Residue
Reviews

Residues of Pesticides
and Other Contaminants in the
Total Environment

Volume 68

RESIDUE REVIEWS

Residues of Pesticides and Other
Contaminants in the Total Environment

Editor
FRANCIS A. GUNTHER

Assistant Editor
JANE DAVIES GUNTHER

Riverside, California

VOLUME 68

SPRINGER-VERLAG
NEW YORK   HEIDELBERG   BERLIN
1977

Coordinating Board of Editors

Foreword

Worldwide concern in scientific, industrial, and governmental communities over traces of toxic chemicals in foodstuffs and in both abiotic and biotic environments has justified the present triumvirate of specialized publications in this field: comprehensive reviews, rapidly published progress reports, and archival documentations. These three publications are integrated and scheduled to provide in international communication the coherency essential for nonduplicative and current progress in a field as dynamic and complex as environmental contamination and toxicology. Until now there has been no journal or other publication series reserved exclusively for the diversified literature on "toxic" chemicals in our foods, our feeds, our geographical surroundings, our domestic animals, our wildlife, and ourselves. Around the world immense efforts and many talents have been mobilized to technical and other evaluations of natures, locales, magnitudes, fates, and toxicology of the persisting residues of these chemicals loosed upon the world. Among the sequelae of this broad new emphasis has been an inescapable need for an articulated set of authoritative publications where one could expect to find the latest important world literature produced by this emerging area of science together with documentation of pertinent ancillary legislation.

The research director and the legislative or administrative advisor do not have the time even to scan the large number of technical publications that might contain articles important to current responsibility; these individuals need the background provided by detailed reviews plus an assured awareness of newly developing information, all with minimum time for literature searching. Similarly, the scientist assigned or attracted to a new problem has the requirements of gleaning all literature pertinent to his task, publishing quickly new developments or important new experimental details to inform others of findings that might alter their own efforts, and eventually publishing all his supporting data and conclusions for archival purposes.

The end result of this concern over these chores and responsibilities and with uniform, encompassing, and timely publication outlets in the field of environmental contamination and toxicology is the Springer-Verlag (Heidelberg and New York) triumvirate:

Residue Reviews (vol. 1 in 1962) for basically detailed review articles concerned with any aspects of residues of pesticides and other chemical contaminants in the total environment, including toxicological considerations and consequences.

Bulletin of Environmental Contamination and Toxicology (vol. 1 in
1966) for rapid publication of short reports of significant advances
and discoveries in the fields of air, soil, water, and food contami-
nation and pollution as well as methodology and other disciplines
concerned with the introduction, presence, and effects of toxicants
in the total environment.

Archives of Environmental Contamination and Toxicology (vol. 1 in
1973) for important complete articles emphasizing and describing
original experimental or theoretical research work pertaining to the
scientific aspects of chemical contaminants in the environment.

Manuscripts for *Residue Reviews* and the *Archives* are in identical
formats and are subject to review, by workers in the field, for adequacy
and value; manuscripts for the *Bulletin* are not reviewed and are published
by photo-offset to provide the latest results without delay. The individual
editors of these three publications comprise the Joint Coordinating Board
of Editors with referral within the Board of manuscripts submitted to one
publication but deemed by major emphasis or length more suitable for
one of the others.

Coordinating Board of Editors

Preface

That residues of pesticide and other contaminants in the total environment are of concern to everyone everywhere is attested by the reception accorded previous volumes of "Residue Reviews" and by the gratifying enthusiasm, sincerity, and efforts shown by all the individuals from whom manuscripts have been solicited. Despite much propaganda to the contrary, there can never be any serious question that pest-control chemicals and food-additive chemicals are essential to adequate food production, manufacture, marketing, and storage, yet without continuing surveillance and intelligent control some of those that persist in our foodstuffs could at times conceivably endanger the public health. Ensuring safety-in-use of these many chemicals is a dynamic challenge, for established ones are continually being displaced by newly developed ones more acceptable to food technologists, pharmacologists, toxicologists, and changing pest-control requirements in progressive food-producing economies.

