8-30-94

DP Barcode : D191898
PC Code No : 105001
EEB Out :

To: Larry Schnaubelt
Chemical Review Manager 72
Special Review and Reregistration Division (7508W)

From: Anthony F. Maciorowski, Chief
Ecological Effects Branch/EFED (7507C)

Attached, please find the EEB review of...

Reg./File # : 105001 SH # 105001
Chemical Name : Terbufos
Type Product : Insecticide
Product Name : Terbufos 15G/Terbufos 20CR
Company Name : American Cyanamid Company
Purpose : List A RED for Terbufos, Case No. 0109.

Action Code : 606 Date Due : 09/15/94
Scientist : E. Fite Date In : 06/04/93

EEB Guideline/MRID Summary Table: The review in this package contains an evaluation of the following:

GDLN NO	MRID NO	CAT	GDLN NO	MRID NO	CAT	GDLN NO	MRID NO	CAT
71-1(A)			72-2(A)			72-7(A)		
71-1(B)			72-2(B)			72-7(B)		
71-2(A)			72-3(A)			122-1(A)		
71-2(B)			72-3(B)			122-1(B)		
71-3			72-3(C)			122-2		
71-4(A)			72-3(D)			123-1(A)		
71-4(B)			72-3(E)			123-1(B)		
71-5(A)			72-3(F)			123-2		
71-5(B)			72-4(A)			124-1		
72-1(A)			72-4(B)			124-2		
72-1(B)			72-5			141-1		
72-1(C)			72-6			141-2		
72-1(D)						141-5		

Y=Acceptable (Study satisfied Guideline)/Concur
P=Partial (Study partially fulfilled Guideline but
additional information is needed
S=Supplemental (Study provided useful information but Guideline was
not satisfied)
N=Unacceptable (Study was rejected)/Nonconcur

DP BARCODE: D191898 REREG CASE # 0109

CASE: 819384 DATA PACKAGE RECORD DATE: 06/04/93
SUBMISSION: S441962 BEAN SHEET

* * * CASE/SUBMISSION INFORMATION * * *

CASE TYPE: REREGISTRATION ACTION: 606 DATA PACKAGE
CHEMICALS: 105001 Terbufos 100.00 %

ID#: 105001
COMPANY:
PRODUCT MANAGER: 72 LARRY SCHNAUBELT 703-308-8058 ROOM: CS1 3C3
PM TEAM REVIEWER: DON MACKEY 703-308-8054 ROOM: CS1 3K4
RECEIVED DATE: 06/04/93 DUE OUT DATE: 09/02/93

* * * DATA PACKAGE INFORMATION * * *

DP BARCODE: 191898 EXPEDITE: N DATE SENT: 06/04/93 DATE RET.: / /
CHEMICAL: 105001 Terbufos
DP TYPE: 999 Miscellaneous Data Package
ADMIN DUE DATE: 10/02/93 CSF: N LABEL: N

ASSIGNED TO	DATE IN	DATE OUT
DIV : EFED	6 / 4 /93	/ /
BRAN: EEB	6 / 4 / 93	8/30/94
SECT:	/ /	/ /
REVR :	/ /	/ /
CONTR:	/ /	/ /

* * * DATA REVIEW INSTRUCTIONS * * *

TERBUFOS (LIST A PRIORITY CHEMICAL)

PLEASE REVIEW THE ATTACHED MINI-DELIVERABLE PKG. FOR TERBUFOS. THIS PKG. IS TO ASSIST YOU IN THE DEVELOPMENT OF SCIENCE CHAPTERS FOR THIS CHEMICAL.

* * * ADDITIONAL DATA PACKAGES FOR THIS SUBMISSION * * *

DP BC	BRANCH/SECTION	DATE OUT	DUE BACK	INS	CSF	LABEL
191897	CCB	06/04/93	10/02/93	Y	N	N
191899	EFGB	06/04/93	10/02/93	Y	N	N
191900	SACS	06/04/93	10/02/93	Y	N	N

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

August 30, 1994

OFFICE OF
PREVENTION, PESTICIDES AND
TOXIC SUBSTANCES

MEMORANDUM

SUBJECT: Reregistration Eligibility Document for Terbufos: Barcode D191898

FROM: Anthony F. Maciorowski, Chief
Ecological Effects Branch
Environmental Fate and Effects Division (H7507C) 8/31/94

TO: Bernice Slutsky, Coordinator
Science and Coordination Branch
Environmental Fate and Effects Division (H7507)

Attached is the EEB Science Chapter for the Terbufos Reregistration Eligibility Document. Terrestrial and aquatic species are at risk based on the use pattern and calculated Levels of Concerns (LOCs) for these species as well as other information discussed in the document. If you have any questions on the above, please let me know.

ECOLOGICAL EFFECTS BRANCH
SCIENCE CHAPTER FOR
REREGISTRATION ELIGIBILITY DOCUMENT
FOR TERBUFOS

Ecological Hazard

Topical Summaries

Effects to Non-Target Birds

The following studies have been evaluated under this topic.

Author	MRID#
Beavers & Fink	FEOTERO2
Roberts & Wineholt	00087717
Krize & Terrell	00035120
Fink & Reno	00097892
Fink & Reno	00085177
Labisky & Anderson	00085178
Wang	00087726
Manuel	00085180
Labisky	00085179
Manuel	00085183
Labisky	FEOTER01
Beavers	00161573
Beavers	00161574
Terrell & Krize	00096392
Hill & Camardese	(1984)[1]
Jaber & Dingledine	BAOTER01
Beavers & Jaber	160387

[1]No MRID number

Fletcher	406607-07
Fletcher	406607-08
Brewer et.al	409855-01
Tank et.al	414758-01
Pedersen	415088-01 & 41849201

In order to establish the toxicity of terbufos to birds, the minimum data required on the technical material are:

- An avian single-dose LD50 test with either one species of waterfowl, preferably the mallard, or one species of upland gamebird, preferably bobwhite (section 71-1); and

- Two avian dietary LC50 tests, one with a species of waterfowl, preferably the mallard, and one with a species of upland gamebird, preferably the bobwhite (section 71-2).

Avian Acute Oral Toxicity - Technical

The acceptable acute oral toxicity studies on terbufos are listed below.

Species	% ai	Results	MRID#	fulfills Req.
Bobwhite	89.6	28.6(22.2-57.2)mg/kg	FEOTER02	yes
Bobwhite	tech	15.0 (12-19) mg/kg	Hill & Camardese 1984[1]	yes

1.No MRID number

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Avian Dietary Toxicity - Technical

The acceptable avian dietary toxicity studies on technical terbufos are listed below:

Species	% ai	Results	MRID #	Fulfills Req.
Mallard	86	520 (400-676) ppm	35120	Partial
Mallard	86	160 (131-195) ppm	87717	Partial
Bobwhite	87.8	157 (125-201) ppm	160387	yes
Bobwhite	86	140 (107-183) ppm	87717	yes

The guideline requirements for acute avian toxicity testing have been fulfilled. These test results show that terbufos is highly toxic to birds.

Avian Dietary Toxicity - End Use Product

Additional avian toxicity data using formulated product can be required on a case by case basis if information suggested the end use product toxicity would be substantially greater than the active ingredient. If needed studies have been conducted with the granular formulation of terbufos and are listed below.

Species	% ai	Results	MRID #	Fulfills Req.
Mallard	15 %	88.1 (0-215) mg formulation /kg	406607-05	Not Req.
Mallard	20 %	160.9(68.1-316) mg formulation /kg	406607-06	Not Req.
Bobwhite	15 %	26 (20-34) mg ai/mg	Hill & Camardese 1984 [1]	Not Req.

1.No MRID number

Avian Reproduction Studies - Technical Terbufos

Avian reproduction studies are required because of the persistent of terbufos (half life of 11 weeks in a siltloam soil). In order to establish the chronic toxicity of terbufos to birds, the data required on the technical material are:

- Two avian reproduction studies, one with a species of waterfowl, preferably the mallard, and one with a species of upland gamebird, preferably the bobwhite quail.

Avian reproduction studies on technical terbufos are listed below.

Species	Results	MRID	Fulfills Req.
Mallard	No significant impairment at dietary levels of 2-20 ppm, but impairment is approaching significance at 20 ppm.	00097892	Partial
Bobwhite	No significant impairment at dietary levels of 2-20 ppm.	161574	yes
Mallard	Possible but not statistically significant effects on embryo viability at 15 ppm.	161574	yes
Bobwhite	No effects at up to 30 ppm.	191573	yes

The guideline requirements for avian reproduction studies have been fulfilled.

Mammal Toxicity

The toxicity data required for evaluating hazards to human and domestic animals are normally adequate to indicate hazard to wild mammals. Examples of circumstances when data on the toxicity of a pesticide to wild mammals may be required, but are not limited to, the following:

- When data indicate that there is considerable variation in the sensitivity of different mammalian species to the toxic effects of a pesticide; and

- When pesticide with bactericidal properties will be applied to the forage of wild ruminants, and toxicological data do not include information on possible interference with rumen fermentation in domestic or wild ruminants.

Terbufos, does not appear to require wild mammal tests, therefore mammal toxicity data submitted for evaluating human and domestic animals will be use to assess potential impacts to wild mammals. Mammalian toxicity tests are listed below.

Species	% ai	Results	MRID #
Rat	96.7	LD50(m)=4.5 (2.6-7.7) mg/kg LD50(f)=9.0 (5.2-15.3) mg/kg	112227
Rat	86.0	LD50(m)=1.74 mg/kg LD50(f)=1.57 mg/kg	00035121
Dog	96.7	LD50(m)=4.5 (2.2-9.0)mg/kg LD50(f)=6.3 mg/kg	112227
Mice	97.7	LD50(m)=3.5(1.9-6.6)mg/kg LD50(f)=9.2(6.0-14.0 mg/kg	112227

These test results show that terbufos is very highly toxic to mammals.

Simulated and/or Actual Field Tests

Simulated or actual field test are required on a case-by-case basis to support the registration of an end-use product intended for outdoor application. These test are required to support the registration of an end-use product if the use of the pesticide is likely to result in adverse effects on wildlife exposed to the pesticide, and if actual or simulated field tests can yield data useful in assessing such risk. Simulated and /or actual field testing with birds is required due to the high acute toxicity of terbufos to birds and the potential for avian exposure to granules at or near the soil surface over the large acreage of agriculture land treated with terbufos.

Simulated and/or actual field tests on terbufos are summarized below.

Terrestrial Field Study-MRID NO. 00085178, 00085180, 00087726 Results - Counter 15G applied to corn fields at 1 lb ai/A at time of plant showed minimal acute effects on wildlife, however carcass searches, residue analyses, and miscellaneous wildlife observations were limited. Fullfills Req. - Partial

Simulated Field Study: exposure to treated soil. MRID No.-00085179,00085183, FETTER01. Results - Ring-necked pheasants were exposed to soil treated with Counter 15G at a rate equivalent to 1 to 5 lbs ai/A and residues were not detected 22 days after initial exposure and no poisoning symptoms were observed during 55 days of observation following treatment.Two of three birds exposed to a simulated spill died within 12 hours of initial exposure. Fulfills Req. - not required.

Terrestrial Field Study - MRID No. BATTER01. Results - Terbufos was applied at planting at 2.6 lbs ai/A and 10 weeks later as a broadcast aerial application at 1 lb ai/A to cornfield in Maryland. Following the at planting application several species of wildlife were observed exhibiting sign of cholinergic poisoning. These included: one bluebird, one morning dove, one blue jay, one robin and one brown-headed cowbird. The bluejay contained residues of 0.24 ppm. Seven feather spots were also found. Following the aerial application eight dead birds, one affected bird, 14 mammals, one reptile, six feather spots and a fur spot were found. Fulfills Req. - yes.

Terrestrial Field Study - MRID No. 409855-01, 414758-01. Results - Three seasons of field research were conducted from 1987 to 1989 in south central Iowa to assess the environmental behavior of terbufos on wildlife in a corn agro-ecosystem. Monitoring and biochemical sampling techniques showed relative low exposure to most species sampled. Results from starling nest box monitoring in the second year suggested some effects in reproduction parameters sampled and third year passerine blood plasma samples showed a significant difference between in-furrow treatment sites and controls in bluejay ChE levels. Fulfills Req. - yes

Simulate Field Study - MRID No. 415088-01 & 41849201. Results - Study was conducted to compare the effects of Counter 15G to Counter 20CR on bobwhite quail and brown-headed cowbirds. Terbufos was applied at corn plant in pens using band and in-furrow applications. Despite study limitations, the results suggest that both formulations could impact non-target wildlife species. All treatment pens showed higher mortality rates than controls. Fulfills Req. - Not required.

