, 1993).

7.1.3 Reproduction

A slight reduction in egg laying was observed in Japanese quail exposed to dietary levels of 50 ppm for 4 weeks, but egg production returned to normal within 2 weeks. Reversible inhibition of blood and brain cholinesterase, more pronounced in females, was observed at concentrations above 5 ppm (Kadota *et al*, 1974).

Exposure of mallards to dietary levels of 30 and 100 ppm had no effect on food consumption and body weight, egg production and viability, and body weights of offspring to 14 days (Fletcher, 1974).

Bobwhite quail approaching their first breeding season (28 weeks old) were continuously exposed to a nominal 35, 51 or 74 ppm fenitrothion in the diet for 19 weeks, with egg laying stimulated in the eighth week. Diets were refreshed at weekly intervals, during which time mean measured concentrations decreased from 85-90 to 70-75% of nominal. Mortality reached 25% (all males) at the intermediate dose, increasing to more than 50% at the highest dose. Birds exhibited symptoms of intoxication as described above and were emaciated at autopsy. A dose responsive reduction in egg production was observed at all concentrations, and hatchability was impaired at the highest dose (Beavers *et al*, 1989a).

Young adult mallards (26 weeks old) approaching their first breeding season were continuously exposed to a nominal 51, 74 or 107 ppm fenitrothion in the diet for 18 weeks, with egg laying stimulated in the tenth week. Diets were refreshed at weekly intervals, during which time mean measured concentrations decreased from 85-90 to about 70% of nominal. There were no treatment related mortalities and no overt signs of toxicity, but effects on adult body weights were observed at the two higher doses. There appeared to be a reduction in egg hatchability at the highest dose, although this was not statistically significant (Beavers *et al*, 1989b).

Sumitomo has provided a further reproduction study in bobwhite quail (Beavers *et al*, 1991). The study reports a NOEC of 20 ppm, based on possible slight reduction in egg production at 25 ppm. Sumitomo further advised that this assessment report should clearly state that “bobwhite quail and mallard duck NOECs are 20 and 51 mg/kg”.

7.1.4 Field studies in Senegal

Pilot studies on unreplicated 2 x 3 km study plots in Senegal where fenitrothion was aerially applied at relatively high rates (485 and 825 g/ha) across areas of semi-arid thornbush savannah with high grasshopper populations found a reduction in total bird numbers, with significant decreases in three of the most abundant species (Abyssinian rollers, blue-naped mousebirds and singing bush-larks - note that the last species occurs widely in inland Australia). Weekly bird counts along 1 km parallel transects on a 250 m spacing between 7 and 10 am provided a relative index of bird abundance, and were supplemented by bird counts between 10 am and 1 pm in shallow topographical depressions that supported a greater diversity and biomass of vegetation. Carcass searches were conducted 24 and 48 hours after treatment, with searching efficiency and disappearance rate evaluated by placement of dead birds. Dead or debilitated birds were collected for analysis, as well as healthy specimens by netting or shooting.

A total of 131 bird species was observed on the study plots between June and October. Removal of rare and incidental species, and of golden sparrows that were sufficiently numerous to mask effects on other species, left 71 species for consideration, 21 being common. Total numbers of birds and the sum of the 21 most common species declined on treated plots, with the largest declines (46 and 51%, respectively) on the plot that received the heaviest treatment. Depression counts also declined on treated plots.

Carcass searching found 3 dead or debilitated birds (3 species) on the lower dose plot and 10 birds (7 species) on the higher dose plot. Button quail, Abysinnian rollers, hoopoes and singing bush-larks were the most commonly found casualties. No dead birds were found on the control plot. After correction for searching efficiency (40-70% for larger birds but only 12% for smaller birds) it was estimated that some 2% of larger birds and 7% of smaller birds on the low dose plot suffered mortality, and 6 and 7%, respectively, on the high dose plot.

Singing bush-larks were noticeably affected, with significant decreases in male singing following treatment, and recovery of flightless fledglings in debilitated condition with reduced brain cholinesterase. These birds were considered a good indicator species because they were abundant, widely distributed, sedentary and nesting in the grassland. Gizzard analysis indicated that this species fed predominantly on grasshopper instars in control plots, compared with treated plots where seeds formed a large part of the diet, apparently because fenitrothion reduced grasshopper populations. Singing bush-larks were breeding before spraying and decreased after treatment as young fledged and birds presumably left the area. These decreases were largest and occurred most rapidly on treated plots, which had significantly fewer larks than control plots in the 2 weeks following spraying. Flightless fledglings were significantly heavier in control plots, and cholinesterase was substantially depressed in fledglings from treated plots in the 3 days following treatment, consistent with exposure to organophosphates, probably via the oral route when parent birds brought contaminated insects back to the nest. Observations suggest adverse effects on nesting success in this species.

Cholinesterase was inhibited by greater than 50% in debilitated adult birds and fledgeling larks recovered from treated plots, and healthy birds collected 1 week after treatment often had lower cholinesterase levels than controls, returning to normal by 3 weeks after treatment. Cholinesterase inhibition remained above 50% in singing bush-larks collected from the high dose plot 2 weeks after treatment.

Three of 14 carcasses laid on a chlorpyrifos treated plot disappeared within 24 hours, and most contained fly larvae by 48 hours. In contrast, none of 33 bird carcasses disappeared from the high dose fenitrothion plot, and there was little evidence of sarcophagic fly and beetle activity.

When corrected for variations in controls, bird numbers on fenitrothion treated plots declined by 30-47%, a much greater reduction than estimated to be due to mortality. A general decrease occurred with all bird species monitored. Population reductions appeared to mainly reflect bird movement in response to a reduction in grasshopper prey (Mullié and Keith, 1993).

7.1.5 Field studies in Canadian and Scottish forest

The following field observations are taken from the review by the IPCS (1992).

Mortality of birds inhabiting the crown canopy was observed occasionally following application of fenitrothion to Canadian forest at rates above 280 g/ha, increasing markedly at rates above 560 g/ha. At lower rates (210-280 g/ha) behavioural changes were observed in adults as well as some juvenile mortality.

Population studies on 9 of 48 bird species in Japanese forest and fields, including the most sensitive species, revealed no effect on diversity, abundance or reproductive success from application of fenitrothion at 1.7 kg/ha twice a year for three years.

Reduced productivity of white-throated sparrows in Canadian forest sprayed at 420 g/ha and again a few days later at 210 g/ha was ascribed to the high rate of nest desertion, occasional death or incapacitation of incubating females, and the high rate of nestling disappearance.

Five species of forest songbirds (Tennessee Warbler, Magnolia Warbler, Blackburnian Warbler, Bay-breasted Warbler and White-throated Sparrow) subjected under wild or captive conditions to sprays of 210-280 g/ha fenitrothion absorbed the toxicant and had significantly inhibited brain cholinesterase activity, but neither mortality nor abnormal behaviour were observed. Residues of fenitrothion and metabolites were detected in all birds, spanning a fairly wide range (0.08-1.4 mg/kg) but with no consistent correlation to brain cholinesterase activity.

Monitoring of Scottish songbirds (Willow Warbler and Chaffinch) found relatively high residues in skin and plumage samples during the first few days after spraying at 280-300 g/ha, but declining rapidly to a low level. There were transient low level detections in viscera. Brain cholinesterase was significantly inhibited in the 2 days after spraying but returned to normal in 7-21 days.

Sumitomo has requested that the effects observed in the Scottish study be described specifically. According to Sumitomo, an application rate of 300 g/ha resulted in no effects on the size of the breeding bird population, or on bird counts immediately before and after spraying, or on reproduction in coal tits (*Parus ater*). Sumitomo did not provide supporting data, but cited a reference not included in the IPCS review.

7.1.6 Australian field observations

Information on avian responses to fenitrothion in Australia can be gleaned from various APLC documents. The 1997 Annual Research Review Report notes an incident from 1985, unrelated to locust control operations, in which white-winged choughs poisoned accidentally by contaminated wheat were found to have up to 154 ppm fenitrothion in gizzard contents.

Fifteen dead black kites (*Milvus migrans*) were found to the north of APLC control operations at Moorebaree, southwestern Queensland in 1992, 24 hours after spraying had taken place. Examination of three dead birds revealed that they had been gorging on locusts. Stomachs contained between 26.3 and 91.5 mg/kg fenitrothion.