These matters are of genuine concern to increasing numbers of governmental agencies and legislative bodies around the world, for some of these chemicals have resulted in a few mishaps from improper use. Adequate safety-in-use evaluations of any of these chemicals persisting into our foodstuffs are not simple matters, and they incorporate the considered judgments of many individuals highly trained in a variety of complex biological, chemical, food technological, medical, pharmacological, and toxicological disciplines.

It is hoped that "Residue Reviews" will continue to serve as an integrating factor both in focusing attention upon those many residue matters requiring further attention and in collating for variously trained readers present knowledge in specific important areas of residue and related endeavors involved with other chemical contaminants in the total environment. The contents of this and previous volumes of "Residue Reviews" illustrate these objectives. Since manuscripts are published in the order in which they are received in final form, it may seem that some important aspects of residue analytical chemistry, biochemistry, human and animal medicine, legislation, pharmacology, physiology, regulation, and toxicology are being neglected; to the contrary, these apparent omissions are recognized, and some pertinent manuscripts are in preparation. However, the field is so large and the interests in it are so varied that the editors and the Advisory Board earnestly solicit suggestions of topics and authors to help make this international book-series even more useful and informative.

"Residue Reviews" attempts to provide concise, critical reviews of timely advances, philosophy, and significant areas of accomplished or needed endeavor in the total field of residues of these and other foreign chemicals in any segment of the environment. These reviews are either general or specific, but properly they may lie in the domains of analytical chemistry and its methodology, biochemistry, human and animal medicine, legislation, pharmacology, physiology, regulation, and toxicology; certain affairs in the realm of food technology concerned specifically with pesticide and other food-additive problems are also appropriate subject matter. The justification for the preparation of any review for this book-series is that it deals with some aspect of the many real problems arising from the presence of any "foreign" chemicals in our surroundings. Thus, manuscripts may encompass those matters, in any country, which are involved in allowing pesticide and other plant-protecting chemicals to be used safely in producing, storing, and shipping crops. Added plant or animal pest-control chemicals or their metabolites that may persist into meat and other edible animal products (milk and milk products, eggs, etc.) are also residues and are within this scope. The so-called food additives (substances deliberately added to foods for flavor, odor, appearance, etc., as well as those inadvertently added during manufacture, packaging, distribution, storage, etc.) are also considered suitable review material. In addition, contaminant chemicals added in any manner to air, water, soil or plant or animal life are within this purview and these objectives.

Manuscripts are normally contributed by invitation but suggested topics are welcome. Preliminary communication with the editors is necessary before volunteered reviews are submitted in manuscript form.

Department of Entomology   F.A.G.
University of California   J.D.G.
Riverside, California
August 17, 1977

Table of Contents

Dispersal and toxicology of the insecticide fenitrothion; predicting hazards of forest spraying

By

P. E. K. Symons[*]

Contents

I. Introduction

The organophosphate insecticide fenitrothion [O,O-dimethyl O-(4-nitro-m-tolyl) phosphorothioate] (Krehm 1973), known commercially as Accothion, Novothion, Sumithion, etc. has been used in the province of New Brunswick, Canada since 1968 in attempts to control a lepidopterous forest pest, the spruce budworm (*Choristoneura fumiferana*).

The present budworm infestation began in the early 1950s when it was treated with DDT (for reviews see Kerswill 1967, Sprague *et al.* 1971, Prebble in press). Although the aerial spray program provided the

[*] Department of the Environment, Fisheries and Marine Service, Biological Station, St. Andrews, N. B. EOG 2XO. Canada.