Effects to Non-Target Fish

Six studies contained in six citations have been evaluated under this topic. Six studies were used in performing a risk assessment.

Author	MRID#
Sleight	00037483
Bentley	00085176
Roberts&Winehold	00087718
USEPA	FEOTER04
USEPA	FEOTER05
McAllister	40009301

Fish Acute Toxicity Tests - Technical

The minimum data required for establishing the acute toxicity of terbufos to fish are the results from two 96-hour studies with the technical product. One with cold water species, preferably rainbow trout, the other with a warm water species, preferably bluegill sunfish (section 72-1). The fish studies are listed below.

Species	% ai	LC50 & 95% C.I.	MRID #	Fulfills Req.
Bluegill sunfish	86.0%	0.77 (0.72-0.83) ppb	00087718	yes
Bluegill sunfish	86.3%	3.8 (2.8-4.9) ppb	00037483	yes
Bluegill sunfish	88.6%	0.87 (0.77-1.0) ppb	00085176	Partial
Brown Trout	86.0%	20 (12.6-34.3) ppb	00087718	yes
Rainbow Trout	86.3	9.4 (7.7-11.4) ppb	00037483	yes
Channel catfish	88.6	9.6 (8.5-11.1) ppb	00085176	Partial

Four of the studies fulfill the guideline requirement for fish acute toxicity tests for terbufos with technical material. They show that technical terbufos is very highly toxic to freshwater fish in acute exposures.

Fish Acute Toxicity Tests - End Use Product

Two 96-hr LC50 fish studies using the 15% granular formulation may be needed for hazard evaluation of terbufos if the LC50 of the technical grade of active ingredient approximates the expected residue level in the aquatic environment when the pesticide product is used as directed, or if a product component other than the active ingredient is expected to substantially enhance the toxicity of the active ingredient. If needed, one study should be conducted on a cold water species and one on a warm water species. Fish LC50 test conducted with the 15 % granular formulation of terbufos are listed below:

Species	% ai	Results[1]	MRID #
Bluegill Sunfish	15 %	12.3 (9.8-15.2) ppb	FEOTER04
Rainbow trout	15 %	59.7 (48.1-74.3) ppb	FEOTER05

1.values based on total formulation

Fish Life Cycle Test - Technical Terbufos

A fish early life-stage test is required because of the toxicity of terbufos to fish is less than 1 mg/kg. Results of the fish early life-stage test on terbufos is given below.

Species	% ai	Results	MRID #	Fulfills Req.
Rainbow Trout	98.5	The MATC could not be calculated. The NOEL was 1.4 ppb, the highest concentration tested.	40009301	Partial

There is insufficient information to completely characterize the chronic toxicity of terbufos to freshwater fish in an early life stage test. The study failed to meet the guideline requirements that "at least one test level must adversely affect a life stage." The MATC can be estimated at > 1.4 ppb and < 11.5 ppb because the NOEL is known and the upper limits of the Rainbow Trout 96hr LC50 are known.

Effects to Non-Target Aquatic Invertebrates

Four studies have been reviewed and used to perform a risk assessment on aquatic invertebrates.

Author	MRID#
Boudreau et al.	FEOTER03
Bentley	00085176
USEPA	FEOTER06
Forbis et al.	162525

Acute Aquatic Invertebrate Testing - Technical

The minimum datum requirement for establishing the acute toxicity of terbufos to aquatic invertebrates is the result from one 48-hour acute toxicity test with the technical product (section 72-2). The acceptable tests are listed below.

Species	% ai	Results	MRID #	Fulfills Req.
Daphnia magna	88.6	0.31 (0.27-0.36) ppb	FEOTER03	yes
Crayfish	88.6	8.0 (6.9-10.2) ppb	00085176	Partial*

* Inappropriate Species

The *Daphnia magna* study fulfills the requirements for an acute toxicity test with aquatic invertebrates and shows that terbufos is very highly toxic to aquatic invertebrates in acute exposures.

Aquatic Invertebrate Reproduction Testing - Technical

An aquatic invertebrate life cycle test is required because the toxicity of terbufos to aquatic organisms is below 1 mg ai/L; the estimated concentration in aquatic environments is greater than 0.01 of the LC50; the hydrolytic half-life is greater than 4 days at pH 5, 7, and 9 and terbufos has broad use on corn. In order to establish the chronic toxicity to aquatic invertebrates the following study is required:

- An aquatic invertebrate reproductive test with the water flea, Daphnia magna

The acceptable freshwater aquatic invertebrate life cycle study is listed below:

Species	% ai	Results	MRID #	Fulfills Req.
Daphnia magna	98.4	MATC > 30 < 76 ng/l (pptrillion)	162525	yes

This test indicates that terbufos is extremely chronically toxic to freshwater invertebrates.

Effects to Non-Target Estuarine and Marine Organisms

Terbufos is registered for uses which will expose estuarine organisms to the pesticide. Such uses include corn and sorghum. To establish the toxicity of terbufos to non-target estuarine/marine organisms, the following studies are required:

72-3(a) Acute Estuarine/Marine Toxicity Fish
72-3(b) Acute Estuarine/Marine Toxicity Mollusk
72-3(c) Acute Estuarine/Marine Toxicity Shrimp

Five studies contained in five citation has been evaluated under this topic. The studies were used in performing the risk assessment.

Author	MRID No.
Swigert et al.	162523
Forbis et al.	162524
Bowman	413736-02
Bowman	412979-03
Sved & Wisk	423815-01

Estuarine/Marine Toxicity Tests - Technical

The submitted study are listed below.

Species	% ai	Results	MRID #	Fulfills Req.
Mysidopsis bahia	98	0.40 (0.34-0.48) ppb	413736-03	partial

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Sheephead minnow	98	3.2 (2.7-3.7) ppb	413736-02	yes
Sheephead minnow	98.4	1.6 (0.77-3.2) ppb	162524	partial
Mysid Shrimp	98.4	0.22 (0144-0.358) ppb	162523	partial
Eastern Oyster (shell growth)	89.2	EC50 = 0.20 mg ai/l (0.16-0.32)	423815-01	yes

The guideline requirements are fulfilled for the esturine/marine toxicity studies. The study shows that technical terbufos is very highly toxic to estuarine/marine organisms and highly toxic to eastern Oyster.

Disciplinary Review

Non-Target Terrestrial

Studies show that terbufos is highly toxic to birds on a acute oral basis. Acute oral studies resulted in an LD50's of 28.6 (95%C.L. 22.2 -57.2) mg/kg (MRID #. FEOTER02) and 15.0 (95%C.L. 12-19) for bobwhite quail (Hill and Camardese 1984). Avian dietary studies demonstrate that terbufos ranges from highly toxic to moderately toxic on a subacute basis. LC50 values range from 140 (95% C.L. 107-183) ppm for the bobwhite quail (MRID# 87717) to 520 (95% C.L. 400-675) for the mallard (MRID No. 35120).

Four avian reproduction study were available for terbufos which indicated that the NOEL level is approximately 15 ppm based on embryo viability (MRID No. 161574) in a mallard study. Possible but not statistically significant effects on embryo viability at 15 ppm.

Non-Target Aquatic

Terbufos has been demonstrated to be very highly toxic to freshwater fish with a 96-hr LC50's ranging from 0.77 ppb for the bluegill (MRID No. 00087718), to 20 ppb for the brown trout (MRID No. 00087718).

An acute aquatic invertebrate study shows a 48-hr EC50 of 0.31 ppb to Daphnia magna which characterizes terbufos as very highly toxic to aquatic invertebrates in acute exposures (MRID No.FEOTER03).

Acute estuarine marine fish studies show that terbufos is very highly toxic to estuarine/marine organisms with LC50's ranging from 0.22 ppb (MRID No. 162523) for the mysid shrimp to 3.2 ppb to the sheephead minnow (MRID No 162523).

A fish early life study shows that the MATC for the rainbow trout can be estimated to be greater than 1.4 ppb and less than 11.5 ppb (MRID No.40009401).

The life cycle aquatic invertebrate study showed that terbufos is extremely chronically toxic to freshwater invertebrates with a MATC between 30 and 76 ppt (MRID no. 162525).

Ecological Effects Risk Assessment

Use Profile

Terbufos is a insecticide/nematicide presently registered in a 15 and 20 percent ai granular from for use on corn, popcorn, sweet corn, grain sorghum and sugarbeets. Terbufos is formulated only as a granular product and is limited to one application per year for all uses. The following summarizes application rates for the two formulations of terbufos:

Crop	Rates*	Application
20 CR Formulation		
Field corn, pop corn, and sweet corn, at planting	Banded or In-furrow 6 oz. per 1000 ft of row for any row spacing (minimum 20-inch row spacing). Do not exceed 9.8 lbs/A.	Banded - Place granules in a 7-inch band over the row, in front of or behind the presswheel and lightly incorporate. In-furrow - Place granules directly in the seed furrow behind the planter shoe.
Post emergence incorporated	Banded - 9 oz. per 1000 ft. of row for any row spacing (minimum 30-inch row spacing).	Apply in a 7 inch band over the row of seeding corn plants and lightly incorporate into the soil when billbugs or damage are observed, usually in 1-6 leaf stage of growth. Use cultivators or other suitable implements to lightly incorporate granules into the soil.
At cultivation	6 oz. per 1000 ft. of row for any row spacing (minimum 30 inch row spacing).	Apply granules to base of plants or over the top of plants just ahead of cultivation shovels so as to cover

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Crop	Rates*	Application
20 CR Formulation cont.		
		granules with soil.
Grain sorghum at bedding	Knifed-in 6-12 oz. per 1000 ft. of row for any row spacing (minimum 20 inch row spacing) or no more than 19.6 lbs. per acre.	Knifed-in Drill granules 1-4 inches directly below the seed or 1-4 inches below the seed and up to 5 inches to the side of the seed.
At planting	Knifed-in 6 oz. per 1000 ft. of row for any row spacing (minimum 20 inch row spacing) or no more than 9.8 lbs/A.	Banded - Place granules in a 7-inch band over the row, in front of or behind the presswheel and lightly incorporate. For corn rootworms, wireworm, white grubs and nematodes place granules in a 5-7 inch band directly behind the planter shoe in front of the presswheel.
Sugarbeets, at planting	Banded 6 oz. per 1000 ft of row for any row spacing (minimum 20- inch row spacing).	
	Knifed-in - 12 oz. per 1000 ft. of row for any row spacing (minimum 20 inch row spacing) or no more than 19.6 lbs per acre.	Knifed-in - Drill granules 2 inches to the side of the seed and 2-4 inches below the seed.

Crop	Rates*	Application
20 CR Formulation cont.		
	Modified in-furrow or banded 3_6 oz. per 1000 ft. of row for any row spacing (minimum 20 inch row spacing).	Modified in-furrow Apply in-furrow at planting time 2-3 inches behind the seed drop zone after some soil has covered the seed.
Post-emergence	Banded - 3-6 oz. per 1000 ft. of row foe any spacing(minimum 20-inch row spacing).	Banded - Apply in a 5 to 7 inch band over the row and lightly incorporate into the soil.
15 G Formulation		
Field corn, pop corn, and sweet corn, at planting	Banded or in-furrow 8 oz. per 1000 ft. of row for any spacing. Do not exceed 8.7 lbs per acre.	Banded - Place granules in a 7-inch band over the row, in front of or behind the presswheel and lightly incorporate. In-furrow - Place granules directly in the seed furrow behind the planter shoe.
Sugarbeets at planting	Modified in-furrow or banded - 4-8 oz. per 1000 ft. of row for any row spacing (minimum 20-inch row spacing.	Apply in-furrow at planting time 2-3 inches behind the seed drop zone after some soil has covered the seed.