Three brown song larks (*Cinclorhamphus cruralis*) found intoxicated during control operations near Coonamble NSW in January 1993 contained 0.1, 0.2 and 1.0 mg/kg fenitrothion. Two of these birds had locusts in their alimentary tracts.

Sumitomo has noted that the foregoing incidents are essentially anecdotal and poorly documented, and that treatment rates and other conditions of application should be specified before the importance of such information can be determined. Unfortunately, only limited information is available on these incidents. More rigorous data would be preferred such as may be obtained from formal monitoring programs, but such data are not available. The Moorebaree incident does not appear to have been followed up. It should be noted that the dead black kites were found at some distance from spraying operations, and that monitoring at the site of application would not have discovered them. In these circumstances, the reported incidents can not be ignored, even if details are sketchy, particularly as extensive and systematic searching for avian casualties has not occurred in Australia.

Caged Japanese quail oversprayed at 343 g/ha contained 14-870 mg/kg fenitrothion in plumage at 1 day after treatment, declining to 3.4-100 mg/kg by 7 days.

A major breeding event for native water birds that occurred after flooding inundated the Gwydir wetlands west of Moree during the 1995-96 control season coincided with locust infestation in surrounding areas. Initially, a 50 km buffer was observed around the Gingham Watercourse, but this was subsequently relaxed to 5 km following consultation with State and local authorities. Buffers were established because of concerns that straw-necked ibis could be placed at risk by their large foraging range and preference for locust nymphs as a food source. Monitoring of populations during control operations found no dead or dying birds, but there is no indication of whether birds were feeding on sprayed insects. It is understood that most breeding species were egrets and herons which are not known to use locusts for nestling food.

The current environmental program for locust control operations began a bird census in October 1996. Six carcasses have been collected to date, but fenitrothion was not implicated in any of these mortalities.

Little information is available on avian behaviour during locust campaigns, notwithstanding that locust plagues would be expected to attract birds. As noted earlier in this report, the APLC has undertaken to modify Target Control Sheets to request details of whether birds were feeding on sprayed locusts, but such details have yet to be reported. Interestingly, an evaluation report that was presented to the 1997 research committee meeting noted that many insectivorous and scavenger birds were seen actively feeding in trial areas following spraying of a different insecticide, with no visible signs of intoxication. Information on avian behaviour when fenitrothion is used would be a fundamental requirement for determining avian exposure.

No information is available on avian exposure during winter applications to southern pastures, apart from the informal claim that no bird deaths have been recorded during two decades of such use in Tasmania. A range of birds would be expected to occur in Tasmanian pasture, and there is anecdotal information that forest ravens arrive in large numbers soon after spraying operations. The results from the Senegal study indicate that impacts to sensitive species may be expected, given the high rates of application.

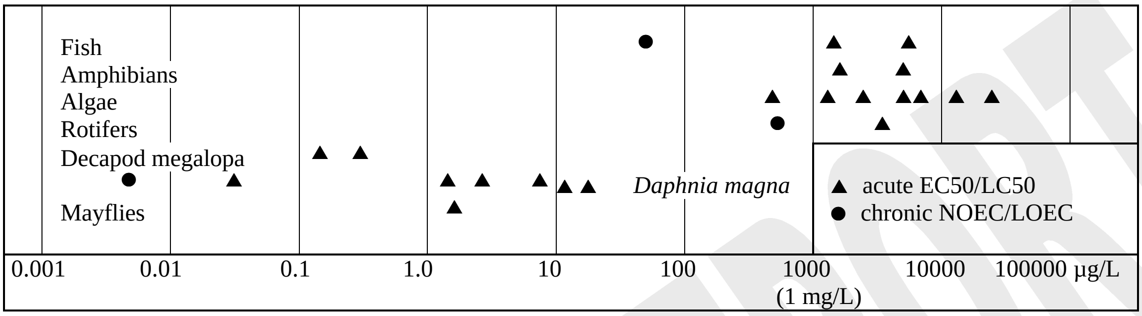
7.2 Aquatic Toxicity

Acute testing under static conditions with 3 species indicated that fenitrothion has moderate acute toxicity to fish (LC50s between 2.3 and 4.1 mg/L). Published data for a much larger number of species indicates that acute LC50s generally fall in the 1-10 mg/L range. Chronic endpoints are about an order of magnitude more sensitive. The acute sensitivities of fish and tadpoles appear similar, based on studies with 3 frog species. Metabolites appear generally to be less toxic than the parent.

No information was provided by the registrant in the original submission, but information available from other sources indicates that, consistent with its insecticidal activity, fenitrothion is much more toxic to aquatic invertebrates than to fish. Acute endpoints in the low ppb range are typical, with sensitive organisms such as crab megalopa killed at sub-ppb concentrations. The most sensitive organism tested is the cladoceran *Daphnia magna*, with a 24 hour LC50 of 0.067 µg/L reported, but only limited details are available and the result is well below the previously accepted range for this species. Again, chronic effects occur at concentrations an order of magnitude lower, based on reproductive testing in daphnids and rotifers.

Fenitrothion is moderately toxic to algae, with acute endpoints generally in the 1-10 mg/L range in testing with a variety of green algae and with blue-green algae and diatoms.

Aquatic toxicity of fenitrothion is summarised in the table below.



Limited field observations (see section 7.1.2.9) indicate reductions in aquatic arthropods in sprayed areas following application at relatively low rates (300 g/ha or less) but with populations recovering within a few weeks.

7.2.1 Fish acute toxicity

Static testing with technical fenitrothion indicated moderate toxicity to fish, as tabulated below (Kagoshima *et al*, 1974). Fish exhibited reduced mobility with symptoms persisting through 72 hours of exposure.

Test	Species	Result
48 hour acute	Rainbow trout	LC50 = 3.0 mg/L
48 hour acute	Common carp	LC50 = 4.1 mg/L
48 hour acute	Southern top-mouthed minnow	LC50 = 2.3 mg/L

The tests results submitted are consistent with a much broader range of data compiled by the IPCS (1992) indicating fenitrothion to be moderately toxic to fish with acute LC50s generally between 1 and 10 mg/L.

7.2.2 Fish early life stage toxicity

Continuous exposure of rainbow trout from newly fertilised eggs through 60 days post-hatch to 0.35 mg/L fenitrothion (mean measured) significantly reduced the survival of fry at days 35 and 60 post-hatch. Growth of fry at 60 days was significantly reduced at concentrations of 0.17 and 0.35 mg/L. The no observed effect concentration was 0.088 mg/L (Cohle, 1988).

7.2.3 Fish sublethal effects

Continuous exposure of eels to 0.02 mg/L under flow-through conditions for 96 hours gave rise to alterations in a number of metabolic parameters, such as increased blood glucose and lactate and decreased proteins, indicative of physiological stress. These disorders generally did not persist when eels were returned to clean water for 7 days. Most of the fish survived the exposure, but exhibited reduced motor and sensory activity (Sancho *et al*, 1997).

7.2.4 Toxicity of metabolites to fish

Acute toxicity data for killifish are available for more than 20 of fenitrothion's metabolites, but without any experimental details. All are less toxic than fenitrothion, except for the occasional metabolite 3-methyl-4-aminophenol which is very highly toxic, having a 48 hour LC50 of 0.078 mg/L (Miyamoto, 1977).

Recent studies confirm that fenitrooxon is slightly less toxic than fenitrothion to killifish. Respective 48 hour LC50s from static testing, apparently expressed as nominal concentrations, are 6.8 and 3.5 mg/L (Tsuda *et al*, 1997).

7.2.5 Amphibian acute toxicity

Newly hatched tadpoles (< 48 hours old) of the leopard frog and green frog were killed or paralysed by exposure to nominal concentrations of 4 and 8 mg/L fenitrothion but mostly recovered within a few days. In contrast, tadpoles of the bullfrog were less immediately affected but all became paralysed or were killed within 5 days at a nominal 4 mg/L, and within 2 days at a nominal 8 mg/L (measured 5.5 mg/L). Significant numbers became paralysed after about 4 days of exposure to a nominal 0.5-2 mg/L (measured 0.27-1.3 mg/L) with no evidence of recovery (Berrill *et al*, 1994).