forests with some protection against defoliation (Nash *et al.* 1971, Ket-
tela and Varty 1972), the intensity and area of infestation have in-
creased. The first spray operation was undertaken in 1952, when 0.075
million ha (1 ha = 2.47 A) were sprayed with DDT at 1,120 g/ha (70
g/ha = 1 oz/A). In 1953 the application rate was halved to 560 g/ha
but the area sprayed was increased to 0.73 million ha. Over the following
five years DDT was applied at 280 g/ha once or twice in areas of heavy
infestation. The area sprayed remained between 0.45 and 0.79 million ha
until 1957 when it increased to 2.3 million ha. Mortality of underyearling
Atlantic salmon was severe ($\approx$50%) in areas receiving 560 g/ha or
more of DDT in one year (Elson 1967) and was followed by declines in
numbers of returning adults (Elson 1974). There was no spraying in
1959, and from 1960 to 1969 the area sprayed annually never exceeded
1.25 million ha. DDT began to be phased out in 1968, and was replaced
completely by organophosphate insecticides, chiefly fenitrothion, in 1970.
However, beginning in 1970 the area sprayed increased in New Bruns-
wick from 1.7 million ha to 4.0 million ha by 1976. Severe infestations
began to appear elsewhere. By 1976 the total area of severe infestation
exceeded 30 million ha, of which about five million ha was in New
Brunswick, nearly 12 million ha was in the province of Quebec, and over
13 million ha was in Ontario. In the state of Maine, USA, 1.4 million ha
in areas lying between New Brunswick and Quebec were also heavily
infested. Small areas (< one million ha total) of severe infestation oc-
curred in the provinces of Nova Scotia, Prince Edward Island, and New-
foundland. Prolongation and increasingly rapid recurrence of heavy bud-
worm infestation almost certainly resulted from preservation of the food
supply following extensive use of insecticides (Blais 1974, Baskerville
1975, Holling *et al.* 1975).

In New Brunswick in 1975 and 1976 application rates of insecticides
were increased. In some areas two applications of fenitrothion at 280
g/ha were used, in others three applications of two different insecticides
{fenitrothion or phosphamidon (2-chloro-2-diethylcarbamoyl-1-methyl-
vinyl dimethylphosphate), and aminocarb [4-(dimethylamino)-3-methyl-
phenyl-N-methylcarbamate]} were applied sequentially in efforts to
combat increasing budworm populations. Two applications of trichlorfon
[dimethyl(2,2,2-trichloro-1-hydroxyethyl) phosphonate] at 280 g/ha each
were used in 1975 near blueberry fields to reduce kills of pollinating
insects; these rates were doubled in 1976.

The area of forest treated with fenitrothion is now so great that though
this insecticide is not registered for agricultural use, it ranks as one of the
most important of those used in Canada. From 1968 to 1974, 2,002 metric
tons of fenitrothion were sprayed over New Brunswick [*Forest Protec-
tion Ltd.* (1976)] (F.P.L.). In 1971, the quantity of fenitrothion used
on New Brunswick by F.P.L. alone (there were considerable but unknown
amounts sprayed by private companies) amounted to 43% of the total
for Canada of all major insecticides used for agriculture in that year or

the latest year for which figures were available (THOMSON 1973, F.P.L. 1976). In Quebec since 1974 the amount of fenitrothion sprayed annually has exceeded that in New Brunswick. Operational or experimental programs against spruce budworm and other forest pests have also been carried out in the provinces of Newfoundland, Ontario, Manitoba, and British Columbia.

The area and quantity of fenitrothion sprayed are perhaps alone sufficient to warrant a review of the available research which has accompanied the operation, and two have been compiled or are in preparation (PREBBLE in press, and *National Research Council of Canada* 1975). Research results led some members of an informal association of scientists which was formed to discuss effects and implications of the New Brunswick spray program (Pesticides Ecology Research Group, PERG), to suggest in 1974 that spraying fenitrothion once at 210 g/ha (3 oz/A) or twice sequentially approximately a week apart at 140 g/ha (2x2 oz/A) could be regarded as environmentally acceptable. They also suggested that any new formulation or altered spray program should be planned to cause no greater mortality to nontarget organisms than these standard applications. Data from these standard spray operations, therefore, form a benchmark with which other insecticides and spray programs might be compared.

The first purpose of this review, then, is to set forth the data which form the benchmark of the standard spray programs. These data include dispersal and degradation of fenitrothion in the physical and biological environment after spraying, and its toxicology in laboratory and field.

A second purpose is to use these data to try to predict consequences of increases in fenitrothion spray application rates, especially since some increases have already taken place. Such predictions may be attempted on the basis of results from experimental spraying at higher than standard doses, and from estimates of the lethal or sublethal hazard of the spray to organisms in the field. These hazards are estimated from the ratio of the concentration of fenitrothion observed at the point of contact after dispersal to the concentration causing a 50% response in laboratory tests. Where the ratio or hazard index equals unity, or one 'toxic unit' (SPRAGUE and RAMSAY 1965), a 50% response after spraying is expected, assuming that organisms in the field respond similarly to organisms in laboratory tests, and that a linear relation exists between the concentrations sprayed and those at the point of contact after dispersal. Under these assumptions, if the slope of the LD_{50} probit plot from laboratory data is known, the percentage of animals responding when the hazard index is less or greater than unity may also be estimated.