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Crop	Rates	Application
15 G Formulation cont.		
Post-emergence	Banded - 4-8 oz. per 1000 ft. of row for any row spacing (minimum 20-inch row spacing).	Banded - Apply in a 5 to 7-inch band over the row and lightly incorporate into the soil.
Grain Sorghum at planting	Banded - 8 oz. per 1000 ft. of row for any row spacing (minimum 20-inch row spacing or no more than 13.1 lbs/A.	

* The information on application rates is from terbufos labels.

Environmental Fate Profile

Dissipation of any pesticide from the site of application can be broken into three major processes:

- degradation, or breakdown, of the parent compound;
- transport or binding of the compound to, down through, or across a soil; or
- accumulation and removal from the soil by target or non-target organisms.

These processes may act in conjunction with or compete for the dissipation of a pesticide in an environment; rarely does any one process account for all of the dissipation. Processes may also occur sequentially.

Two fate characteristics often used to assess the potential environmental impacts resulting from the use of a pesticide are persistence and mobility. The persistence of the parent and degradates may indicate that a pesticide has a potential to contaminate ground water or surface water bodies (e.g., the longer the persistence, the greater the potential). Persistence is often expressed as a half-life ($T_{1/2}$), or the time necessary for the pesticide concentration to decrease to half the initial concentration. Laboratory environmental fate studies provide an understanding of the different dissipation pathways of the pesticide. These studies were used to obtain the aerobic and anaerobic soil metabolism half-lives. Pesticides and degradates that persist in the environment beyond a week or two can, under some circumstances, move beyond the microbial active soil layer and, therefore, increase their potential to enter ground water. Persistent compounds may also enter surface water bodies on eroded sediment or in runoff water. Persistence (half-lives) of terbufos is summarized in the following table.

Environmental Fate Data

Solubility	15ppm
Hydrolysis	15.4 days @ pH 5,7,9
Aerobic soil metabolism	27 days
Anaerobic soil metabolism	72.4 days
Aqueous photolysis	1 day
Leaching	K_{ads} 4.2-14.6 K_{oc} 297-1414
Field dissipation	24 days(not detected below 6 inches)
Degradates	K_{ads} of terbufos sulfoxide was 0.40 and terbufos sulfone was 0.55

The affinity of a pesticide to be bound or sorbed depends on soil properties such as clay type and organic carbon content, as well as chemical properties of the pesticide. The greater affinity for a compound to be sorbed by the soil, the lower the leaching potential. Pesticides sorbed to soil particles may however, be transported to surface water bodies. Two parameters related to the sorption of a chemical to soil are often reported to reflect a chemical's mobility. First, the Freundlich (K_{ads}) adsorption isotherm represents the relationship between the adsorbed concentration and the dissolved concentration at equilibrium. The often-used K_d (mL/g) is a special case of the Freundlich isotherm, where there is a linear relationship between the adsorbed and solution phase concentrations. The second is the soil sorption coefficient, or K_{oc} (mL/g organic carbon), which is calculated by dividing the K_d by the soil organic carbon content. The range of K_d and K_{oc} values for terbufos are listed in the above table.

Laboratory information on individual dissipation processes indicates the relative rates and interactions of the processes involved. Field data are interpreted in light of laboratory information. However, rates reported from all studies cannot be considered absolutes. Some degree of variability in the reported numbers is inherent in such studies; consequently, these numbers must be used in an appropriate and relative manner.

The major route of dissipation appears to be biotic degradation (aerobic half-life = 26.7 days in silt loam soil, anaerobic half-life = 72.4 days), abetted by hydrolysis (half-life = 2.2 weeks). If solubilized in runoff and carried to surface water, photolysis could be a major source of degradation ($T_{1/2}$ = 1 day).

Terbufos is slightly mobile to immobile in soils with reported K_{ads} values ranging from 5.42 in loamy sand to 14.6 in a loam soil. The major degradates identified in aerobic soil metabolism studies, terbufos sulfoxide and terbufos sulfone, are much more mobile, with reported K_{ads} values ranging from 0.40 to 2.93 in four soils. Reported field dissipation half-lives ranged from 24 to 40 days. Terbufos was not detected below 6 inches. Terbufos sulfone was not detected below 6 inches, and terbufos sulfoxide was not detected below 12 inches. Terbufos residues have been detected in ground water in four states (levels from 0.2 to 20 μg/L [ppb]) (USEPA, 1992).

Terbufos hydrolyzed with a reported half-life of 2.2 weeks in buffer solutions at pH 5.0, 7.0, and 9.0. Formaldehyde was the major degradate. The aqueous photolysis half-life was 1.1 day when exposed to xenon light.

The aerobic soil metabolism half-life in a silt loam was 27 days. The major degradates were terbufos sulfone and terbufos sulfoxide. Terbufos appeared moderately persistent in an anaerobic silt loam soil, with a reported half-life of 72 days. The identified degradates were terbufos sulfoxide, terbufos sulfone, and terbufoxon sulfoxide.

Terbufos appeared slightly mobile to immobile in four soils, with K_{ads} ranging from 4.2 (loamy sand) to 14.6 (loam). Terbufos sulfoxide and terbufos sulfone were more mobile, with reported K_{ads} values ranging from 0.4 (loamy sand) to 2.8 (silt loam) for terbufos sulfoxide and 0.55 (loamy sand) to 2.93 (silt loam) for terbufos sulfone.

Supplemental field dissipation studies indicated that terbufos dissipated with half-lives of 24 days (California), 14 days (Illinois), and 40 days (Colorado) in loam and sandy loam soils. Terbufos and terbufos sulfone were not detected below 6 inches. Terbufos sulfoxide was not detected below 12 inches.

Terbufos did not accumulate significantly in bluegill sunfish, with a reported BCF of 320X in fillet, 680X in whole fish, and 940X in visceral tissue. After 14 days depuration, there was 84% to 93% reduction.

<u>Aquatic Exposure Estimation</u>

The following section describes the aquatic exposure scenarios and results of the modeling efforts.

A. Expected Concentrations in Standard Pond and Soil

This section will:

- assess the probable levels of aquatic exposure of terbufos;

- calculate EECs in potential receiving waters in corn-growing areas.

The principal tools in this aquatic exposure assessment are environmental fate and transport computer models in use by EFGWB. This analysis uses the Pesticide Root Zone Model (PRZM1) to simulate pesticides in field runoff and the Exposure Analysis Modeling System (EXAMS) to simulate pesticide fate and transport in an aquatic environment.

This modeling assumes that each of the respective pesticides is applied to a 10-hectare field that is uniform in soil, slope and cropping characteristics. Rainfall and all other weather conditions are assumed to impact uniformly across the site. All runoff from this field drains into a 1-hectare, 2-meter-deep pond. The pond is constant in volume and is assumed to have no flows in or out. Pond water and pond bottom characteristics also remain constant except for temperature, which varies monthly.

Modeling is conducted on two diverse soil series selected to represent corn culture in the United States. The first is the Marshall silty clay loam taken as representative of a typical midwestern "average exposure" site in Iowa. The second is the Loring silt loam series in Mississippi chosen as a "high exposure" site with a highly erosive rainfall and highly erodible soil.

The sites are chosen because of the availability of actual measured runoff data for the soils which are found at both sites. This permits adjusting the modeled runoff amount if necessary to match the actual amount of runoff coming from the sites in response to a rainfall event.

Basic data on soils come from the data bases contained within the PRZM Input Calculator (PIC) and GLMSOIL programs and the National Resources Inventory (NRI). Corn culture and management information is taken from Universal Soil Loss Equation Handbook Predicting Erosion Losses and from the USDA Agricultural Research Service (ARS) and Soil Conservation Service (SCS) in Iowa, Missouri and Mississippi.

The typical "medium exposure" corn growing site chosen for this computer simulation is set in the USDA-ARS Treynor watershed 2 in Pottawottamie County, Iowa. The site is well characterized in terms of soil, topography and land use and has available extensive rainfall, runoff and sediment data. Data was collected from 1964 to present.

The second site is the "high exposure" site chosen to represent relatively adverse conditions. This site is near Jackson

Mississippi in Yazoo County. The Mississippi watershed in the heart of south-central Mississippi provides a site which contains a highly erodible soil and an very erosive rainfall. Rainfall and runoff data have also been collected at this site by the USDA Agricultural Research Service. Measured runoff on this soil series averages 35% annually. These sites together provide a wide range of runoff conditions.

The Pottawottamie County, IA site is gently rolling with two to five percent slopes. The Marshall silty clay loam is classified as a fine-silty, mixed, mesic Typic Hapludoll. The NRI soils data base gives USLE slope lengths of from 120 to 150 feet. The Mississippi site is also gently rolling land with slopes ranging from two to six percent. Slope lengths as used the Universal Soil Loss Equation (USLE) are 75 to 150 feet.

Marshall silty clay loam soil series is a deep, well drained, moderately permeable soil formed in loess on uplands and high stream benches. It has a ULSE K value of 0.32. Loring silt loam is a very highly erodible soil with a USLE K value of 0.49 and has a fragipan at a depth of about two feet. Soil characteristics are as estimated by the GLMSOIL program and by the PIC input file builder.

Weather for the PRZM simulations is 36 years of actual National Weather Service data as developed for MLRA 108 in Iowa and MLRA 134 in Mississippi for the PRZM program.

This PRZM and EXAMS simulations are carried out for 36 years, the maximum for which rainfall data are available at this location. The typical worst case is the 10-year return period for each simulation. This is between the third and forth largest years of the period modeled.

Curve numbers are used within the PRZM model to divide the portion of rainfall which infiltrates from the portion which runs off. These numbers are predicted by the PRZM Input Calculator file builder facility for each site based on the soil hydrologic group and the crop type. Because it is empirical and can be site specific, the curve number can be adjusted marginally upwards or downwards to make the modeled runoff values agree with the measured runoff data as a calibration exercise. This reduces one potential source of error in the modeling.

Soil loss ratios (USLE C values) were developed with the Universal Soil Loss Equation Handbook, "Predicting Erosion Losses". The scenario assumes fall plowing, moderate crop residues remaining on the field after harvest, good productivity, and continuous corn without rotation to another crop.

The modeling assumes contour plowing on a 3% slope. The USLE practice (P) factor is therefore taken as 0.5.

The 1-hectare by 2-meter pond that receives runoff from the 10-hectare field has the characteristics of the Georgia pond provided with the EXAMS program. The latitude and climatic regimes are similar between Mississippi and Georgia.

Input parameters

Table 1. lists the input parameters used in the modeling.

TABLE 1. Input Parameters for EXAMS

Terbufos

Variable	Description	Value	Units
HENRY	Henry's law rate	6.58e-3	atm-m^3/mole
KAH	Acid hydrol rate	0.0	hour^{-1}
KBACS	Benthic bact rate	4.0e-4	(cfu/mL)$^{-1}$hr^{-1}
KBACW	Water col bact rate	1.08e-3	(cfu/mL)$^{-1}$hr^{-1}
KBH	Base hydrol const	0.0	hour^{-1}
KDP	Direct photol rate	2.89e-2	hour^{-1}
KNH	Neutral hydrol rate	4.5e-2	hour^{-1}
KOC	Partition coef.	633	liter/kg
KOW	Octanol water part.		liter/kg
KPS	Sediment part. coef.		liter/kg
MWT	Molecular weight	288	grams/mole
QTBAS	Sediment bacteria temperature coef.	2	dimensionles s
QTBAW	Water bacteria temp coef	2	dimensionles s
SOL	Solubility	15.0	mg/liter
VAPR	Vapor pressure	2.6e-4	torr

Results:

Table 2. gives the expected concentrations in a standard, 1-hectare pond.

TABLE 2. Expected Concentrations in Standard, 1-Hectare Pond

Terbufos (Counter)									
Site	Applic Method	Incorp Depth (inch)	Applic Time	Applic Rate (#/ac)	Inst EEC	96-HR EEC	21-DAY EEC	60-DAY EEC	90-DAY EEC (PPB)
IA	Banded	- or 1	Plant	1.3	16.0	3.5	0.93	0.74	0.52
MS	Banded	- or 1	Plant	1.3	83.3	20.3	4.9	2.5	1.7
IA	Banded	- or 1	Plant	1.0	12.3	2.7	0.72	0.57	0.40
MS	Banded	- or 1	Plant	1.0	64.1	15.5	3.8	1.9	1.3
IA	Furrow	1	Plant	1.0	12.3	2.7	0.71	0.56	0.40
MS	Furrow	1	Plant	1.0	31.9	7.8	1.8	0.98	0.66

Terrestrial Exposure

Granular pesticide products such as terbufos represent an unique potential risk to nontarget wildlife in that granules may be ingested directly by birds foraging for seed and grit at or below the soil surface on treated areas. Birds and mammals may also ingest granules adhered to the surface of invertebrate prey items such as earthworms and grubs or through ingestion of water or food sources contaminted with pesticides. In addition wildlife species may receive dermal exposure through contact with treated soil.