Follow up studies found similar responses in 1 day and 8 day old tadpoles exposed to 2-9 mg/L fenitrothion for 24 hours, and no increase in sensitivity when 8 day old tadpoles were exposed for a second time following initial exposure at 1 day post-hatch (Berrill *et al*, 1995).

7.2.6 Aquatic invertebrate acute toxicity

No test data were originally provided by the registrant in this critical area. A static acute study (Forbis, 1987a) was provided in May 1998, showing a 48 hour LC50 of 8.6 µg/L (mean measured concentrations) to *Daphnia magna*. Sumitomo has also advised the results (48 hour EC50 = 2.3, 4, 11 and 24 µg/L) from four other acute studies with *Daphnia magna* said to have have been reviewed by the US EPA.

The following information is available from a variety of sources.

Field collected specimens of the crayfish *Procambarus clarkii* survived static exposure for 48 hours to a nominal 10 µg/L fenitrothion, albeit with significant inhibition (34% reduction at 2 µg/L) of acetylcholinesterase, but became moribund at a nominal concentration of 50 µg/L (Escartín and Porte, 1996b).

Flow-through testing of Australian native species found the freshwater decapod crustaceans *Paratya australiensis* and *Astacopsis gouldi* to be particularly sensitive. Test organisms were acclimated for 5-10 days before exposure and fed throughout the test. The LC50 (mean measured concentration) for *Paratya australiensis* was about 1 µg/L over 7-10 day exposures, increasing to about 2 µg/L over 4 days. Mortality was complete following 10 days exposure to 5.4 µg/L fenitrothion, or 21 hours to 20 µg/L. The LC50 for *Astacopsis gouldi* was 0.7 µg/L for a 7 day exposure, relaxing to 2.5 µg/L over 4 days (Davies *et al*, 1994).

The APLC reports a 48 hour LC50 of 1.5 µg/L in preliminary testing with *Daphnia obtusa*, but discounts this result as it falls outside the range reported in the literature. More recent testing has reportedly found a 24 hour LC50 of 0.067 µg/L for *Daphnia magna* (see next section) but the result remains to be confirmed.

Further data in this area are taken from the IPCS review.

The 48 hour EC50 for *Daphnia magna* using static procedures was 8.6 µg/L, with a NOEC below 2 µg/L.

Fenitrothion has high acute toxicity to a range of crustaceans and arthropod insects. Sensitive endpoints include a 24 hour LC50 of 0.2-0.5 µg/L for crab megalopa and a 48 hour LC50 of 3.2 µg/L for mayfly larvae. Crab megalopa would be expected to be more sensitive in 48 hour testing.

7.2.7 Aquatic invertebrate reproduction

Survival of *Daphnia magna* through 21 days of static-renewal exposure to fenitrothion was reduced at low concentrations, including the lowest test concentration of 0.009 µg/L, with complete mortality above 0.013 µg/L, occurring within 7 days at the highest test concentration of 0.033 µg/L. These authors had earlier obtained a 24 hour LC50 of 0.067 µg/L, but further details are lacking. This finding needs to be confirmed before it can be used for risk assessment as it is much lower than the previously accepted value of 8.6 µg/L. However, the earlier result is consistent with the observation of complete mortality within 7 days at 0.033 µg/L. Reproductive parameters (size and survivorship of first clutches) were adversely affected above 0.011 µg/L. Procedures followed are well documented and consistent with internationally recognised guidelines. No mortalities occurred in controls, which satisfied criteria for number of young produced, and a clear dose-response is evident. The results reported in the reproductive test appear sound, and are consistent with the reported acute endpoint. However, it may be that the consistency between acute and chronic responses reflects hypersensitivity in the particular laboratory strain used for testing.

Similar testing with rotifers (*Brachionus calyciflorus*) returned a NOEC of 1.0 mg/L and LOEC of 1.6 mg/L based on the intrinsic rate of reproduction. These authors had earlier obtained a 24 hour LC50 of 6.7 mg/L (Ferrando *et al*, 1996).

The IPCS review reports adverse impacts in reproductive testing with *Daphnia magna* at concentrations of 0.23 µg/L and above. The dynamic flow-through study from which this observation derives (Burgess, 1988) was provided by Sumitomo in May 1998. The NOEC was 0.087 mg/L, based on survival through 21 days and fecundity. All daphnids died within 12 days at a mean measured concentration of 0.44 µg/L.

7.2.8 Algal toxicity

No effects on the growth of green algae (*Chlorella vulgaris*) were apparent following static exposure for 7 days to a nominal 100 mg/L fenitrothion. However, average cell volume, dry weight and photosynthetic $^{14}CO_2$ fixation per cell were all increased, and studies with synchronised cells revealed an underlying prolongation of the time for cell division. Effects were reversible on transfer to clean media (Kikuchi *et al*, 1984b).

The reported LD50s for *Chlorella vulgaris*, the diatom *Nitzschia closterium* and the blue-green alga *Anabaena flos-aquae* are > 100, 3.9 and 8.6 mg/L, respectively (Kikuchi *et al*, 1984a).

A more recent static test with *Selenastrum capricornutum* returned a 96 hour EC50 of 1.3 mg/L (mean measured concentrations at initiation and termination of exposure). Affected cells were deformed, having a bloated appearance compared with controls (Forbis, 1987b).

Chlorella vulgaris was the least sensitive of five unicellular green algae tested, with a nominal 96 hour EC50 of 24.4 mg/L based on growth rate as determined by final biomass estimates, compared with 0.8-6.9 mg/L for other species, 1.1 mg/L for a blue-green alga (*Anabaena* sp) and 3.5 mg/L for a diatom (*Navicula* sp). Sensitivity was correlated with cell surface area/volume ratios, cell lipid content, and bioconcentration factors (Kent and Currie, 1995).

The nominal 96 hour EC50 to the freshwater alga *Nannochloris oculata* was 11.9 mg/L based on maximum specific growth rates as determined by cell counts (Ferrando *et al*, 1996).

In general, results indicate fenitrothion to be moderately toxic to green algae, diatoms and blue-green algae.

7.2.9 Aquatic field studies

Little information is available from Australia on aquatic field impacts from fenitrothion. APLC operations require observation of a minimum 1.5 km buffer upwind from water. While it would appear superficially that this should not give rise to conflict, given that the APLC conducts operations across the semi-arid inland, locust outbreaks occur in response to rain and the APLC's first Locust Bulletin for 1998 records several examples of locust bands and swarms that could not be treated because they were congregating along creeks that contained water. Similar problems arose in far NW NSW during the 1997 summer/autumn campaign.

Recovery of 10 dead koonaks from farm dams has been reported from Western Australian operations, but this was a deliberate overspray situation on request from the landholder who wanted to control a locust infestation in green feed immediately around the dams (Crisp, 1992).

The following information is taken from the IPCS review.

Most of the standing crop of benthic arthropods in a Canadian stream were decreased following treatment with an estimated 73 µg/L but populations recovered completely within 50 days.

Aquatic insect populations remained stable in the face of two applications at 140 g/ha, but reductions were apparent in other Canadian studies involving rates of 140-280 g/ha. Mayfly and especially stonefly nymphs appear particularly susceptible.

The maximum concentration in a Scottish river flowing through a forest area sprayed at 300 g/ha was about 19 µg/L, declining to 0.5 µg/L within 24 hours. Invertebrate drift increased 12-16 hours after spraying but returned to normal within 48 hours. Caged insects survived a 5 day post-spray period.

7.3 Non-target Terrestrial Invertebrates

Fenitrothion is toxic to a broad range of non-target invertebrates, as would be expected of an organophosphorous insecticide. Available data are limited, but field observations, including from APLC operations, indicate that repopulation from unexposed areas may be expected to compensate for any mortality.

Toxicity to bees has been demonstrated in laboratory testing and is also manifested in the field, although applications at low rates (280 g/ha) do not appear to exert long-term adverse impacts on populations.

Fenitrothion is extremely toxic to earthworms in laboratory contact testing on filter paper, but the laboratory situation is unrealistic as earthworms live within the soil and generally do not come into contact with surface deposits. Fenitrothion does not appear to cause adverse effects in the field even at higher than normal application rates. In artificial soil tests, fenitrothion is slightly toxic with a 14 day LC50 of 231 mg/kg.