The predicted hazards may be checked against responses observed in the field during operational and experimental spraying, and if there is disagreement, then the data and assumptions for either or both the dispersal and toxicology of fenitrothion are inadequate. A third purpose of this review, therefore, is to identify these inadequacies.

II. Distribution and fate of fenitrothion after spraying

a) Concentrations in the physical environment

The amount of fenitrothion reaching tree-top or ground level depends on height of the spraying aircraft, type of carrying agent (usually water with an emulsifying agent, but in cold weather, oil), evaporation rate of the carrying agent, spray droplet size, wind direction and speed (NORRIS and MOORE 1970), and purity of the insecticide (ZITKO and CUNNINGHAM 1974).

Deposition may be measured directly by distributing glass plates at the location to be sprayed and later analyzing acetone or benzene washings from these plates for fenitrothion by gas chromatography (WOOD and STEWART 1976). Alternatively, it may be estimated by counting spray droplets on cards posted in sprayed areas and then by calculating the amount of fenitrothion from the volume of droplets/unit area and known spray concentration (CHANSLER and DIMOND 1971).

In the New Brunswick (F.P.L.) spray program, modified Grumman (TBM) aircraft spray at approximate heights of 30 to 50 m above treetop. There is only limited information available on concentration of fenitrothion reaching the ground. In open fields sprayed at 210 g/ha during standard spraying by F.P.L., the percentages reaching the ground at three locations were 17, 30, and 63, but in another field sprayed by a private operator at 280 g/ha, only 8, 14, and 15% reached the ground (WOOD and STEWART 1976). In studies with DDT, only about 40% of the pesticide arrived near the ground in open or cleared areas (HURTIG et al. 1955, HINDIN et al. 1966). For the F.P.L. operation at least, the 40% figure derived for DDT appears applicable to fenitrothion. If all the spray were to reach the ground, a treatment rate of 210 g/ha would equal 2.1 μg/cm^2, but if only about 40% of this reaches tree-top or open ground level the effective concentration on open ground would be about 0.8 μg/cm^2. Actual concentrationus of fenitrothion reaching the ground in open fields sprayed by F.P.L. averaged 0.8 μg/cm^2 (WOOD and STEWART 1976).

The maximum concentration expected in a forest stream 15 cm deep after spraying at 210 g/ha has been estimated to be about 25 ppb (EIDT and SUNDARAM 1975), assuming again that 40% of emitted spray reaches tree-tops and only half of this filters through the canopy to the stream. Actual measurements of peak or near-peak concentrations in small streams, when a major portion of the drainage is sprayed at 210 g/ha and a definite peak is discernible, seldom exceed 15 ppb (Table I). If the median peak concentration from all streams where measurements of fenitrothion have been made (Table I) is plotted against the median time to reach peak concentrations, and the same procedure is followed for declines to 50% and 10% concentrations, a generalized curve of fenitrothion in streams following spraying at 140 to 210 g fenitrothion/ha can be drawn (Fig. 1). This generalized curve is useful for experimental simulation of dose or

Table I. Concentrations of fenitrothion in streamwater after forest spraying at 140 to 210 g/ha (2 to 3 oz/A) and time to reach peak concentration and 10% of peak after spraying (only those data in which a definite peak was attained are given).[a]