Because of these somewhat unique routes of exposure, particularly the potential for direct ingestion of the formulated product, the Agency uses a different approach for estimating exposure than that used for foliar application. Granular exposure is estimated by the Agency on the amount of toxicant exposed per square foot of treated area. A square foot exposure area was first suggested as a basis of determining pesticide hazard to avian wildlife in the field more than 20 years ago (DeWitt 1966). Felthousen (1977) proposed the Agency classify granular pesticides on the basis of the amount of toxicant per square foot available to an animal following application. Exposure estimates using treated acres was based on studies that showed birds confined to band treated areas suffered greater mortality than birds confined to broadcast treated areas.

Incorporation of granules reduces the number of exposed granules. Several researchers have confirmed that both band and in-furrow applications of granular pesticides with incorporation using conventional commercial equipment greatly reduced the number of exposed granules, however does not eliminate potential exposure of non-targets. Beskid and Fink (1981) and Dingledine (1985) demonstrated substantial soil surface exposure of granular corn rootworm pesticides after incorporation by commercial farm equipment. Whitehead (1975) and Balcomb et al. (1984) reported that carbofuran granules were present on the soil surface after application in corn. Using a variety of incorporation techniques and several models of planters operated at different speeds, Hummel (1983) demonstrated that granule incorporation ranged from 69.0 to 96.3% for band and generally 99% for in-furrow application in a laboratory soil bin study. Erbach and Tollefson (1983) determined the number of granules exposed using conventional equipment averaged 6.9% following light incorporation (5.8% spring tine; 7.9% drag chain) after application in front of the press wheel, and averaged 11.7% following light incorporation (7.4% spring tine; 16.0% drag chain) after application behind the press wheel. Where no additional incorporation methods other than press wheel were utilized, the researchers counted 14.7% of applied granules visible after application in front of the press wheel, and 40.2% visible after application from behind the press wheel. These reported percentages probably underestimate the actual number of granules remaining because counts were within rows and did not include row ends. Also, fluorescent techniques used to detect granules were not 100% efficient and thus did not permit researchers to identify all of the granules in the study (Tollefson 1979).

Band application is specified on both terbufos product labels for all crops. The method of banding may be highly variable, depending on planter models used and the specific configuration selected by the operator. Optional settings of opening and closing discs, planter shoes, drop tubes, granule spreaders, press wheels, and type of following incorporation all result in variation in the number of granules potentially available to wildlife.

Terbufos granules may also be applied using in-furrow (at plant) or drill (below the seed furrow or side-dressed) and knifed-in applications. Use of a press wheel or other incorporating device following application decreases, but does not eliminate, the number of granules remaining exposed. Granules also become exposed when (1) machinery is being loaded, (2) application equipment is lifted out of the furrows to permit turning, (3) delivery tubes rise out of the ground on irregularly contoured fields, (4) soils are too wet or too dry to adequately fill in or cover the granules, and (5) application equipment is improperly calibrated or positioned. Further, label rates may be inadvertently exceeded during application; O'Brien (1987) reported it is not uncommon to find a 50% variation in granule application rate when ground speed is changed by as little as 2-3 miles per hour.

Varying numbers of exposed granules may result from each type of use specified on terbufos product labels. However, in an effort to quantify and simplify the percentage of product exposed after application, the Agency has conservatively used the following mean estimates (Table 3).

Table 3. Percentage of COUNTER granules remaining exposed after application and incorporation.

Application Method	% Exposure
Banded (in front or behind press wheel; applied over emerged plants[1]).	15
In-furrow; Drill; Knifed-in	1

[1] Because cultivators are positioned on either side of the row, granules directly in line with seedlings will not be incorporated; actual exposure is therefore likely to be greater than this value.

The Agency notes that these exposure values are estimated for along treated rows where some type of incorporation is concurrent with application. The number of granules that may be found in turn areas at row ends where application equipment is raised from the soil may be considerably higher than along rows. Although label directions specify deep disking at row ends, in actual use the applicator cannot practically do this immediately after granules are deposited. Estimates for the number of applied granules exposed in turn row areas are therefore determined without adjustments for incorporation.

The amount of Terbufos applied to each square foot of treated area for a labeled method of application is determined using the following calculation:

$$\text{ai (mg)/ft}^2 = \frac{\text{(oz product per 1000 ft of row * \% ai) * 28,349 mg/oz}}{\text{(1000 ft * width of band or furrow (ft))}}$$

$$\text{Exposed ai (mg)/ft}^2 = \text{ai (mg)/ft}^2 \text{ * \% unincorporated}$$

$$\text{Exposed granules per square foot} = \text{exposed mg ai/ft}^2 \text{ / (\% ai * granule weight)}$$

Results:

Tables 4,5,6, and 7 give the estimated concentrations of terbufos and number of granules on or near the soil surface. Also shown in these tables is the number of granules equivalent to an LD_{50} for bird and mammal species of varying sizes. While the weights selected are somewhat arbitrary, they were chosen to represent the range of weights of the majority of bird and mammal species that frequent agro-ecosystems where terbufos is used.

Risk Assessment

Non-Endangered Terrestrial Organisms

Granular pesticides, such as terbufos, are used throughout the United States to control pest insects in several agro-ecosystems. Granular formulations are often preferred over other formulations because they are safer to the applicator and easier to use. However, in some instances granular insecticides have been found to impact nontarget species. In the initial screen of these products the Agency uses risk indices that are based on the amount of toxicant per unit area for identifying granular pesticides which pose high risk and thus warrant closer examination to evaluate if modifications of use are required to reduce concerns. In assessing the potential impacts of these chemicals, in addition to the risk

TABLE 4. Estimated Number of Granules per Square Foot and Number of Granules per LD_{50} Index For Terbufos 20 CR

Use/application method	Formulation	Granule Wt.	App. Rate	Band Width	Percent Unincorporated	Amount of Active Ingredient Exposed[1]	No. of Exposed Granules[2]	No. of Granules /LD503 27 g bird[4]	No. of Granules/ LD_{50}[3] 170 g bird[4]
	(%AI/100)	(mg)	(oz/1000 ft of row)	(ft)	(decimal)	(mg/ft^2)	($/ft^2$)	granules	granules
Field Corn, Popcorn, & Sweet Corn Banded at planting	0.20	0.85	1.2	0.6	0.15	8.5	50.00	2.38	15.00
In-furrow at planting	0.20	0.85	1.2	0.1	0.01	3.4	20.00	2.38	15.00
Banded Post Emergence-incorporated	0.20	0.85	1.8	0.6	0.15	12.8	75.29	2.38	15.00
Banded At cultivation	0.20	0.85	1.2	0.6	0.15	8.5	50.00	2.38	15.00
Grain Sorghum Knifed-in at bedding	0.20	0.85	2.4	0.1	0.01	6.8	40.00	2.38	15.00
Knifed-in at planting	0.20	0.85	1.2	0.1	0.15	8.5	50.00	2.38	15.00
Sugarbeets Banded at planting	0.20	0.85	1.2	0.6	0.15	8.5	50.00	2.38	15.00
Knifed-in at planting	0.20	0.85	2.4	0.1	0.01	6.8	40.00	2.38	15.00
Banded at planting	0.20	0.85	1.2	0.6	0.15	8.5	50.00	2.38	15.00
Modified in-furrow at planting	0.20	0.85	1.2	0.1	0.01	3.4	20.00	2.38	15.00
Banded Post-Emergence	0.20	0.85	1.2	0.6	0.15	8.5	50.00	2.38	15.00

1. Amount of pesticide exposed = {[oz. ai/1000 ft of row] * 28349mg/oz}/[1000 ft of row * band width * % unincorporated]
2. No. exposed granules = (mg ai/ft^2)/(% ai product/ granule wt)
3. No. granules per LD_{50} = (LD_{50} * body wt.)/(%ai*100 * granule wt.)
4. Sparrow size bird with LD_{50} = 15 mg/kg
5. Quail size bird LD_{50} = 15 mg/kg

TABLE 5. Estimated Number of Granules per Square Foot and Number of Granules per LD_{50} Avian Index For Terbufos 15 G

Use/application method	Formulation	Granule Wt.	App. Rate	Band Width	Percent Unincor-porated	Amount of Active Ingredient Exposed[1]	No. of Exposed Granules[2]	No. of Granules/LD_{50}[3] 27 g bird[4]	No. of Granules/ ED50[5] 170 g bird[5]
	(%AI/100)	(mg)	(oz/1000 ft of row)	(ft)	(decimal)	(mg/ft²)	(/ft²)	granules	granules
Field Corn, Popcorn, & Sweet Corn, Banded at planting	0.15	0.066	1.2	0.6	0.15	8.50	858.59	40.91	257.58
In-furrow, at planting	0.15	0.066	1.2	0.1	0.01	3.40	343.43	40.91	257.58
Sugarbeets, banded at planting	0.15	0.066	1.2	0.6	0.15	8.50	858.59	40.91	257.58
In-furrow at planting	0.15	0.066	1.2	0.1	0.01	3.40	343.43	40.91	257.58
Post-Emergence	0.15	0.066	1.2	0.6	0.15	8.50	858.59	40.91	257.58
Grain Sorghum Banded at planting	0.15	0.066	1.2	0.6	0.15	8.50	858.59	40.91	257.58

1. Amount of pesticide exposed = {[oz. ai/1000 ft of row] * 28349mg/oz}/[1000 ft of row * band width * % unincorporated]
2. No. exposed granules = (mg ai/ft²)/(% ai product/ granule wt)
3. No. granules per LD_{50} = (LD_{50} * body wt.)/(%ai*100 * granule wt.)
4. Sparrow size bird with LD_{50} = 15 mg/kg
5. Quail size bird LD_{50} = 15 mg/kg

TABLE 6. Estimated Number of Granules per Square Foot and Number of Granules per LD_{50} Mammalian Index For Terbufos 15 G

Use/application method	Formulation	Granule Wt.	App. Rate	Band Width	Percent Unincorporated	Amount of Active Ingredient Exposed[1]	No. of Exposed Granules[2]	No. of Granules/ LD_{50}[3] 25 g mammal[4]	No. of Granules/ LD_{50} 1 kg mammal
	(%AI/100)	(mg)	(oz/1000 ft of row)	(ft)	(decimal)	(mg/ft^2)	(/ft^2)	granules	granules
Field Corn, Popcorn, & Sweet Corn, Banded at planting	0.15	0.066	1.2	0.6	0.15	8.50	858.59	3.97	158.59
In-furrow, at planting	0.15	0.066	1.2	0.1	0.01	3.40	343.43	3.97	158.59
Sugarbeets, banded at planting	0.15	0.066	1.2	0.6	0.15	8.50	858.59	3.97	158.59
In-furrow at planting	0.15	0.066	1.2	0.1	0.01	3.40	343.43	3.97	158.59
Post-Emergence	0.15	0.066	1.2	0.6	0.15	8.50	858.59	3.97	158.59
Grain Sorghum Banded at planting	0.15	0.066	1.2	0.6	0.15	8.50	858.59	3.97	158.59

1. Amount of pesticide exposed = {[oz. ai/1000 ft of row] * 28349mg/oz}/[1000 ft of row * band width * % unincorporated]
2. No. exposed granules = (mg ai/ft^2)/(% ai product/ granule wt)
3. No. granules per LD_{50} = (LD_{50} * body wt.)/(%ai*100 * granule wt.)
4. Mouse size mammal with LD_{50} = 3.5 mg/kg

TABLE 7. Estimated Number of Granules per Square Foot and Number of Granules per LD_{50} Index For Terbufos 20 CR for Mammals