Overseas field studies indicate that canopy insects suffer widespread mortality following application of fenitrothion in forest areas, but longer term effects on populations are not apparent. Preliminary measurements on ground-inhabiting invertebrates found similar outcomes. Similarly, long term population stability in soil dwelling arthropods does not appear to be compromised by surface application of fenitrothion at high rates in New Zealand pasture. Pitfall trapping by the APLC found that populations of major arthropod groups returned to normal within 1-4 months of locust control operations.

Fenitrothion does not appear to adversely affect microbial processes operating in soils.

7.3.1 Bees

Fenitrothion is toxic to honey bees with a contact LD50 of 0.29 µg per bee when applied using vacuum bell-jar duster equipment (Anon, undated).

More recent testing involving topical application in 2 µL acetone to the dorsal surface of the mesoscutum of honey bees found a 48 hour LD50 of 0.17 µg/bee, in the same range as found by others (0.018-0.383 µg/bee). Fenitrothion was also found to be toxic to three other species of bee (Helson *et al*, 1994).

The IPCS review reports that field observations found mortality of adult foraging honey bees, estimated at about 1% of the hive population, following application at 280 g/ha. Mortality rates returned to normal within 4 days and significant long-term effects on colonies were not apparent. Other species appeared more sensitive, with some years elapsed before population recovery was complete.

7.3.2 Earthworms

Fenitrothion, broadcast as granules at 2.24 kg/ha, exerted no deleterious effects on populations of the earthworm *Allolobophora caliginosa* in trial plots of New Zealand pasture (Martin, 1976).

Fenitrothion proved extremely toxic under the artificial conditions of acute contact toxicity testing on filter paper, with LC50s of 1.0 µg/cm^2 for *Dendrobaena octaedra* and 6.9 µg/cm^2

for *Eisenia fetida*. By way of comparison, the APLC rate of 267 g/ha equates to 2.67 µg/cm^2. Survivors of the former species at an exposure of 1.7 µg/cm^2 appeared to recover normally when transferred to uncontaminated leaf litter. This species also survived in 2 cm layers of leaf litter sprayed at 280 g/ha and a 10-fold overdose, but suffered 40% mortality at a 100-fold overdose. In microcosms consisting of 5 cm mineral soil topped with 3 cm humus material and 2 cm leaf litter, there was no evidence for impacts on survival through 35 days even at a 100-fold overdose, consistent with the earlier results from New Zealand (Addison and Holmes, 1995).

Sumitomo has provided the repoprt from an artificial soil test (Ellgehausen *et al*, 1985) that confirms the low toxicity of fenitrothion to earthworms under realistic exposure conditions. The 14 day LC50 was 231 mg/kg, indicative of slight toxicity.

7.3.3 Insects

Information in this area is taken from the IPCS review.

Canadian and North American studies using drop cloths revealed that other defoliating insects apart from the target pest were killed by forest applications (140 or 210 g/ha) including large numbers of *Lepidoptera*, sawfly larvae, balsam twig aphids and perching flies.

Similar impacts have been observed on Canadian ground-dwelling invertebrates, but populations were generally able to recover to normal in subsequent years.

7.3.4 Arthropods

Pitfall trapping at Broken Hill and Hillston (NSW) and Longreach (Qld) over a 3 year period before and after spraying found a reduction in total daily catch per trap in sprayed plots at four of five sites following early spring application at 381 g/ha. The major arthropod groups collected were Collembola, mites, spiders, Coleoptera, Homoptera, Diptera, ants and other Hymenoptera. Recovery to unsprayed levels required four weeks to four months. Catches increased on two of the unsprayed plots at 1 year after application. It was noted that the environmental impact depended on the area sprayed and the order examined, and that much more work would be needed before the full effect of fenitrothion on non-target arthropods could be understood (Carruthers *et al*, 1993).

Fenitrothion, broadcast as granules at 2.24 kg/ha to trial plots of New Zealand pasture in early May, exerted no obvious deleterious effects on all members of any Family of Collembola or Acari, and had no statistically significant effects on overall populations of these arthropods. Immediate effects were not studied; rather, populations were counted at approximate 8 week intervals following application. While widespread impacts were not found, populations of four species of Collembola and three of Acari were reduced by the treatment, and a few mite species had increased their populations by the final sampling in November (Martin, 1978).

7.3.5 Soil microrganisms

A 12 month incubation of forest soil with the equivalent of 112 kg/ha fenitrothion did not alter the population or respiration of the soil microflora (Salonius, 1972).

Fenitrothion at 1 and 5 mg/kg did not significantly affect microbial respiration in soil or inhibit cellulose-degrading microorganisms (Spillner *et al*, undated).

Fenitrothion at 1 and 10 mg/kg did not significantly affect soil respiration and nitrogen transformation in sandy loam soils (Mikami *et al*, 1984d).

7.4 Mammals

The IPCS review reports that fenitrothion has moderate mammalian toxicity with rodent oral LD50s between 330 and 1416 mg/kg.

Field observations reported by the IPCS have not revealed any effects of fenitrothion on wild small mammals at application rates below 420 g/ha.

Sumitomo has advised that there is no reason to believe that Australian native species would be more or less sensitive to fenitrothion than other mammalian species, and reported acute oral LD50s for a number of mammalian species (rat, mouse, guinea pig, dog, cat, cattle, mule deer, sheep, pig) ranging from 142 to 1850 mg/kg, based on unreferenced data sourced from the APLC.

7.5 Phytotoxicity

Aside from the effects on algae, fenitrothion does not appear to have significant phytotoxicity given use on a broad range of crops.

7.6 Summary of Environmental Toxicity

Toxicity tests with fenitrothion have been conducted in the following organisms.

7.6.1 Birds

Reports from acute, dietary and reproductive testing in quail and mallards have been submitted, and laboratory and field information for a large number of species has been obtained from the scientific literature. Fenitrothion is slightly to very highly toxic to birds by acute oral and dietary routes. Quail are sensitive and mallards relatively insensitive. Similar trends are apparent in reproductive testing, with the no observed effect concentration with respect to egg production in quail below 35 ppm, but no statistically significant impacts on reproductive parameters in mallards exposed to 107 ppm in feed. In general, it appears that small birds are more sensitive than larger birds to the toxic effects of fenitrothion.

Adult mortality has been reported from the field at rates above 280 g/ha, increasing markedly at rates above 560 g/ha. Cholinesterase activity is inhibited and mortality of juvenile birds has been reported at lower rates. Songbird impacts are commonly reported. The lower end of this range slightly exceeds the rate generally used by the APLC for control of Australian plague locust, and other rates for locust and grasshopper control fall within it, except for the high rates approved under Permit for control of spur-throated locusts in maize and grain sorghum. In contrast, application rates for control of subterranean pasture pests exceed this range, in some cases being more than double the upper limit.

Available field data from Scotland, Canada and Senegal indicate that a proportion of the bird population will receive a significant exposure to fenitrothion in sprayed areas, and that some birds will die and others suffer sub-lethal effects. Emigration from sprayed areas will also occur in response to a reduction in invertebrate food resources. This is best demonstrated by the detailed study of avian effects of fenitrothion used at relatively high rates for grasshopper control in semi-arid thornbush savannah in Senegal, involving weekly bird counts before and after application, carcass searches, and collection of sick and healthy specimens for cholinesterase analysis. One of the main species affected also occurs widely in Australian locust habitat and may be expected to be routinely exposed to fenitrothion during APLC operations. Sumitomo has advised that it should be clearly stated in this overview of avian toxicity that the rates used in the Senegal study (485 and 825 g/ha) were very much higher than the routine dose (267 g/ha) used by the APLC.

Detailed monitoring of avian effects from APLC operations has yet to occur, although a bird census was commenced in October 1996. Little information is available on avian behaviour during and after control operations, notwithstanding that locust plagues would be expected to attract birds. Only a few avian casualties have been collected, the most notable examples being fifteen dead black kites found dead near control operations in southwestern Queensland in 1992, with high residues (26-92 mg/kg) found in the stomachs of three specimens subjected to analysis.