Stream and date	Maximum observed conc. in water (ppb)	Time after spraying of peak conc. in water	Approx. time after spraying for conc. to decrease to		Reference
			50% of peak (hr)	10% of peak (hr)	
1 Hayden Bk 1973	1.33	40 min	2	4	Eidt & Sundaram (1975)
2 Cove Bk 1973 second half of first appl.	2.4	55 min	—	—	Hall in Eidt & Sundaram (1975)
3 Cove Bk 1973 first half of first appl.	2.8	3 hr	—	—	Hall in Eidt & Sundaram (1975)
4 Cove Bk 1972 second appl.	3.8	3 hr	—	—	Hall in Eidt & Sundaram (1975)
5 Narrows Mtn Bk 1974	3.8	3.5 hr	8	24	Eidt (1975 b)
6 Waweig R. 1973	4.8	1 hr	3½	8	Peterson & Zitko (1974)
7 Narrows Mtn Bk 1973	5.25	40 min	8	30	Eidt & Sundaram (1975)
8 Lake Bk 1973	6.38	55 min	6	15	Eidt & Sundaram (1975)
9 Cove Bk 1972 first appl.	7.4	2 hr	—	—	Hall in Eidt & Sundaram (1975)
10 Cove Bk 1973	11.2	50 min	—	—	Hall in Eidt & Sundaram (1975)
11 Cove Bk 1971	57	?	—	—	Penney in Eidt & Sundaram (1975)

[a] Median maximum concentration is 4.8 ppb; median time to peak is 55 min; median approximate time for concentrations to fall to 50% of peak concentration is six hr and to reach 10% of peak concentration is 15 hr.
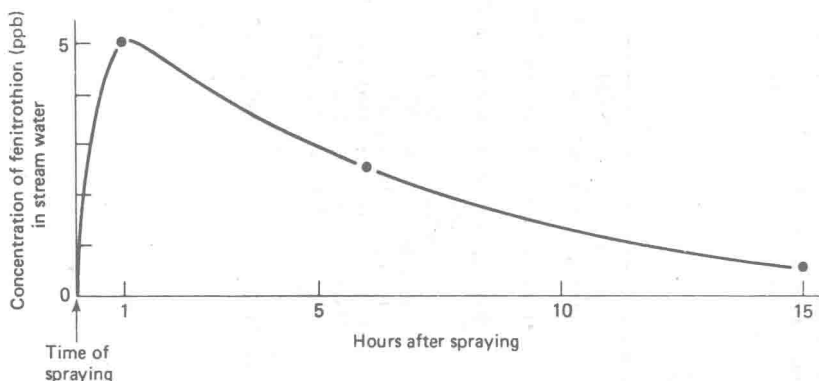
Fig. 1. Generalized curve of concentrations of fenitrothion in stream water after forest spraying at 1 to 210 g/ha (2 to 3 oz/A) drawn through median peak concentration and median times for reduction to 50 and 10% of peak concentrations from Table I.

exposure times observed in the field, but actual time-concentration curves may depart widely from it.

If only portions of streams or their drainage basins are sprayed, there may be no discernible peak, and fenitrothion may persist at varying concentrations for 24 to 48 hr (EIDT and SUNDARAM 1975). In these instances concentrations rarely exceed one ppb and therefore fall within the area enclosed by the generalized curve of Figure 1.

Rain following spraying might be expected to increase concentrations of fenitrothion in streams. Only 0.04 ppm or less of fenitrothion, however, is found in the top 15 cm of forest soil (YULE and DUFFY 1972) and, in addition, fenitrothion is readily adsorbed to silty loams, though not to sandy soils, and when adsorbed it is not easily leached by water (*Sumitomo Chemical Co.* 1973, ZITKO and CUNNINGHAM 1974). Even if fenitrothion is washed from tree foliage to the ground by the rain, most of it will remain and be decomposed in the soil. The result is that concentrations of fenitrothion in streams rarely increase during or after rainstorms (one exception in FLANNAGAN 1973); they generally decrease because of dilution and transport (EIDT and SUNDARAM 1975).

If only 40% of fenitrothion leaving the aircraft reaches open ground or tree-top level, 60% must remain in the atmosphere where it is broken down by sunlight, or it drifts into and settles in areas outside the target zone. Measured drift of spray can be considerable; fields located three to eight km from areas sprayed have received detectable amounts (0.02 to 0.15 g/ha) (WOOD and STEWART 1976). EIDT and SUNDARAM (1975) report detecting low concentrations ($\approx$0.2 ppb) of fenitrothion in streams whose watersheds were four km distant from the nearest spray operation. Even greater dispersion can be expected with faster, higher-flying

aircraft such as the DC6 now being used in New Brunswick and Quebec. Properly managed, drift can be used to advantage to produce an evenly spread application of insecticide.

b) Concentrations in plants and animals

The concentrations of fenitrothion in coniferous foliage and in various animals have been measured after spraying at 140 to 280 g/ha (Table II).