Use/application method	Formulation	Granule Wt.	App. Rate	Band Width	Percent Unincorporated	Amount of Active Ingredient Exposed[1]	No. of Exposed Granules[2]	No. of Granules/ LD_{50}[3] 25 g mammal[4]	No. of Granules/ LD_{50} 1 kg mammal
	(%AI/100)	(mg)	(oz/1000 ft of row)	(ft)	(decimal)	(mg/ft²)	(/ft²)	(granules)	(granules)
Field Corn, Popcorn, & Sweet Corn Banded at planting	0.20	0.85	1.2	0.6	0.15	8.50	50.00	0.23	9.24
In-furrow at planting	0.20	0.85	1.2	0.1	0.01	3.40	20.00	0.23	9.24
Banded Post Emergence-incorporated	0.20	0.85	1.8	0.6	0.15	12.76	75.06	0.23	9.24
Banded At cultivation	0.20	0.85	1.2	0.6	0.15	8.50	50.00	0.23	9.24
Grain Sorghum Knifed-in at bedding	0.20	0.85	1.2 to 2.4	0.1	0.01	3.40	20.00	0.23	9.24
Knifed-in at planting	0.20	0.85	1.2	0.1	0.15	51.03	300.18	0.23	9.24
Sugarbeets Banded at planting	0.20	0.85	1.2	0.6	0.15	8.50	50.00	0.23	9.24
Knifed-in at planting	0.20	0.85	2.4	0.1	0.01	6.80	40.00	0.23	9.24
Banded at planting	0.20	0.85	1.2	0.6	0.15	8.50	50.00	0.23	9.24
Modified in-furrow at planting	0.20	0.85	0.6 to 1.2	0.1	0.01	1.70	10.00	0.23	9.24
Banded Post-Emergence	0.20	0.85	0.6 to 1.2	0.6	0.15	4.25	25.00	0.23	9.24

1. Amount of pesticide exposed = {[oz. ai/1000 ft of row] * 28349mg/oz}/[1000 ft of row * band width * % unincorporated]
2. No. exposed granules = (mg ai/ft²/(% ai product/ granule wt)
3. No. granules per LD_{50} = (LD_{50} * body wt.)/(%ai*100 * granule wt.)
4. Mouse size mammal with LD_{50} = 1.57 mg/kg

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indices several factors , or combinations of factors need to be considered. These include:

* The chemical proprieties of the pesticide (e.g. persistence, bioaccumilation;

* Intended use pattern (e.g. treated habitats, expected presence of species, extent of use areas, number of applications and treatment intervals time of application;

* Characteristics of the granule including size, shape and surface texture, composition of the carrier material, color, the period that they remain intact after application and the concentration of the toxicant per granule.

* Field and incident data;

In assessing these factors a great deal of judgment is required. The correlation between the index and field effects is poorly defined due to the numerous variables involved. These above parameters have been identified as variables which can influence the impact of the chemical in the environment, however limited information is available which defines the degree to which each or a combination of these factors affects the magnitude of impacts. The Agency believes that these factors need to be weighed to the extent possible to evaluate the potential impacts to nontarget organisms from the use of pesticides, if not quantitatively, at least qualitatively.

Terbufos is formulated only in granular products marketed under the product names Counter 15G and Counter 20 CR. The 15 G formulation, a clay granule weighing 0.066 mg, and the 20 CR formulation, a plastic granule weighing 0.85 mg, contain 15 % and 20% active ingredient, respectively. A restricted use granular systemic organophosphate soil insecticide/nematocide, is used for the control of rootworms and nematodes in corn as well as in other crops, sugarbeets and grain sorghum. Approximately 90% of the 5-10 million pounds of terbufos used annually is applied during the spring (usually April, May) of the year to field corn acreage nationwide. Label instructions for corn permit one ground application at a maximum rate of 1.8 ai per 1000 ft of row for the 20 CR formulation and 1.2 ai per 1000 feet of row for the 15 g formulation. Label instructions for grain sorghum permit one ground application at a maximum rate of 2.4 ai per 1000 ft of row for the 20 CR formulation and 1.2 ai per 1000 feet of row for the 15 g formulation. Label instructions for sugarbeets permit one ground application at a maximum rate of 2.4 ai per 1000 ft of row for the 20 CR formulation and 1.2 ai per 1000 feet of row for the 15 g formulation.

Acute Avian Risk Indices

Terbufos is classified as very highly toxic to birds based on acute oral toxicity studies. Testing of the technical grade material resulted in LD50 values of 15 mg/kg and 29 mg/kg for the bobwhite quail in two separate tests. Dietary testing resulted in LC50 values of 143 and 157 ppm for the bobwhite quail.

As mentioned previously, granular products represent an unique potential hazard to nontarget wildlife in that granules may be ingested directly by birds foraging for seed and grit at or below the soil surface on treated areas. Birds may also ingest granules adhered to the surface of invertebrate prey items such as earthworms and grubs. Further, exposure may occur form contaminated food items after the chemical has moved from the granule and some exposure may occur through dermal absorption from either contact with surface granules of contaminated soil. While the contribution of each of these exposure routes is poorly defined, the Agency uses a risk index based on the number of LD50's to an individual animal per ft^2 exposed on or near the soil surface to indicate the potential to impact nontarget terrestrial species. Using the previous exposure information on toxicant per unit area the following formula gives the risk index used by the Agency to indicate potential effects to non-target terrestrial organisms.

$$\frac{\text{Granules}}{ft^2} \Big/ \frac{\text{Granules}}{LD_{50}} = \frac{LD_{50}}{ft^2}$$

Risk indices greater than 0.5 LD_{50}/ft^2 (level of concern) is considered to indicate the potential for high risk to non-target terrestrial organisms. Tables 8 and 9 show the avian risk indices for the various uses and application methods of terbufos.

For terbufos for both formulations, 15G and the 20CR, the risk indices ranges for in-furrow application from a minimum of 1.33 for a 170 gram bird (quail size bird) to 8.4 for a 27 gram bird (sparrow size bird). For knifed-in applications indices range from 2.67 to 21.01. For banded application of terbufos the index range is somewhat greater due to the less efficient soil incorporation accomplished with this method of application. Indexes for banded applications of terbufos range from a minimum of 3.33 for a 170 gram bird to 31.63 for a 27 gram bird. Therefore, the index suggests that terbufos presents an acute hazard to nontarget terrestrial species for both formulations and for all use rates and application methods with banded application resulting in somewhat higher exposure, or that, **for all uses, the level of concern is exceeded** (Tables 10 & 11). It should be noted that these index values are estimated for along treated rows where some type of incorporation is concurrent with application. The number of granules that may be found in turn areas at row ends where application equipment is raised from the soil may be considerably higher than along rows significantly increasing the above indexes.

TABLE 8. 20 CR ACUTE AVIAN RISK INDICES

USE/APPLICATION METHOD	FORMULATION	NO. OF EXPOSED GRANULES/FT^2	NO. OF GRANULES/ LD_{50} 27 G BIRD	NO. OF GRANULES/ LD_{50} 170 G BIRD	RISK INDEX LD_{50}/FT^2 27 G BIRD	RISK INDEX LD_{50}/FT^2 170 G BIRD
FIELD CORN, POPCORN & SWEET CORN, BANDED AT PLANTING	20 CR	50.0	2.38	15.0	21.01	3.33
IN-FURROW AT PLANTING	20 CR	20.0	2.38	15.0	8.40	1.33
BANDED POST EMERGENCE INCORPORATED	20 CR	75.29	2.38	15.0	31.63	5.02
BANDED, AT CULTIVATION	20 CR	50.0	2.38	15.0	21.01	3.33
GRAIN SORGHUM KNIFED-IN AT BEDDING	20 CR	40.0	2.38	15.0	16.81	2.67
KNIFED-IN AT PLANTING	20 CR	50.0	2.38	15.0	21.01	3.33
SUGARBEETS BANDED AT PLANTING	20 CR	50.0	2.38	15.0	21.01	3.33
KNIFED-IN AT PLANTING	20 CR	40.0	2.38	15.0	16.81	2.67
MODIFIED IN-FURROW AT PLANTING	20 CR	20.0	2.38	15.0	8.40	1.33
BANDED POST EMERGENCE	20 CR	50.0	2.38	15.0	21.01	3.33

TABLE 9. 15 G AVIAN ACUTE RISK INDICES

USE/APPLICATION METHOD	FORMULATION	NO. OF EXPOSED GRANULES/FT^2	NO. OF GRANULES/ LD_{50} 27 G BIRD	NO. OF GRANULES/ LD_{50} 170 G BIRD	RISK INDEX LD_{50}/FT^2 27 G BIRD	RISK INDEX LD_{50}/FT^2 170 G BIRD
FIELD CORN, POPCORN & SWEET CORN, BANDED AT PLANTING	15 G	858.59	40.91	257.58	20.99	3.33
IN-FURROW AT PLANTING	15 G	343.43	40.91	257.58	8.39	1.33
GRAIN SORGHUM BANDED AT PLANTING	15 G	858.59	40.91	257.58	20.99	3.33
SUGARBEETS BANDED AT PLANTING	15 G	858.59	40.91	257.58	20.99	3.33
IN-FURROW AT PLANTING	15 G	343.43	40.91	257.58	8.39	1.33
POST EMERGENCE BANDED	15 G	858.59	40.91	257.58	20.99	3.33

TABLE 10. Avian Risk Quotients and LOC's for 20 CR

USE/APPLICATION METHOD	FORMULATION/ APPLICATION RATE	RISK INDEX LD_{50}/FT 27 G BIRD	RISK INDEX LD_{50}/FT 170 G BIRD	LOC
FIELD CORN, POPCORN & SWEET CORN, BANDED AT PLANTING	20 CR 1.2 oz/1000 ft of row	21.01	3.33	High Risk > 0.5 RU > 0.2 ES > 0.1
IN-FURROW AT PLANTING	20 CR 1.2 oz/1000 ft of row	8.40	1.33	High Risk > 0.5 RU > 0.2 ES > 0.1
BANDED POST EMERGENCE INCORPORATED	20 CR 1.8 oz/1000 ft of row	31.63	5.02	High Risk > 0.5 RU > 0.2 ES > 0.1
BANDED, AT CULTIVATION	20 CR 1.2 oz/1000 ft of row	21.01	3.33	High Risk > 0.5 RU > 0.2 ES > 0.1
GRAIN SORGHUM KNIFED-IN AT BEDDING	20 CR 2.4 oz/1000 ft of row	16.81	2.67	High Risk > 0.5 RU > 0.2 ES > 0.1
KNIFED-IN AT PLANTING	20 CR 1.2 oz/1000 ft of row	21.01	3.33	High Risk > 0.5 RU > 0.2 ES > 0.1
SUGARBEETS BANDED AT PLANTING	20 CR 1.2 oz/1000 ft of row	21.01	3.33	High Risk > 0.5 RU > 0.2 ES > 0.1
KNIFED-IN AT PLANTING	20 CR 2.4 oz/1000 ft of row	16.81	2.67	High Risk > 0.5 RU > 0.2 ES > 0.1
MODIFIED IN-FURROW AT PLANTING	20 CR 1.2 oz/1000 ft of row	8.40	1.33	High Risk > 0.5 RU > 0.2 ES > 0.1
BANDED POST EMERGENCE	20 CR 1.2 oz/1000 ft of row	21.01	3.33	High Risk > 0.5 RU > 0.2 ES > 0.1

Table 11. Avian Risk Quotients and LOC's for 15 G

Use/Application Method	Formulation / Use Rate	Risk Index LD_{50}/ft 27 g Bird	Risk Index LD_{50}/ft 170 g Bird	LOC
Field corn, popcorn & sweet corn, banded at planting	15 g 1.2 oz/1000 ft of row	20.99	3.33	High Risk > 0.5 RU > 0.2 ES > 0.1
In-furrow at planting	15 g 1.2 oz/1000 ft of row	8.39	1.33	High Risk > 0.5 RU > 0.2 ES > 0.1
Grain sorghum banded at planting	15 g 1.2 oz/1000 ft of row	20.99	3.33	High Risk > 0.5 RU > 0.2 ES > 0.1
Sugarbeets banded at planting	15 g 1.2 oz/1000 ft of row	20.99	3.33	High Risk > 0.5 RU > 0.2 ES > 0.1
In-furrow at planting	15 g 1.2 oz/1000 ft of row	8.39	1.33	High Risk > 0.5 RU > 0.2 ES > 0.1
Post emergence banded	15 g 1.2 oz/1000 ft of row	20.99	3.33	High Risk > 0.5 RU > 0.2 ES > 0.1

Mammal Risk Indices

Mammals appear to be somewhat more sensitive to terbufos than birds. Terbufos is also classified as very highly toxic to mammals based on acute oral toxicity studies, but toxicity values are somewhat lower. Testing of the technical grade material resulted in LD50 values that ranged from 1.57 mg/kg to 4.5 mg/kg for the laboratory rat and dog, respectively. Dietary testing resulted in a 30 day LC50 value of 26 ppm for the rat.