7.6.2 Aquatic organisms

Acute testing under static conditions with 3 species indicated that fenitrothion has moderate acute toxicity to fish (LC50s between 2.3 and 4.1 mg/L). Published data for a much larger number of species indicates that acute LC50s generally fall in the 1-10 mg/L range. Chronic endpoints are about an order of magnitude more sensitive. The acute sensitivities of fish and tadpoles appear similar, based on studies with 3 frog species. Metabolites appear generally to be less toxic than the parent.

No information was provided by the registrant in the original submission, but information available from other sources indicates that, consistent with its insecticidal activity, fenitrothion is much more toxic to aquatic invertebrates than to fish. Acute endpoints in the low ppb range are typical, with sensitive organisms such as crab megalopa killed at sub-ppb concentrations. The most sensitive organism tested is the cladoceran *Daphnia magna*, with a 24 hour LC50 of 0.067 µg/L reported, but only limited details are available and the result is well below the previously accepted range for this species. Again, chronic effects occur at concentrations an order of magnitude lower, based on reproductive testing in daphnids and rotifers.

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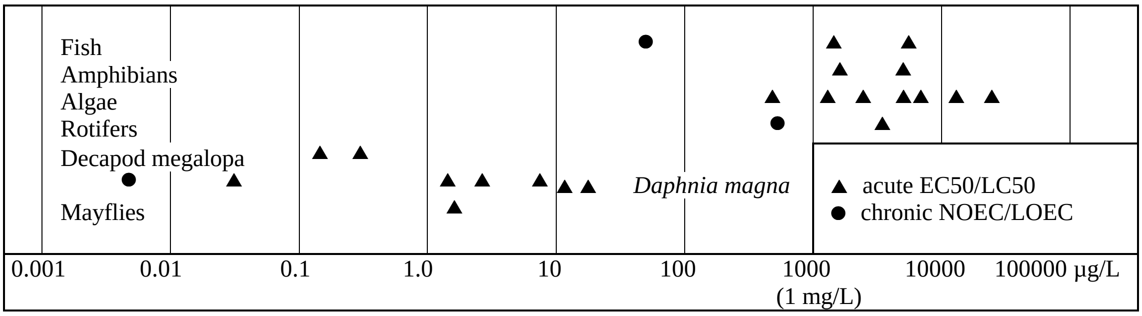

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Fenitrothion does not adversely affect microbial processes operating in soils.

7.6.4 Plants

Aside from the effects on algae, fenitrothion does not appear to have significant phytotoxicity given use on a broad range of crops.

8. PREDICTION OF ENVIRONMENTAL HAZARD

The evaluation of environmental hazard will focus on the insect control uses in cropping and pastoral situations, including use by the APLC. Environmental exposure from structural and storage applications is low, as outlined in section 6.1.2.1, and such uses therefore present low environmental hazard. The one situation where some environmental exposure may be anticipated is the spreading of broiler litter as fertiliser, but simple worst case calculations indicate the hazard to be low. For a conservative stocking rate of 10 birds/m^2, each producing 3.3 kg excreta during 40 days in the broiler house, the estimated fenitrothion residue at the end of a cycle is 0.14 g in 33 kg, or about 4.2 mg/kg. Use of such chicken manure as fertiliser at a heavy rate of 20 tonnes/ha would apply about 80 g/ha fenitrothion, a relatively low rate even if no dissipation occurs before manuring. Fenitrothion would dissipate from the soil during the following crop cycle, and accumulation from repeated manuring is not expected. Accordingly, release to farmland of fenitrothion residues in broiler litter is not expected to lead to significant environmental contamination or impact.

The approach used below is essentially that of the US EPA and involves determining the ratio of concentration to toxicity, a parameter generally known as the risk quotient (Q). According to methodology used by the US EPA for its reregistration program (US EPA, 1994) a Q of less than 0.2 (for terrestrial species) or 0.1 (for aquatic species) indicates that acute risk is minimal and no further assessment is needed. A potential acute risk is indicated where Q falls above this threshold but below 0.5, but may be mitigated by restricted use classification. Higher Q values indicate high acute risk and possible regulatory action. The risk quotient is an essentially qualitative parameter rather than a highly quantitative measure of ecological risk, particularly as exposure and environmental fate are currently excluded from its derivation. Environmental concentrations used to derive the risk quotient are simply estimated from the application rate.

8.1 Terrestrial hazard

Birds and terrestrial insects are sensitive to fenitrothion. Hazard to these organisms is evaluated below.

8.1.1 Birds

Maximum residues following spraying may be estimated using the updated Kenaga nomogram (Fletcher *et al*, 1994). For APLC operations against Australian Plague Locusts, the lower rate (270 g/ha) would leave predicted maximum residues of 60 ppm on short range grass, and the higher rate (380 g/ha) used in more heavily vegetated situations would leave residues of 40 ppm on long grass. These residues are consistent with measured residues on grass generally in the 5-50 ppm range, which in turn approaches the dietary LC50 for sensitive species. Higher residues may be encountered as drift spraying as practiced by the APLC leaves uneven deposits on the ground.

As an approximation, residues on locusts may be estimated using the fruits and seed pods category of the above nomogram, at 3.6-5.1 ppm for APLC operations, consistent with measured residues in *Chortoicetes terminifera* nymphs and adults of 0.2-7.4 ppm.

Comparison of the dietary LC50 of 126 ppm in bobwhite quail with the above estimates indicates that risk may be significant for sensitive birds that feed on sprayed vegetation, but that residues in locusts should be below levels of concern.

Sumitomo has noted that the pasture residues of 37 ppm following treatment at 280 g/ha would offer a safety factor of 3 based on the dietary LC50 in bobwhite quail. This conclusion is misleading. The US EPA's risk quotient approach finds no such safety factor, but rather a potential acute risk as Q approaches 0.3. Furthermore, white-throated sparrows (see section 7.1.1.2) have been shown to be more acutely sensitive to fenitrothion than the standard test organism used in this analysis, bobwhite quail.

Sumitomo also suggests that the seed pods category of the updated Kenaga nomogram would better represent the locusts that are likely to be consumed by birds, and that residues from a 280 g/ha application would be about 1 ppm. It appears that Sumitomo has misinterpreted the nomogram, which predicts residues of 3.8 ppm. However, Sumitomo's conclusion that risk from consumption of contaminated insects appears minimal, based on the risk quotient approach, remains valid.

In contradiction to the above analysis, the only incidents reported in Australia appear to have involved consumption of contaminated locusts, probably because insectivores are attracted to locust plagues. Heavy levels of contamination (approaching 100 ppm in one bird) are apparent from analysis of stomach contents for black kites.

Field evidence indicates fenitrothion to be hazardous to birds, particularly when applied at higher rates. Bird impacts at higher application rates (485 and 825 g/ha) have been clearly demonstrated by the Senegal study (section 7.1.1.4) which is by far the most comprehensive conducted to date.

Pathways of exposure are not well understood, as exemplified by the inexplicably high residues in stomach contents for black kites found poisoned by fenitrothion contaminated locusts. Sumitomo contends that no weight should be attached to these observations because of their anecdotal nature, but it is considered that such incidents can not be ignored unless there are sound reasons to discount them.

Insectivorous bird exposure is difficult to assess because residues enter insects through a variety of routes such as inhalation, contact and ingestion, and insects will move through areas of high and low exposure. Others have noted that the unevenness of localised insecticide deposits may account for much of the variability in biological response that is observed in the field (Ernst *et al*, 1989). Some locusts will receive a larger dose than others, and it may be that these would be eaten preferentially by scavenging birds as they would be the first to succumb to intoxication. A further consideration with phosphorothioate compounds such as fenitrothion is that metabolic activation to the oxon form may greatly increase the avian toxicity of residues in locusts.

Birds will also be exposed through a variety of routes apart from feeding, although that would not explain the high residues reported in the stomachs of black kites. Dermal and respiratory uptake have been shown to be important, the latter being the the major route of exposure for parathion methyl at 1 hour post-spray (Driver *et al*, 1991). These routes would be particularly relevant to species that may stay put during spraying, such as ground nesters or birds that rely on being cryptic for survival.