Table II. *Concentrations of fenitrothion at various locations in the environment after spraying at 140–280 g/ha.*

Location	Residue	· References
Spray cards near trees	0.07–14 µg/cm²	CHANSLER & DIMOND (1971)
Coniferous foliage (fresh)	2–4 ppm	YULE & DUFFY (1972)
Forest soil, top 15 cm	0.04 ppm	YULE & DUFFY (1972)
Terrestrial insects	0.20 ppm	CARROW (1974)
Dead budworm larvae and dragonflies	5–14 ppm	FINDLAY et al. (1974)
Honeybees	0.4–2.1 ppm	SUNDARAM (1974 a)
Caged quail, whole body	0.1 ppm	FINDLAY et al. (1974)
Stream water	see Table I and Fig. 1	
Aquatic insects	3.2 ppm	PENNEY (1971 c)
Atlantic salmon and brook trout	range 0–2.7 ppm means 0.01–0.09 ppm	HATFIELD & RICHE (1970)
Atlantic salmon	max. conc. 0.01 ppm 3–4 days after spraying	CÔTÉ & TÉTREAULT (1973)
Dace	4.8–13.7 ppm	LOCKHART et al. (1973)

Concentrations usually peak between about 0.2 and 5.0 ppm though both lower and higher concentrations have been recorded (Table II). Variation in concentrations in faunal samples can be expected to be great not only because of the variable concentration in the physical environment, but also because uptake into the animal may occur by various routes depending on species, habitat, behavior, and other factors.

Birds may obtain fenitrothion either through ingesting insects killed by the insecticide or by direct contact through the feet (PEARCE 1971) or respiratory tract (FINDLAY et al. 1974). To investigate the relative importance of uptake by these two routes, FINDLAY et al. (1974) placed cages of Japanese quail (*Coturnix coturnix japonica*) under trees and in the open. The amount of insecticide reaching the forest floor beneath trees is only about 40 to 50% of that reaching the ground in the open (HURTIG et al. 1955), but quail under trees ate some poisoned insects which were not available to the birds in the open. Eight hr after spraying at 280 g/ha quail in the open contained higher concentrations of fenitrothion in their bodies (0.12 ppm) than did those held under trees (0.02 ppm) but had lower concentrations in their crops (0.2 and 0.8 ppm,

respectively), suggesting that the chief route of uptake into the body is by direct contact rather than by ingestion (FINDLAY et al. 1974).

Little is known about the concentrations of fenitrothion in aquatic insects following spraying. PENNEY (1971 b) was unable to detect fenitrothion in mayfly nymphs from a brook sprayed at 210 g/ha and later at 140 g/ha despite reductions in populations of these insects.

The relative importance to fish of direct uptake from the water vs. ingestion of contaminated food is uncertain. Rainbow trout (Salmo gairdneri) held in a sprayed stream in cages that excluded food organisms had average concentrations of 0.4 to 0.6 ppm one day after spraying at 280 g/ha, but dace (Chrosomus eos and C. neoganeus) and brook sticklebacks (Culaea inconstans) captured outside the cages had filled stomachs and contained 4.8 ppm of fenitrothion in their bodies six hr after spraying, and 13.7 ppm by the following day (LOCKHART et al. 1973). CÔTÉ and TÉTREAULT (1973) found concentrations increased to a maximum of 0.01 ppm of fenitrothion in the flesh of young Atlantic salmon (Salmo salar) by three to four days after spraying at 140 g/ha. The gradual increase suggests uptake may have been through ingestion of poisoned insects. Ingestion of poisoned terrestrial insects from the water surface could result in intake of 0.2 µg of fenitrothion/g of food (CARROW 1974), and concentrations of fenitrothion in the stomach contents of Atlantic salmon and brook trout (Salvelinus fontinalis) varied between zero and 2.2 ppm in areas sprayed at 210 or 140 g/ha twice (HATFIELD and RICHE 1970).

c) Degradation of fenitrothion

Laboratory studies have revealed various means of degradation of fenitrothion and the time required for degradation to occur. In water fenitrothion is hydrolyzed when pH > 7, but under acidic conditions it is more persistent. The half-life in water at 25°C ranges from 60 hr at pH 5.42 to 22 hr at pH 8.22 (SUNDARAM 1973 a). Dissolved in methanol and then in distilled water, fenitrothion is broken down by sunlight with a half-life of about 11 hr (temperature not recorded) (Sumitomo Chemical Co. 1973). In flasks containing silty loam soils flooded with water, fenitrothion has a half-life of 3 to 6 days at 23°C (Sumitomo Chemical Co. 1973).