As mentioned previously, granular products represent an unique potential hazard to nontarget wildlife. Mammals have the same potential sources of exposure to granules as birds, with the exception of grit. Granules may be ingested directly while foraging for seeds or insects at or below the soil surface on treated areas. Mammals may also ingest granules adhered to the surface of invertebrate prey items. Further, exposure may occur form contaminated food items after the chemical has moved from the granule and some exposure may occur through dermal absorption from either contact with surface granules of contaminated soil. As with birds, the Agency uses a risk index based on the number of LD50's to a individual animal per ft^2 exposed on or near the soil surface to indicate the potential to impact nontarget mammals. Tables 12 and 13 show the mammalian risk indices for the various uses and application methods of terbufos.

For terbufos for both formulations, 15G and the 20CR, the risk indices ranges for in-furrow applications from 2.16 for a 1 kilogram(kg) mammal (cottontail rabbit sized mammal) to 217 for a 25 gram mammal (meadow mice sized mammal). For knifed-in applications indices range from 4.33 for a 1 kg mammal to 173.9 for a 25 gram mammal. For banded application of terbufos the index range is somewhat greater due to the less efficient soil incorporation accomplished with this method of application. Indexes for banded applications of terbufos range from a minimum of 5.41 for a 1 kilogram mammal to 217 for a 25 gram mammal. Therefore, the index suggests that terbufos presents a acute hazard to mammalian species for both formulations and for all use rates and application methods with banded application resulting in somewhat higher exposure or that, **for all uses, the level of concern is exceeded (Tables 14 & 15)**. It should be noted that these index values are estimated for along treated rows where some type of incorporation is concurrent with application. The number of granules that may be found in turn areas at row ends where application equipment is raised from the soil may be considerably higher than along rows significantly increasing the above indices.

Table 12. 20 CR Mammal Acute Risk Indices

Use/application method	Formulation	No. of exposed Granules/ft²	No. of Granules/LD_{50} 35 g Mammal	No. of Granules/LD_{50} 1kg Mammal	Risk Index LD_{50}/ft² 25 g Mammal	Risk Index LD_{50}/ft² 1 kg Mammal
Field Corn, Popcorn & Sweet Corn, Banded at Planting	20 CR	50.0	0.23	9.24	217.39	5.41
In-furrow at Planting	20 CR	20.0	0.23	9.24	86.96	2.16
Banded Post Emergence Incorporated	20 CR	75.29	0.23	9.24	327.35	8.15
Banded, at Cultivation	20 CR	50.0	0.23	9.24	217.39	5.41
Grain Sorghum Knifed-in at Bedding	20 CR	40.0	0.23	9.24	173.91	4.33
Knifed-in at Planting	20 CR	50.0	0.23	9.24	217.39	5.41
Sugarbeets Banded at Planting	20 CR	50.0	0.23	9.24	217.39	5.41
Knifed-in at Planting	20 CR	40.0	0.23	9.24	173.91	4.33
Modified In-furrow at Planting	20 CR	20,0	0.23	9.24	86.96	2.16
Banded Post Emergence	20 CR	50.0	0.23	9.24	217.39	5.41

Table 13. 15 G Mammal Acute Risk Indices

Use/application method	Formulation	No. of exposed Granules/ft^2	No. of Granules/ LD_{50} 25 g Mammal	No. of Granules/ LD_{50} 1kg Mammal	Risk Index LD_{50}/ft^2 25 g Mammal	Risk Index LD_{50}/ft^2 1kg mammal
Field Corn, Popcorn & Sweet Corn, Banded at Planting	15 G	858.59	3.97	158.59	216.27	5.41
In-furrow at Planting	15 G	343.43	3.97	158.59	86.51	2.17
Grain Sorghum Banded at Planting	15 G	858.59	3.97	158.59	216.27	5.41
Sugarbeets Banded at Planting	15 G	858.59	3.97	158.59	216.27	5.41
In-furrow at Planting	15 G	343.43	3.97	158.59	86.51	2.17
Post Emergence Banded	15 G	858.59	3.97	158.59	216.27	5.41

Table 14. Mammal Acute Risk Quotients and LOC's for Terbufos 20 CR

USE/APPLICATION METHOD	FORMULATION/ APPLICATION RATE	RISK INDEX LD_{50}/FT 25 G Mammal	RISK INDEX LD_{50}/FT 1 kg Mammal	LOC
FIELD CORN, POPCORN & SWEET CORN, BANDED AT PLANTING	20 CR 1.2 oz/1000 ft of row	217.39	5.41	High Risk > 0.5 RU > 0.2 ES > 0.1
IN-FURROW AT PLANTING	20 CR 1.2 oz/1000 ft of row	86.96	2.16	High Risk > 0.5 RU > 0.2 ES > 0.1
BANDED POST EMERGENCE INCORPORATED	20 CR 1.8 oz/1000 ft of row	327.35	8.15	High Risk > 0.5 RU > 0.2 ES > 0.1
BANDED, AT CULTIVATION	20 CR 1.2 oz/1000 ft of row	217.39	5.41	High Risk > 0.5 RU > 0.2 ES > 0.1
GRAIN SORGHUM KNIFED-IN AT BEDDING	20 CR 2.4 oz/1000 ft of row	173.91	4.33	High Risk > 0.5 RU > 0.2 ES > 0.1
KNIFED-IN AT PLANTING	20 CR 1.2 oz/1000 ft of row	217.39	5.41	High Risk > 0.5 RU > 0.2 ES > 0.1
SUGARBEETS BANDED AT PLANTING	20 CR 1.2 oz/1000 ft of row	217.39	5.41	High Risk > 0.5 RU > 0.2 ES > 0.1
KNIFED-IN AT PLANTING	20 CR 2.4 oz/1000 ft of row	173.91	4.33	High Risk > 0.5 RU > 0.2 ES > 0.1
MODIFIED IN-FURROW AT PLANTING	20 CR 1.2 oz/1000 ft of row	86.96	2.16	High Risk > 0.5 RU > 0.2 ES > 0.1
BANDED POST EMERGENCE	20 CR 1.2 oz/1000 ft of row	217.39	5.41	High Risk > 0.5 RU > 0.2 ES > 0.1

Table 15. Mammal Acute Risk Quotients and LOC's for 15 G

Use/Application Method	Formulation / Use Rate	Risk Index LD_{50}/ft 25 g Mammal	Risk Index LD_{50}/ft 1 KG Mammal	LOC
Field corn, popcorn & sweet corn, banded at planting	15 g 1.2 oz/1000 ft of row	216.27	5.41	High Risk > 0.5 RU > 0.2 ES > 0.1
In-furrow at planting	15 g 1.2 oz/1000 ft of row	86.51	2.17	High Risk > 0.5 RU > 0.2 ES > 0.1
Grain sorghum banded at planting	15 g 1.2 oz/1000 ft of row	216.27	5.41	High Risk > 0.5 RU > 0.2 ES > 0.1
Sugarbeets banded at planting	15 g 1.2 oz/1000 ft of row	216.27	5.41	High Risk > 0.5 RU > 0.2 ES > 0.1
In-furrow at planting	15 g 1.2 oz/1000 ft of row	86.51	2.17	High Risk > 0.5 RU > 0.2 ES > 0.1
Post emergence banded	15 g 1.2 oz/1000 ft of row	216.27	5.41	High Risk > 0.5 RU > 0.2 ES > 0.1

Chronic Risk

Laboratory studies indicate that terbufos may present chronic effects. Results of an mallard chronic study suggested possible, but not statistically significant effects on embryo viability at dietary levels of 15 ppm terbufos. (Beavers 1986a) Another study with bobwhite quail found no reproductive effects at dietary levels up to 30 ppm terbufos (Beavers 1986b). From the above mallard chronic study, a NOEL of 15 ppm may be derived. A three generation rat reproduction study with technical Terbufos reported a NOEL of 0.25 ppm and a LOEL of 1 ppm. Major effect observed was an increase in offspring deaths as compared to controls.

While no standard procedures have been develop to calculate chronic risk indices for granular products, it seems reasonable to assume for chemicals like terbufos, if acute risk indices exceed LOC's indicating acute toxic levels in the environment, these levels would also exceed chronic levels. Therefore, while no chronic risk indices will be generated, since acute risk indices are exceeded for all uses of terbufos, it indicates that at least initial concentrations in the environment from all uses of terbufos would also exceed chronic levels of concerns. Hence, **for all terbufos uses, the chronic level of concern is exceeded.**

Other Factors Influencing Risk

In addition to the indexes, as mentioned above, other factors need to be considered when evaluating the potential for effects to nontarget wildlife. These include characteristics of the granule including size, shape and surface texture, composition of the carrier material, color, the period that they remain intact after application, the concentration of the toxicant per granule and the chemical proprieties of the pesticide (e.g. persistence, bioaccumilation).

For avian species the similarity of the granular to natural forage or grit has been suggested as a important characteristic which may influence ingestion of granules. While direct ingestion is not the only route of exposure, and in some instances may not be the primary route, it can contribute significantly under some circumstances. The terbufos 15 G formulation granules are made of clay (attapulgite, montmorillionite and kaolin) weighing from 0.056 to .080 mg, average 0.066 with a mesh size of 24 to 48 or .3 to .84 mm. The terbufos 20 CR formulation granules are made of a plastic resin weighing from 0.51 to 1.47 mg, average 0.85 mg, with a mesh size of 16 to 20 or 0.84 to 1.19 mm. Although the mean grit sizes found in gizzards of some larger bird species exceed the upper size range for terbufos granules, almost all species have some grit (0.2 to 1.2 mm) in their gizzard which overlaps the size range of terbufos granules. However, grit size distribution profiles of most species have definite peaks, with the grit found in gizzards declining abruptly on either side of the preferred grit size. Thus, on the basis of grit size, there is the potential that most common bird species associated with agro-ecosystems to consume terbufos granules for grit. The likelihood, however, that granules will be consumed is dependent in part on the over lap in size between the grit naturally consumed and the insecticide granules. The greater the overlap, the more probable the consumption. A comparison of grit size consumed by species and granule size could help identify species at high risk, unfortunately, grit consumption profiles for most birds species is not available for this analysis.

However, since it appears that most bird species have some grit in their gizzard that overlaps the size range of terbufos granules, the likelihood of ingesting a lethal number would seem to be related to the number of granules containing an LD50, their availability and their size. The indexes discussed above address this in some what a different manner, however, further insight into the likelihood of ingesting a lethal dose may be gained by examining the number of granules which contain an LD50, and the number available. It seems logical, since, most species will consume at least a few grit particals in the size range of terbufos granules, the fewer the number of granules equal to a toxic dose, the greater the number of species at risk. Also, given the inverse relationship of grit size selection by avian species and toxic dose to a individual, as the size of the granule increases within the range of grit size utilized by birds, the risk to avian species may also increase.

For the 20CR formulation, the overlap in granule size and grit utilized by birds is in the higher range. The 20CR granule range in size from 0.84 to 1.19 mm compared to grit utilized by avian species in and around corn fields ranging in size from .2 to 1.2 mm. With 2 to 15 granules estimated to be equivalent to an LD50 depending on weight of the bird, seem to suggest the potential to impact a variety of species. That is, small birds would be expected to consume relative few large granules, however, only a few are required to equal a lethal dose. While, larger birds require on the average a greater number of granules to equal a lethal dose, they have a higher likelihood to consume a larger number of the large granules.