One such species, the Plains-wanderer (*Pedionomus torquatus*), lives in areas of sparse native grassland and similar vegetation where control operations against Australian plague locust may be carried out. Its conservation status is vulnerable. There is a recognised risk that exposure to fenitrothion may kill these birds, but the necessary research to confirm or deny this has not been conducted. The Royal Australian Ornithologists Union (now Birds Australia) identified an urgent need for such research some years ago, recommending that, pending its completion, any locust control operations to be carried out in known Plains-wanderer habitat should eschew aircraft in favour of ground based application with a maximum speed of 15 kph that provide opportunity for birds to avoid spray exposure (Baker-Gabb, 1993).

Plains-wanderer populations vary with seasonal conditions and can recover quickly from low population levels following droughts and fires, but it remains the case that little is known about the impact of fenitrothion. Birds Australia has recently repeated its recommendation that the impact of fenitrothion on ground-dwelling animals be studied because of periodic aerial application for plague locust control within a large proportion of Plains-wanderer habitat at rates that could kill birds (Baker-Gabb, 1998). Plains-wanderers are known to be reluctant to flush during daylight, meaning that risks would not necessarily be reduced by ground based application, and this is no longer recommended.

A recovery plan has been developed for the Plains-wanderer, which is listed as vulnerable, but has yet to be implemented because of higher conservation priorities. The main threats identified are habitat clearance for agriculture and overgrazing by stock and rabbits, with locust spraying a suspected additional factor. One of the objectives of the recovery plan is to shed more light on this latter question (Garnett, 1992).

Application rates against other locust species are higher, and non-target risks can be expected to be correspondingly higher than for Australian Plague Locust control operations. Landholder operations are also riskier as application rates are higher and restrictions fewer. Application rates remain generally below the threshold of 560 g/ha above which marked increases in avian mortality have been reported, but there is clearly scope for reducing risks by reducing application rates and tolerating greater delays before locust mortality occurs.

The foregoing analysis of avian impacts from fenitrothion operations considers only the immediate effects of exposure to the toxicant. Less obvious avian impacts are also likely, as illustrated by the Senegal study, because locust spraying effectively denies valuable invertebrate food resources to birds and forces them to forage elsewhere.

For insect control in southern pastures during winter, the short range grass category would seem most appropriate for estimating residues. Maximum predicted residues may range from 110 ppm for control of cockchafers (500 g/ha) though 170 ppm for control of underground grass grub (800 g/ha) to 280 ppm for control of oxycanus grass grub or winter corbie (1300 g/ha). Predicted residues on vegetation are sufficiently high to represent a significant toxic hazard to birds. Marked increases in avian mortality that occur when application rates in forestry exceed about 560 g/ha support the conclusion that use of fenitrothion for insect control in southern pastures presents a high risk to birds. Only very limited information has been provided on this use pattern, and it appears that no avian monitoring has been conducted.

8.1.2 Mammals

APLC operations are also likely to expose native mammals such as fat-tailed dunnarts to residues of fenitrothion. This carnivorous marsupial, widespread in southern Australia, feeds on a broad range of insects and other invertebrates and forages in bare open areas (Strahan, 1983). The toxicity of fenitrothion to native mammals is not known and would be difficult to determine given legislative restrictions against testing on native vertebrates. Impacts on small native mammals must therefore be determined by field studies, and the work planned in this area by the APLC will provide valuable information.

Sumitomo considers that mammals should not be at risk from locust treatments at 280-350 g/ha, based on the reasonable argument that mammals tend to be significantly more tolerant than birds to fenitrothion, but agrees that a final analysis should await the outcomes of the APLC monitoring program, and has offered to cooperate with the APLC in planning the program and assessing mammalian impact.

8.1.3 Insects

Insecticides used to control locusts inevitably exert effects on other insects that are exposed, and this has been demonstrated in overseas field trials. Longer term observations indicate that populations of ground dwelling invertebrates and soil arthropods are generally able to recover from fenitrothion exposure. The APLC regards fenitrothion as relatively "soft" on non-target insects, based largely on field observations rather than detailed analysis. Local pitfall trapping studies are consistent with overseas findings in confirming that populations of major arthropod groups return to normal within 1-4 months of spraying for locust control. Thus, while insects in target areas will be affected, hazard to non-target insect populations appears relatively low when fenitrothion is applied by the APLC for locust control. Repeat treatments are unlikely, and only relatively small areas are treated. Similar conclusions can not be drawn concerning the use on Tasmanian pasture as little information is available, and application rates are high.

8.1.4 Reptiles

In responding to an early draft of this report, the APLC noted that effects on reptiles had received little attention. Only limited information is available on the susceptibility of reptiles to insecticides. Dead lizards have reportedly been found in Mauritania after locust spraying with chlorpyrifos at 240 g/ha (Lambert, 1997).

The limited information available indicates that reptiles may become intoxicated by fenitrothion used for locust control. Observations by APLC personnel may help clarify whether reptile impacts are likely to attend locust control operations. There may also be scope to investigate levels of reptile exposure as lizards have been proposed as ideal indicator organisms to assess organophosphate exposure in the Canary Islands, using nondestructive sampling techniques (Sanchez *et al*, 1997).

8.1.5 Alternative insecticides

The APLC has conducted limited trials with the synthetic pyrethroid deltamethrin applied at 10 and 12.5 g/ha. While control of locust bands was good, and pyrethroid insecticides would not be expected to present a significant hazard to birds, these trials were discontinued because of concerns for the high rate of mortality observed in ground dwelling invertebrates. Synthetic pyrethroids tend to stimulate highly visible invertebrate responses.

Trials with chlorpyrifos found that rates of 75-105 g/ha provided insufficient residual activity, and that rates of 165 g/ha gave unsatisfactory control of swarms. These rates are considerably lower than currently registered rates of chlorpyrifos for locust control.

8.2 Aquatic hazard

The exposure route of primary concern with respect to aquatic contamination is spray drift. Direct overspray of water bodies is not expected, although there are no specific label restraints against this. The APLC operates mainly in arid regions and requires a minimum downwind buffer of 1.5 km for sensitive areas such as water bodies, to be increased when winds exceed 5 m/s. Original decisions concerning the size of the buffer zone do not appear to have been supported by any data, but recent work using the FSCBG model predicts residues in the order of 0.16, 0.3 and 0.6 µg/L in 15 cm water at 2000, 1500 and 1000 m downwind, respectively, from application at 292 g/ha.

As a worst case scenario, drift of 10% will be assumed. Estimated environmental concentrations (EECs) in 15 cm standing water contaminated through drift equivalent to 10% of applied are 18-26 µg/L for APLC operations (270-380 g/ha) increasing to 20-38 µg/L for locusts and wingless grasshopper in cropping situations (300-550 g/ha) and 34-52 µg/L for higher rate uses (510-770 g/ha) approved under permit for control of spur throated locust in maize and sorghum.

For winter uses in southern pastures, aquatic contamination of 33-87 µg/L may be predicted based on drift of 10% from the rates used (500-1300 g/ha).

Given limited persistence and infrequent application, it is appropriate to assess the hazard of fenitrothion based on its acute toxicity.

The ratio of concentration to toxicity is generally known as Q (for quotient). According to methodology used by the US EPA for its reregistration program (US EPA, 1994) a Q of less than 0.1 indicates that risk to aquatic organisms is minimal. A potential acute risk is indicated where Q falls between 0.1 and 0.5, but may be mitigated by restricted use classification. Higher Q values indicate high acute risk and a need for further use restrictions or special review.

Predicted concentrations are consistently below 100 µg/L, while acute endpoints for fish and tadpoles are above 1 mg/L. Risk to these organisms from use of fenitrothion would appear to be minimal.

Acute endpoints for aquatic invertebrates are much lower than predicted concentrations. For example, acute LC50s of 0.067 µg/L have been recorded for *Daphnia magna*, 0.2-0.5 µg/L for crab megalopa, and 3.2 µg/L for mayfly larvae. Full experimental details are not available for the daphnid result, which is an extreme outlier that can not be used for risk assessment. Original studies from which the crab data were derived have not been sighted, but the data are reported in a respected international review (IPCS, 1992). Preliminary local testing with daphnids has found acute toxicity at 1.5 µg/L. It would seem appropriate for protection of most aquatic life to assess hazard against an effects concentration of 1 µg/L. Values for Q estimated on this basis are tabulated below, assuming drift of 10 or 1% or predictions from the FSCBG model.