Fenitrothion may also be broken down biologically. The bacterium Bacillus subtilis decomposes fenitrothion to amino fenitrothion (Sumitomo Chemical Co. 1973), and some plants (rice) oxidize it to fenitrooxon (MIYAMOTO and SATO 1968). Tested species of fungus and yeasts are, however, unable to break it down (YASUNO et al. 1965). Resistant flies (Musca domestica) metabolize fenitrothion to nontoxic water-soluble derivatives more rapidly than do sensitive flies (GWIAZDA and CHRUSCIELSKA 1972). Fenitrothion is metabolized by mammals into various products (BULL 1972), but, with the exception of fenitrooxon, little is known of their toxicity and persistence. Fenitrooxon is highly toxic, but

unstable (MIYAMOTO 1964 a and b, 1969). Fenitrothion has a lower toxicity to mammals relative to insects probably because of enhanced detoxification through dealkylation involving glutathione dealkyl transferase (*National Research Council of Canada* 1975).

In general, fenitrothion is rapidly broken down by most plants and animals with production of oxon and cresol derivatives and some phosphorothioic acids, but the chief metabolite is desmethyl fenitrothion (MENZIE 1969; for further details see HOLLINGWORTH *et al.* 1967 and KREHM 1973). However, details of routes by which derivatives arrive at environmental sinks, their rates of arrival, and their chemistries and toxicities are not known (*National Research Council of Canada* 1975).

Because degradation may occur rapidly by various pathways, fenitrothion is generally not persistent in the environment. Concentrations in the top 15 cm of forest soil decreased from about 0.04 ppm in samples taken immediately after spraying, to undetectable levels in samples taken between 32 and 64 days later (YULE and DUFFY 1972). In pond and stream water samples, concentrations of fenitrothion diminished rapidly, having a half-life of 0.3 to 3.5 days and becoming very low (<0.03 ppb) within 40 days (SUNDARAM 1973 b). In neutral to slightly acid stream water, hydrolysis is likely to be slow and degradation of the insecticide in stream water in New Brunswick is therefore chiefly attributable to microbial degradation (ZITKO and CUNNINGHAM 1974). In terrestrial insects fenitrothion residues could not be detected past the fourth day after spraying (KETTELA and VARTY 1972). In fish, fenitrothion is initially concentrated, reaching levels 20 to 160 times that in the surrounding water (BULL 1971, *Sumitomo Chemical Co.* 1973), but it is then broken down rapidly. After spraying at 280 g/ha, concentrations in caged rainbow trout fell from peak levels of 0.4 to 0.6 ppm on the day of spraying to trace or undetectable amounts by the fourth day (LOCKHART *et al.* 1973). CÔTÉ and TÉTREAULT (1973), however, detected measurable levels in bodies of wild young salmon captured 11 days after spraying. In caged Japanese quail, concentrations at 0.02 to 0.12 ppm eight hr after spraying at 280 g/ha fell to 17 to 25% of peak values two days later (FINDLAY *et al.* 1974).

One exception to the rapid disappearance of fenitrothion in the forest environment occurs in coniferous foliage where detectable amounts may persist longer than a year. Concentrations of fenitrothion in spruce and fir foliage after spraying at 280 g/ha (4 oz/A) range between two and four ppm (foliage as sampled, not dried), but are reduced to about half this within four days, and to only 15 to 30% of the original concentration in about two wk (YULE and DUFFY 1972). This rapid reduction in concentration probably results from evaporation of fenitrothion, removal by rain, and breakdown by sunlight while on the surface of the conifer needles (YULE and DUFFY 1972). However, a small proportion, about 1 to 10% or 0.01 ppm (SUNDARAM 1974 b) to 0.28 ppm (YULE and DUFFY 1971 and 1972) persists for at least a year possibly through being absorbed internally or into the waxy leaf cuticle where further breakdown