For the 15G formulation, the overlap in granule size and grit utilized by birds is on the lower spectrum. The 15G granule range in size is from approximately 0.3 to 0.84 mm compared to grit utilized by avian species in and around corn fields ranging in size from .2 to 1.2 mm. With 41 to 257 granules estimated to be equivalent to an LD50 depending on weight of the bird, seem to suggest that larger avian species are at lower risk due both to the relative large number of granules need to equal an LC50 and the lower probability of larger birds consuming the smaller granules in comparison to the range of grit sizes utilized by avian species in and around corn fields.

The composition of the granule may also influence avian risk. The composition of the carrier may affect the likelihood that the granule will be mistakenly consumed as a source of grit or food; the composition may influence the integrity of the granule in the field after application; and the composition may influence how long the insecticide remains on the granules and in what amounts. The materials used for terbufos, clay or plastic resin, would not seem to be similar to materials normally consumed as grit by avian species (i.e. quartz). However, they may be mistakenly consumed as a source of grit in that they overlap the size range of grit particles consumed by birds, however the likelihood of this is unknown. Further influencing the likelihood of consumption is the rate granules disintegrate in the environment. Granular carriers which breakdown rapidly have a shorter period to be mistaken for grit reducing the likelihood of ingestion. While the clay granule, when exposed to soil moisture and precipitation, would seem to be relatively short lived, no information is available which address its breakdown rate under any environmental conditions. The 20CR plastic resin granule may be longer lived, however, no information is available which address its breakdown rate under any environmental conditions, either. Even if the granule is relative long lived, the rate the chemical dissipates from the granule would influence it potential effects. Granules, without insecticides present minimal hazard. Unfortunately this information is not available either.

For the most part these factors have not been investigated to define the influence of these factors for the two formulations. However, a pen study (Pederson 1990) was completed which attempted to compare the relative risk of the two formulations of terbufos to avian species. Bobwhite quail and brown headed cowbirds were exposed to a application of terbufos at a target rate of 1.3 lbs ai/A. Half the test pens were treated with 15G and the other half were treated with 20 CR with equal applications of in-furrow and banded treatments between formulations. The cowbirds had the most mortality in this study. When Terbufos was applied in a band, statistically significant increases in mortality were noted in both the 15G and 20CR treatments in comparison to controls. Also there was a statistically significant reduction in mortality in pens treated with 20CR verses those pens treated with 15G. When terbufos was applied in-furrow there was a statistically significant increase in mortality in pens treated with the 15G and the 20CR formulations in comparison to the control pens. For the in-furrow applications there was not a significant difference in mortality in pens treated with the 20CR formulation in comparison to pens treated with the 15G formulation.

For the bobwhite quail, there were no statistically significant differences in mortality between the control pens and the pens treated with either formulation. In addition, no statistically significant difference in bobwhite quail mortality was found between formulations.

While the difference in cowbird mortality rate between 20CR and 15G banded pens was founded to be statistically significant, care must be employed in extrapolating these results. While not statistically significant, the tend in the opposite direction, higher mortality in the 20CR than the 15G, in the in-furrow pens seems to caution against suggesting a difference between the two formulations in potential to impact non-target species.

Results of these pen trials suggest that both formulations have the potential to impact non-target wildlife species. However, the data collected is insufficient to draw inferences about the relative hazard of the two formulation to non-target species under actual use conditions.

Field and Incident Reports

Documented wildlife field kills or observations of adverse effects due to terbufos either through field studies or incident reports are useful information in evaluating the hazards associated with the use of terbufos to nontarget organisms. Three studies evaluating the effects of terbufos under field conditions have been conducted. Although most of these studies have been limited in scope and sensitivity, they have show some effects, both acute and chronic. However while results are somewhat equivocal, effects detected appear limited in extent and intensity.

In comparing the results of the three field studies care must be employed in that application rates were significantly different as well as location and techniques used. The central Illinois study application rate was 1 lb ai/A and the Maryland study was 2.6 lbs ai/A. Only the Iowa study used 1.3 lbs ai/A. At the lower rate in Illinois at 1 lb ai/A, two dead birds were found: a common grackle and a killdeer. No terbufos residues were detected in the killdeer; the grackle contained 2.74 ppm. In addition, 22 other specimens were collected and analyzed. Two deer mice and a house mouse contained terbufos residues. In the second study in Maryland at the higher use rate fewer carcasses were found. Two dead birds, an eastern bluebird and a mourning dove, seven feather spots, and two dead reptiles, a black rat snake and a box turtle, were found. Three additional birds were found alive, a blue jay, a brown-headed cowbird and a robin, but exhibiting what was reported to appear to be signs of acute cholinergic poisoning (i.e. lower limb rigidity, wing droop, salvation). All three affected birds were sacrificed as soon as recovery was evident and analyzed for residues. The blue jay collected alive had detectable levels of terbufos (0.24 ppm) as well as the bluebird fledgling (0.15 ppm). No other residues were found.

In evaluating field study results, the sensitivity of the study design needs to be considered in interpreting results. Rosene and Lay (1963) found that dead birds are easily over looked in the field even by experienced and highly motivated observers.

Intoxicated animals may move to heavier cover before dying, decreasing the probability of detection. Poisoned birds may fly away from sites, succumbing outside of search areas. Scavengers may also remove carcasses before they can be found. Balcomb (1986) found that as high as 92% of song birds carcasses placed in corn fields disappeared 24 hours after placement. When these factors are not accounted for in studies using carcass searching to evaluate impacts results may under estimate the extent of the actual hazard. As Rosene and lay (1963) point out, finding even a few dead animals may suggest that there has been considerable mortality.

While interpretation of the two above studies appears to be limited by the above mentioned sensitivity problem, the three seasons of field work in south central Iowa from 1987 to 1989 help clarify the above study results. While the south central Iowa study is not with out questions, and the initial two seasons of study were indicated to be mainly to develop and refine techniques, results of the third year of the Iowa study also showed relative low exposure to most species sampled. Results of terbufos residue analysis in food of wildlife species as well as in different avian and mammalian species showed most with residues below detectable limits. In the few samples which residues were detected, general less than 2%, residues appeared minimal, less than a ppm. Biological monitoring of nesting success or survival in several species reveled no difference between treatments and controls. Survival rates in radio-tagged eastern cottontails and bobwhite quail were not different between treatments and control. Nesting success for 16 bird species monitored showed no effects from the application of terbufos.

However, for northern bobwhite quail mean blood plasma activities (total ChE, AchE, and BChE) were lower on in-furrow treatments than controls and lower on in-furrow than on banded sites suggesting exposure. Further exposure of avian species is indicated from cholinesterase analysis of blood samples from nestling starlings. Approximately 95% of the control nestlings had continuous increase in BChE activity, whereas the nestlings from in-furrow and banded treatment sites had periods of BChE depression in 26.5% and 35.9% of the sample individuals, respectively. Approximately 83% of the control nestling sampled had continuous increase in total ChE activity, while nestling on banded and in-furrow treatment sites had periods of ChE depression during this period in 60.5% and 64.7% of the nestlings, respectively. However survival of nestlings was not difference. Also of 799 blood samples taken from passerine cholinesterase activity was only effected in blue jays. Another indication of a potential effect was from the starling nest box monitoring. The 1989 data showed a significant difference in the reproductive variables between treated and control sites. Further analysis showed that the difference between banded and control sites in 1989 involved a greater nestling survival rate on in-furrow sites than on controls. However, a slightly lower egg survival rate on banded treatments compared to control was found.

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These monitoring and biochemical sampling techniques showed relatively low exposure to most species sampled. However, result from starling nest box monitoring in the third year suggested some effects in reproduction parameters sampled and third year passerine blood plasma samples showed a significant difference between in-furrow treatment sites and controls in blue jay ChE levels. While their are several points which need to be considered in evaluating results of this three year study, such as, relative limited sample sizes, species monitored may not have been those at the highest risk, and sampling methods may be biased towards the least sensitive individuals and species, results of the study suggest limited exposure for most nontarget species monitored in this corn agro-ecosystem in south central Iowa.

Incident data on terbufos in relation to terrestrial wildlife is extremely scant. Only one incident report is available and appears to be a possible miss use.

Therefore, based on the weight of the evidence terbufos, both the 20CR and 15G formulation appear to present an acute as well as a chronic risk to non-target wildlife species. While data are extremely scant on the 20 CR formulation, based on the indication that the carrier is more durable and only a few granules present an acute hazard, the 20 CR formulation may be of greater risk. Few studies have been completed that evaluate the effects of terbufos on nontarget wildlife species under actual field conditions, and those that have been completed are somewhat limited in scope and sensitivity. However, while these studies have consistently documented acute hazard and shown an indication of potential chronic problems from the use of the 15 G formulation, the extent of the effects appears to be limited to a relative small number of species.

Aquatic Organisms

Acute toxicity data were available for five species of freshwater fish. LC_{50} values ranged from 0.77 μg/L (bluegill sunfish) to 390 μg/L (fathead minnow), Terbufos is very highly toxic to highly toxic to freshwater fish. Four species of freshwater invertebrate were tested, and values ranged from 0.2 μg/L (scud) to 8.0 μg/L (crayfish), which are in the very highly toxic category.

One species of marine/estuarine fish was tested, with a value of 1.6 μg/L (sheepshead minnow), placing it in the very highly toxic category. One specie of marine/estuarine invertebrate was with a value of 0.22 μg/L (mysid), placing terbufos in the very highly toxic category for marine/estuarine invertebrates.

Chronic data were available for one species of freshwater fish (rainbow trout, LOEC = 1.4 μg/L) and one species of freshwater invertebrate (water flea, LOEC = 0.076 μg/L), indicating terbufos is very highly toxic to aquatic organisms on a chronic basis. No marine/estuarine chronic data were available.

Terbufos is slightly mobile and moderately persistent, with soil half-lives of 24 to 40 days. The photolysis half-life is one day.

Aquatic Risk Quotients

Risk quotients were calculated for the maximum and typical application rates for banded and in-furrow application methods for the corn use of terbufos. Its assumed that these scenarios are conservative representative of all uses and application methods of terbufos in that the majority of applications are at plant and that the corn use for banded and in-furrow are the lower registered rates for terbufos. The acute risk quotients were calculated by dividing the EEC by the LC_{50} for the given species[2]. The resulting number reflects how many times the LC_{50} value is exceeded at the given site, under the conditions used in the EFGWB model. This quotient is a relative index of risk based on the relationship between toxicity and predicted exposure. The assumption is made that if a pesticide is present in an aquatic system, any fish or aquatic invertebrate present in that system will be exposed to it. The quotient can be compared to EPA's LOC for non-endangered aquatic nontarget organisms, which is 0.5. If the risk quotient is greater than the LOC, risk to aquatic organisms is assumed. Acute aquatic risk quotients are summarized in Table 16.

The chronic risk to aquatic organisms was assessed by comparing the EEC over time to NOELs determined by life-cycle and early-life-stage tests for fish and aquatic invertebrates. Chronic risk quotients were calculated for maximum and minimum use rates for banded and minimum for in-furrow. The LOC is exceeded if the EEC/LOEL is greater than 1. Chronic aquatic risk quotients are summarized in Table 17.

Risk quotient information was calculated for banded and in-furrow applications to corn at plant as representative of all uses of terbufos. **Both application rates and methods exceed the acute and chronic LOC in both exposure scenarios.**

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[2]When sufficient data were available, the least sensitive and most sensitive species' LC_{50}s, as well as the geometric mean LC_{50} of all available data for a given class of aquatic organism, were used to provide a range of risk quotients for each use of the chemical. The LOC, however, is based on the most sensitive species' LC_{50}.

TABLE 16. Summary of acute aquatic risk quotients across use rates for corn in-furrow and banded at planting.