Situation	Rate (g/ha)	Drift (%)	EEC (µg/L)	Q (1 µg/L)
Pasture	500	10 1	33.3 3.3	33.3 3.3
	800	10 1	53.4 5.3	53.4 5.3
	1300	10 1	86.6 8.7	86.6 8.7
Plague locust	325-510	10 1	21.6-34.0 2.2-3.4	21.6-34.0 2.2-3.4
Wingless grasshopper	300-320	10 1	20.0-20.7 2.0-2.1	20.0-20.7 2.0-2.1
Migratory & spur-throated	380-550	10 1	25.7-36.7 2.6-3.7	25.7-36.7 2.6-3.7
APLC (FSCBG predictions)	292	0.08 0.15 0.31	0.16 (2000 m) 0.3 (1500 m) 0.6 (1000 m)	0.16 0.3 0.6
	380	0.15	0.4 (1500 m)	0.4
	550	0.15	0.6 (1500 m)	0.6

It is clear from the above table that standard evaluation procedures based on acute toxicity of 1 µg/L predict high acute risk for all situations except APLC operations, even if off target movement is restricted to 1%. For control of subterranean pasture pests, significant off-target movement is likely to occur with runoff from heavy winter rains, particularly in the case of blackheaded pasture cockchafer where applications are timed for when rain is imminent.

Sumitomo contends that risk should be assessed against an endpoint of 8.6 µg/L as reported in the acute daphnid study of Forbis (1987a). It is not considered that assessment against an endpoint of 8.6 µg/L to be valid as data are available to indicate that other aquatic invertebrates are more sensitive, with acute endpoints in some cases below 1 µg/L. Even for *Daphnia magna*, 48 hour EC50s in studies reviewed by the US EPA reach as low as 2.3 µg/L (see section 7.1.2.6). Risk is more appropriately assessed against an acute toxicity endpoint of 1 µg/L at this time. A more demanding endpoint (*Daphnia magna*, 48 hour EC50 = 0.067 µg/L) has been published, but represents an extreme outlier from the main body of data and would need to be confirmed before it could be used for risk assessment.

Risk is reduced in APLC operations because of the large buffer observed upwind of waterbodies. Based on an assessment endpoint of 1 µg/L that is expected to protect most aquatic species, predictions from the FSCBG model for a wind speed of 3 m/s indicate that high acute risk would arise when controlling Australian plague locust if the buffer were relaxed to 1 km, but that risk remains within acceptable bounds for buffers of 1.5 km or more, given the restrictions that apply to APLC operations. For spur-throated locusts, high acute risk is predicted at the upper rate of 550 g/ha, but the quotient is only slightly above the high risk threshold of 0.5, and the conditions under which this higher rate is used (dense vegetation) would be expected to be less conducive to drift of spray off-target.

Field observations confirm the above analysis, with no incidents reported for fish, but major reductions in aquatic arthropod populations following spraying (see section 7.1.2.9). It may be noted, however, that populations generally recover within a few weeks of acute exposures.

By way of comparison, the Canadian review (Agriculture Canada, 1995) used data from large, single-engined spray planes to calculate buffers to protect aquatic life in shallow ponds (15 cm deep). The droplet size is not specified. For a spray block 1.34 km wide (10 swaths) a buffer of 300 m would be needed before residues were reduced below 8.6 µg/L, the 48 hour LC50 for *Daphnia magna* as determined by Sumitomo. No assessment factor was applied to the endpoint used as the rapid dissipation of fenitrothion from water was considered to offer a sufficiently protective safety margin for resident fauna. The largest buffer considered, 800 m, reduced the predicted concentration to 3.8 µg/L, significantly higher than the concentration of 0.6 µg/L predicted at 1000 m downwind of ULV applications by the APLC using the FSCBG model. Note that even the 800 m buffer would be insufficiently protective if assessed against a toxic endpoint of 1 µg/L. Naturally, if the more toxic endpoint of 0.067 µg/L is confirmed, the assessed hazard will be higher.

Landholders may use a variety of equipment to defend their crops from locust attack, but most such applications would use low boom spray or misters. Sumitomo has provided the following estimates of environmental exposure based on the AgDRIFT® model developed for use by the US EPA. The estimates are for a pond or stream 60 m (208 feet) wide with an average depth of 15 cm (6 inches) or 2 m (6 feet) situated with the near edge 30 m (100 feet) downwind from the site of application. Deposition is integrated across the water body to provide an estimated average concentration.

Mean deposition across the water body and estimated concentrations are tabulated below for low boom, mister and medium particle size aerial applications. The aerial treatment is included, but is more likely to be used by State authorities rather than landholders. Two values are specified for each entry, the lower based on an application rate of 280 g/ha and the higher on a rate of 350 g/ha. Estimated concentrations have the same magnitude as the risk quotient based on an assessment endpoint of 1 µg/L.

	Low boom	**Mister**	**Aerial**
Mean deposition (g/ha)	1.0/1.2	3.1/3.9	19.1/23.8
Concentration 15 cm (µg/L)	0.65/0.81	2.00/2.57	12.5/15.6
Concentration 2 m (µg/L)	0.054/0.067	0.15/0.21	0.95/1.19

The estimates provided by Sumitomo indicate that use of boom sprays and misters by landholders presents minimal risk to aquatic life inhabiting deeper waterbodies, provided a 30 m buffer is observed. However, high acute risk is predicted in shallow water, based on an assessment endpoint of 1 µg/L.

The AgDRIFT® model has been used to predict the buffer widths needed to reduce estimated concentrations in 15 cm water from application at 280 g/ha to 0.5 µg/L. Boom spray treatments should observe a downwind buffer of 50 m, and mister applications a buffer of 100 m. Buffer zones are a natural consequence of the use pattern where misters are used to target locusts within the crop, as the crop will be immediately downwind of application. It can be argued that similar buffers would be suitable for the higher rate treatments (350 g/ha) used against spur-throated locusts, as these are targetted in areas of heavier vegetation which will reduce drift.

The model is unable to estimate a buffer distance for medium particle size aerial applications, representing EC treatments as may be used by State authorities, or by landholders in situations such as the outbreak of spur-throated locusts in Queensland during the 1995-96 season. Until such a buffer can be established, a minimum downwind buffer of 300 m, as adopted by Canada, would seem appropriate.

Based on results from the AgDRIFT® model, Sumitomo originally proposed removal from the labels of all uses except locust control. Application rates would be reduced to a maximum of 280 g/ha except for spur-throated locusts, for which a higher rate of 350 g/ha would be retained. Buffer zones would be recommended to protect water bodies downwind of spraying. Sumitomo did not wish to commit itself to any specific mitigation measures until it had discussed the issues with stakeholders. Evaluation trials would also be necessary to confirm that the lower rates would be efficacious.

Sumitomo has since revised its position, based on discussions with the APLC and more detailed consideration of the issues raised. Rate ranges of 270-508 g/ha (ULV) and 300-500 g/ha (EC) for locust/grasshopper control are supported by Sumitomo. In respect of the higher rate uses against pasture grubs, Sumitomo accepts the need to reduce rates, but is concerned that lack of efficacy at lower rates may incur liabilities. Sumitomo has indicated that these uses will be retained on labels for EC products but that it will not be directly supporting them. Other registrants will be responsible for meeting the requirements necessary to enable such retention.

9. CONCLUSIONS

Fenitrothion is used to control insect pests in structures and stored grain, soil insects in pasture in temperate southern regions, and insects (predominantly locusts) in summer cropping and pastoral situations, including arid regions of Queensland, NSW and SA where the APLC conducts control operations. Field applications of fenitrothion generate widespread environmental exposure, with residues persisting in soils for some weeks but dissipating from aquatic systems with half-lives of less than a day.

Reliable information on volumes of fenitrothion used in Australia is not available, apart from the well defined APLC operations. It is difficult to conduct an environmental assessment of fenitrothion, or for that matter any other chemical, while the extent of its use remains uncertain.

Overseas, fenitrothion has been implicated in avian mortality incidents, and some bird deaths have been reported in Australia. Avian risk is particularly notable at higher application rates (above 560 g/ha) and such rates are applied in Australia, albeit not by the APLC.