Pesticide	Application method	Use rate (range) (lb ai/A)	Class of organism	Low exposure site (Iowa) RQ	High exposure site (Mississippi) RQ
Terbufos	banded	1.0 - 1.3	freshwater fish	0.03 - 20.00	0.16 - 52.06
			freshwater invertebrate	8.78 - 80.00	45.78 - 416.50
			marine fish	7.69 - 10.00	40.06 - 52.06
			marine invertebrate	61.50 - 80.00	320.00 - 416.50
	in-furrow	1.0	freshwater fish	0.03 - 15.38	0.08 - 39.88
			freshwater invertebrate	8.78 - 61.50	22.78 - 159.50
			marine fish	7.69	19.94
			marine invertebrate	61.50	159.50

Table 17. Aquatic Chronic Risk Quotients for Terbufos

Species	Test Type	App.Rate/ Method lb a.i./A	NOEL(ppb)	Initial EEC	Initial RQ	21-day EEC	21-day RQ	60-day EEC	60-day RQ	90-day EEC	90-day RQ
Iowa Site											
Rainbow	Early life	1.3 banded	1.4	16.0	11.43	0.93	0.66	0.74	0.53	0.52	0.37
Daphnia	Life cyc	1.3 banded	0.03	16.0	533.33	0.93	31.00	0.74	24.67	0.52	17.33
Rainbow	Early life	1.0 banded	1.4	12.3	8.79	0.72	0.51	0.57	0.41	0.40	0.29
Daphnia	Life cyc	1.0 banded	0.03	12.3	410.00	0.72	24.00	0.57	19.00	0.40	13.33
Rainbow	Early life	1.0 in-furrow	1.4	12.3	8.79	0.71	0.51	0.56	0.40	0.40	0.29
Daphnia	Life cyc	1.0 in-furrow	0.03	12.3	410.00	0.71	23.67	0.56	18.67	0.40	13.33
Mississippi Site											
Rainbow	Early life	1.3 banded	1.4	83.3	59.50	4.9	3.50	2.5	1.79	1.7	1.21
Daphnia	Life cyc	1.3 banded	0.03	83.3	2,776.67	4.9	163.33	2.54	84.67	1.7	56.67
Rainbow	Early life	1.0 banded	1.4	64.1	45.79	3.8	2.71	1.9	1.36	1.3	0.93
Daphnia	Life cyc	1.0 banded	0.03	64.1	2,136.67	3.8	126.67	1.9	63.33	1.30	43.33
Rainbow	Early life	1.0 in-furrow	1.4	31.9	22.79	1.8	1.29	0.98	0.70	0.66	0.47
Daphnia	Life cyc	1.0 in-furrow	0.03	31.9	1,063.33	1.8	60.00	0.98	32.67	0.66	22.00

Aquatic Incidents and Field Data

Documented fish kills due to terbufos use can be useful data confirming the hazard as predicted by the Agency's risk assessment. Such data may be obtained from reported fish kill incidents, simulated (mesocosum pond studies) field studies, or actual full scale field studies where aquatic habitats are monitored following application of the chemical to surrounding fields. While no field studies have been completed to evaluate terbufos impacts to aquatic organisms, there are reported fish kill incidents which support the Agency's estimates that terbufos could reach aquatic environments at toxic levels.

EPA has received 32 fish kill incident reports. Twenty-eight of these incidents were reported from the use of terbufos on corn. The incidents did not necessarily occur immediately following application, but generally after rain. The incidents appeared to occur after both banded and in-furrow applications, although not all of the reports indicated the application method. These kills may be summarized as follows:

> Terbufos was implicated, possibly with Furadan 15G and Temik (aldicarb), in a fish kill in a small pond adjacent to tobacco and corn fields in North Carolina on June 12, 1992 (I000165-052. FMC Corporation. 1992).
>
> On May 4, 1991, terbufos was applied on each row at a rate of 8.7 lb ai/A on a no-till corn field adjacent to Taylor Lake, IL. A 2-inch rainfall occurred 13 days post-application, and a fish kill occurred within 24 hours of the rain. A total of 90,461 fish were found dead. The species affected included bluegill, largemouth bass, green sunfish, black crappie, red-ear sunfish, and hybrid sunfish (Illinois Department of Conservation, 1991).
>
> On July 10, 1991, American Cyanamid summarized 11 incidents resulting from the use of terbufos that occurred that year in Illinois, Indiana, and Iowa. The numbers of fish ranged from 400 bass to 42,000 bluegill. Apparently, heavy rainfall (2 inches to 10 inches) occurred within 10 to 28 days after application (American Cyanamid, 1991).
>
> In 1991 it was reported that a large number of fish killed in two ponds adjacent to corn fields treated with terbufos in Chariton, Iowa. The chemical was unincorporated. The night following application, 2.5 inches of rain fell. Five days later, the farmer noticed large amounts of dead fish surrounding the edges of the pond (I000254. EPA 1992).
>
> On May 15, 1990, bass, bluegill, catfish, crappie, and a snake were reported killed from the use of terbufos at-plant on a corn field at a rate of 8.7 lb ai/A in Licking County, Ohio.

The Ohio Department of Agriculture measured residues at 10 ppb. A heavy rainfall was reported one to five days before the mortalities were discovered. The total kill was reported for the 4- to 5-acre pond that was 5 to 6 feet deep (422059-01. American Cyanamid, 1992).

American Cyanamid reported 16 incidents in 1990 from various parts of the U.S., including Iowa, Kansas, Michigan, Ohio, and Illinois. Numbers of dead fish reported ranged from 20 to 15,000. Since vague information was supplied, EEB was unable to summarize the conditions under which the incidents occurred (422059-01. American Cyanamid, 1992).

A large fish kill was reported in 1990 from the use of terbufos on corn prior to a heavy rainfall in Ohio. One dead water snake was found (EPA, 1990).

On May 5, 1989, a fish kill occurred from the use of Counter 15G on a nearby corn field. About 600 small fish and 12 crayfish were found dead in an adjacent water body. The metabolite of terbufos, terbufos sulfone, was detected in the water samples (IR89-40. North Carolina Department of Agriculture, 1989).

On May 1, 1989, thousands of fish in the Alligator River were killed following the application on corn of Counter 15G and Lasso. One and one-half inches of rain fell in 30 minutes and 6 to 7 inches fell within a week of the application. Terbufos had been used underneath during planting and lasso on top after planting. Terbufos sulfone, the metabolite of terbufos, was detected in soil samples (R89-37. North Carolina Department of Agriculture, 1989).

On May 16, 1989, about 400 fish died from the use of Counter 15G. Terbufos was measured in the water samples taken in a pond adjacent to a pond that was treated with terbufos on corn. Another adjacent field had been treated with Mocap and Tillam on tobacco, but no measurable residues were detected for those chemicals (IR89-44. North Carolina Department of Agriculture, 1989).

Terbufos was applied in a corn field on May 8, 1985. Heavy rain fell five days later and fish were killed nine days later (I000598-001. Nebraska Game and Parks Commission, 1985).

In 1985, terbufos was applied in a field near a pond. Heavy rain fell, and a fish kill is suspected as a result (I000598-007. Nebraska Game and Parks Commission).

Terbufos reportedly killed fish on May 29, 1981 in Krueger Pond, Lafayette County, MO. A one acre lake was affected. (EPA, 1981).

On June 3, 1981, terbufos was implicated in a Missouri fish kill with multiple pesticide use (atrazine, Sutan and terbufos) and runoff from heavy rain. Many small bluegill and a few crappie reportedly were affected from the use on corn (Missouri Department of Conservation, 1981).

Terbufos was applied in a corn field in Iowa in 1978. Runoff into a farm pond after heavy rains drained about 1/2 acre of the treated corn field. Many dead fish were found in the pond (Pesticide Incident Monitoring System, 1981.).

Around April 1976, terbufos was applied to a field across the road from a 0.8 acre pond in Illinois. After runoff from heavy rains drained into the pond, about 20 dead bluegill were found. Laboratory work did not confirm the presence of terbufos (Pesticide Incident Monitoring System, 1981).

Incident reports, however, may greatly underestimate the extent of the actual hazard. No systematic or reliable mechanism exists for accurate monitoring and reporting of kill incidents to the Agency. Moreover, before a pesticide incident can be reported or investigated, the dead fish must first be found, and in the absence of monitoring aquatic environments following pesticide applications, kills are not likely to be noticed in agricultural settings away from human activity. Further, if the impact is to invertebrates or young age classes of fish such as fry, the kill may not be noticed by casual observers, or even by experienced biologists unless systematic samples are being taken. Even if dead fish are found, they may not be reported. Persons unfamiliar with the toxicity of terbufos or other pesticides to fish may fail to associate the finding of dead fish with a pesticide application, especially if the two events are separated by several days.

Therefore, the Agency does not believe that minimal reported incident data exonerates the pesticide from hazard as calculated in this risk assessment. The reporting of even a few fish kills associated with a chemical use suggests that there may be considerable kills occurring. Therefore, the reporting of approximately two and half dozen kill incidents associated with the use of terbufos products suggests that substantial widespread fish kills could be occurring.

Endangered Species

The established LOC for terrestrial species for granular products is 0.1 and for aquatic species 0.05. If the risk quotient, LD_{50}/ft^2 for terrestrial species and EEC/LC_{50} for aquatic species is equal to or greater than the LOC potential risk is assumed for endangered species. The level of concern for endangered species, both aquatic and terrestrial species, on an acute and chronic basis is exceeded for all uses of terbufos (Tables 8 through 17).

The Endangered Species Protection Program is expected to become final in 1994. Terbufos has existing biological opinions for which EPA will require generic endangered species label statement (or equivalently protective alternative) when the program is in place. Additional consultation with the Fish and Wildlife Service will be required to address newly listed species and also any use sites not previously considered. However, no additional label changes are anticipated as a result of consultation if the label already contains the generic label statement

Risk Mitigation

The risk assessment for terbufos indicates that broad scale use of terbufos presents high environmental risk to aquatic and terrestrial wildlife resources. An examination of the risk mitigation options for terbufos does not change this basic assessment. The toxicity and the fate characteristics of terbufos offer few options which would appear to offer effective mitigation. The major options appear to be severely reducing the total use and or taking measures to reduce the availability and exposure of the chemical to aquatic and terrestrial organisms. The following discussion summarizes these options.

Limitations on Use

Application Rates

Reduction in the rate of application is a way of mitigating the risk. However, for terbufos, due to its toxicity level and relative low application rates, required reductions do not appear practical and still provide control of damage caused by target pests. The percent reduction that would be required to get below the Level of Concern for aquatic risk would be approximately 99% and for terrestrial 93%.

Number of Applications/Application Intervals

Label restrictions already limit the use of terbufos to one application per season. Therefore reduction in the number of applications and changes in the application intervals are not a viable alternative for the uses of terbufos. Also, in the general category of label restriction is timing of application. For terbufos, since most of its use is at planting, the window of opportunity for pre-plant applications is too small to allow for adjustments due to other factors such as migration, nesting, etc. providing limited potential for mitigation.

Soil Incorporation: Depth/Efficiency

In general, the greater the degree of soil incorporation the less probability of direct consumption of granules by wildlife species and the lower the potential runoff in surface water. Although risk for the in-furrow and knifed-in applications are present the risk from banded applications are greater. Limiting application methods to the most efficient incorporation application methods would reduce the amount of chemical on the surface potentially lowering exposure of direct consumption of granules by terrestrial species and lowering runoff to aquatic environments.

Other Use Limitations

There are several methods for limiting use which have been identified to fall under the category of prescription use. Examples include: limiting the total number of acres treated; limiting the total use (lbs/year); limiting the corps of use; specifying environmental and habitat conditions for use such as yearly rain fall, distance from aquatic habitat, slop of fields, presents of filter strips or buffer zones. However, the level of concern would still be exceeded in the areas where use continued.

Compensatory Mitigation

Compensatory mitigation is a possibility but is not evaluated in this assessment due to its complexities and dependence on other decisions yet to be made.

Added Value of the Information

No additional data is required at this time to support the registration of terbufos for current registered uses.

Labeling

Manufacturing Use

"This pesticide is toxic to fish and wildlife. Do not discharge effluent containing this product into lakes, streams, ponds, estuaries, oceans, or other waters unless in accordance with the requirements of a National Pollutant Discharge Elimination System (NPDES) permit and the permitting authority has been notified in writing prior to discharge. Do not discharge effluent containing this product to sewer systems without previously notifying the local sewage treatment plant authority. For guidance, contact your State Water Board or Regional Office of the EPA."

End-Use

Granular End-Use Products

"This pesticide is toxic to fish and wildlife. Do not apply directly to water, or to areas where surface after is present or to intertidal areas below the mean high-water mark. Runoff may be hazardous to aquatic organisms in neighboring areas. Do not contaminate water when disposing of equipment washwater or rinsate."

Data Requirements

No additional data requirements.