Simple calculations indicate that mortality of fish or tadpoles is unlikely provided that drift to waterbodies is restricted to less than 10% of applied. However, high risk is apparent to aquatic invertebrates, particularly crustacea and insect larvae. Overseas observations are that such organisms suffer acute impact from fenitrothion exposures but that populations generally recover within a few weeks. Locally, the APLC has established procedures to ensure that drift to waterways is minimised, but no such restrictions apply to private users, who also apply higher rates.

Fenitrothion is used in response to insect outbreaks. Retreatment of a particular area is unlikely to occur where locusts and grasshoppers are the target pest, but the frequency of treatment for subterranean pasture pests is unclear. As fenitrothion does not persist in the environment, chronic impacts on non-target organisms from locust and grasshopper control are unlikely, and populations of organisms with high reproductive capacity such as invertebrates are generally able to recover from acute insults.

However, acute impacts on non-target organisms are undesirable even in the absence of longer term environmental harm, and alternative control measures that do not elicit such adverse effects need to be actively investigated. A particular problem for the APLC is that large buffer zones need to be observed around sensitive areas such as water bodies and organic farms because of the application method, drift spraying from aircraft. The use of ULV formulations has advantages in remote arid regions where water may be in short supply, but is disadvantageous in less remote pastoral country where sensitive areas are more frequently encountered and access to spray may be denied.

Even in the arid areas, the presence of surface water during control operations may not be unusual given that locust populations increase after rain. State legislation makes it an offence to contaminate waters, which are broadly defined. For example, the NSW Clean Waters Act prohibits pollution of any area where the polluting material "is likely to fall, descend, be washed, be blown or percolate into any waters, on to the dry bed of any waters, or into any drain, channel or gutter used or designed to receive or pass rainwater, floodwater or any water that is not polluted". Greater flexibility in application methods, in particular placement spraying using EC formulations of fenitrothion which are less prone to drift, may help avoid such legislative restrictions.

Apart from increased flexibility in the use of fenitrothion, benefits may also accrue from greater flexibility in the control agents used. For example, the fungal pathogen *Metarhizium flavoride*, while not providing the quick knockdown desired by many landholders, may be acceptable to organic producers.

Fenitrothion has undesirably high acute non-target toxicities (birds and aquatic invertebrates) that militate against its use in cropping and pasture situations, particularly where such use requires higher application rates. The use of fenitrothion has been reviewed in Canada because of environmental concerns, with the registrant agreeing to some use patterns being phased out and maximum rates for outdoor application restricted to 210 g/ha. Similarly, ecological concerns were raised during the US EPA's reregistration of fenitrothion. Only limited outdoor uses were retained, with a maximum rate for single applications of 350 g/ha. Remaining high rate uses in Australia are difficult to defend based on the hazards assessed in this report, and on the overseas actions that have been taken.

Fenitrothion remains the chemical of choice for control of Australian plague locusts, as alternative organophosphate and pyrethroid insecticides do not match its performance and some appear to give rise to excessive non-target mortality. However, alternative insecticides are emerging that appear to offer good control at low application rates while at the same time appearing to present relatively low risk to birds and aquatic organisms. Risks to terrestrial invertebrates may be more significant, and need to be investigated. Investigation into such alternatives needs to receive high priority so that alternative control options to the use of fenitrothion become available. Further work also needs to be conducted to better define the environmental impacts of fenitrothion as used by the APLC, to allow meaningful comparisons with newer insecticides as they become available. A critical area for investigation is avian behaviour during locust plagues and control operations, particularly whether birds feed on sprayed locusts. The APLC has previously undertaken to update Target Control Sheets to encourage reporting of such observations, and this undertaking needs to be followed through.

This assessment predicts higher acute risk when fenitrothion is used by landholders rather than by the APLC, adding extra urgency to the quest for more environmentally benign methods for locust control. Risk appears from the high rates of application to be particularly high for the winter uses in southern pastures. Information provided on this use pattern is very limited.

In summary, the following general conclusions have been reached:

- environmental exposure from use of fenitrothion in structural and storage applications is minimal.

- only limited information is available regarding use of fenitrothion to control subterranean pests of pasture. Application rates are high, and application at such high rates has been phased out in the USA and Canada, primarily because of risks to birds and aquatic invertebrates. Label instructions to spray just before rain for one pasture pest would appear to exacerbate risks of aquatic contamination. Further information is needed to clarify the risks to birds and aquatic invertebrates before these high rate uses can be considered.

- control of locusts and grasshoppers by landholders and local authorities is not subject to the same level of control, coordination and scrutiny as APLC operations. Ideally application rates for use by landholders could be reduced to align with those found effective by the APLC. Some of these activities could be conducted on a more professional basis by an organisation such as the APLC but with a wider range of locust control options than the current focus on wide swath ULV spraying of fenitrothion.

Subject to consultation with user groups, Sumitomo originally proposed to reduce risks by deleting all uses except locust control from labels, and to reduce rates to a maximum of 280 g/ha, apart from spur-throated locusts for which a higher rate of 350 g/ha would be retained. Buffer zones would be recommended to protect downwind water bodies. As outlined earlier in this report, a restricted use pattern can be supported, provided that minimum downwind buffers of 50 m are observed for boom sprays, 100 m for misters, and 300 m for aerial applications of EC formulations. A buffer of 1.5 km should be observed upwind of water bodies for the ULV formulation.

Sumitomo has since indicated that higher application rates up to 510 g/ha may be necessary for locust/grasshopper control in some circumstances. These rates can be supported for this use pattern, provided that rates for EC fomulations in excess of 350 g/ha are applied by ground based equipment only, and that a minimum buffer of 100 m is observed upwind of water bodies. A buffer of 1.5 km should be observed upwind of water bodies for the ULV formulation.

The following specific conclusions relating to use of fenitrothion by the APLC and State authorities have been reached:

- the APLC has conducted considerable research into the environmental effects of fenitrothion, particularly when compared with other users, but a number of uncertainties remain that need to be addressed, as discussed below;

- recent field work in which similar kill rates were obtained with low and high residue samples, including aged deposits, indicates that application rates for Australian Plague Locust can be reduced well below 270 g/ha. The APLC is researching the feasibility of further reducing rates, taking advantage of the further economies conferred by use of DGPS equipment in spray aircraft to ensure accuracy of application;

- the toxicity of fenitrothion to native mammals is not known and would be difficult to determine given legislative restrictions against testing on native vertebrates. Impacts on small native mammals can therefore only be determined by field studies, and the work planned in this area by the APLC will provide valuable information;

- the APLC is conducting further research into alternative insecticides, such as alternative synthetic insecticides and the fungal pathogen *Metarhizium flavoviride*, and alternative application methods to the currently favoured wide swath drift spraying, such as placement spraying using larger droplets, with a view to diversifying its techniques and improving operational flexibility as well as reducing the risk of spray drift reaching natural waters;

- based on overseas field studies, incident reports and regulatory action, use of fenitrothion by the APLC appears unlikely to incur widespread avian mortality, but there is considerable uncertainty about the actual level of impact. Some birds are likely to be affected, and particular concerns have been expressed for the Plains-wanderer. The level of impact on such species is difficult to determine, adding urgency to the search for alternative insecticides with a more benign avian profile;

- the APLC is improving the information base on the environmental impact of its use of fenitrothion. Information on avian behaviour during control operations, for example whether birds feed on dead or dying locusts, is fundamental to defining exposure. Operational staff could be encouraged to observe and report the behaviour of birds, for example through inclusion of specific questions on the Target Control Sheet as previously undertaken by the APLC;

- given the relatively low level of specialist avian expertise within the APLC, consideration could be given to engaging a professional with experience in this area, particularly for smaller and less conspicuous species; and

- standard evaluation procedures using an assessment endpoint of 1 µg/L indicate that use of fenitrothion by the APLC and State authorities presents a potential acute risk to aquatic organisms, but that the risk is sufficiently small to be mitigated by the buffer restriction of 1.5 km observed by the APLC upwind of waterbodies, and by less restrictive buffers for ground based and EC treatments. The outcome is less favourable if risk is assessed against the recently published 48 hour EC50 of 0.067 µg/L for *Daphnia magna*. However, this lower figure can not be used for risk assessment at this time as it can not be confirmed. Details of testing are lacking, and the result falls well below those accepted to date.

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