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

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OFFICE OF
PREVENTION, PESTICIDES AND
TOXIC SUBSTANCES

November 13, 1998

Mr. John J. Wrubel
Product Registration Manager
U.S. Plant Regulatory Affairs
American Cyanamid Company
Agricultural Products Research Division
P.O. Box 400
Princeton, NJ 08543-0400

Dear Mr. Wrubel:

Enclosed for your information are comment responses and chapter updates pertaining to the EPA Office of Pesticide Programs (OPP) Environmental Fate and Effects Division (EFED) RED chapter for terbufos. The following documents are enclosed:

- Updated RED chapter addressing American Cyanamid comments (D. Farrar to P. Noyes, 11/4/98)
- Responses to American Cyanamid Comments on the 1996 RED draft (D. Farrar to A. Chiri, 10/1/98)
- EFED understanding of tasks and needs related to the American Cyanamid rebuttals (D. Farrar to A. Chiri, 7/28/98)

Please be aware that these documents will be placed in the EPA public docket in two weeks following the date of this letter. I can be reached at (703) 308-8179 should you have any questions.

Sincerely,

Pamela Noyes, CRM
Special Review Branch
Special Review and
Reregistration Division

031 OPP #F

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

OFFICE OF PREVENTION,
PESTICIDES AND TOXIC SUBSTANCES

DP BARCODE: D225276,D227482,
D248246,D248249

MEMORANDUM

**DATE:** November 4, 1998

**TO:** Pam Noyes, CRM
Special Review and Reregistration Division

**FROM:** David Farrar, Statistician, EFED task leader for terbufos
Jim Breithaupt, Fate and Exposure scientists.
Environmental Risk Branch II
Environmental Fate and Effects Division (7507C)

David Farrar
Jim Breithaupt 11/4/98

**THROUGH:** Betsy Grim, Acting Branch Chief
EFED/ERB II

Betsy Grim 11/4/98

**RE:** **Terbufos**: Updated RED chapter addressing Am. Cyanamid comments

The purpose of this communication is to respond to a request from SRRD for electronic files containing the EFED RED chapter for terbufos, updated to address comments submitted by American Cyanamid Co. (ACC). A hard copy of the revised chapter is attached to this memo. We have transmitted electronically the computer files containing the revised chapter.

The revisions are described in our memo to SRRD on Oct. 1 1998 (D. Farrar to A. Chiri), which gives our responses to registrant comments on a 1996 EFED RED draft. In addition, we are carrying forward significant revisions that we submitted to SRRD on Feb. 6 1998 (D. Farrar to L. Nisenson-Bergstrom), which ACC may not have reviewed. The Feb. 6 revision resulted from EFED's preparation of a drinking water assessment for inclussion in the chapter; changes of the drinking water exposure estimates also resulted in changes of the risk quotients for aquatic organisms.

On Oct. 12 ACC submitted additional comments, in connection with the public docket process for OPs (memo J. Wrubel to P. Noyes). We have reviewed these comments and believe that they do not indicate a need for additional revisions of the EFED chapter. We believe the essential points have been addressed in our communication on Oct. 1.

*OUTLINE OF SECTION C. ENVIRONMENTAL ASSESSMENT*

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## C. ENVIRONMENTAL ASSESSMENT

### 1. Use Characterization

Terbufos is a systemic organophosphate pesticide used for control of soil pests (insects and/or nematodes) on corn (field and sweet corn), grain sorghum, and sugar beets. As a systemic insecticide terbufos can also be used for control of sucking insects such as greenbug and chinch bug.

A communication from American Cyanamid (10/12/98) describes terbufos products as follows: "Terbufos was first registered in 1974. The American Cyanamid product, COUNTER, is currently marketed as either a clay-based granule containing 15% active ingredient or a polymer-based granule containing 20% a.i. The insecticide is labeled for use on corn, sugar beets, and grain sorghum. COUNTER applications are restricted to ground equipment and are made at planting (in-furrow or banded), at cultivation, or post-emeragent over the crop row. The product is classified as 'restricted use' due to acute oral and dermal toxicity. Currently 75% of COUNTER is sold in the LOCK'n LOAD® closed handling system. The LOCK'n LOAD® returnable container eliminates the bag disposal problem and reduces the possibility of accidental spills."

Corn accounts for about 90% of terbufos use by pounds. The extensive use on corn is due to a large degree to use for control of corn rootworm, but terbufos is used for control of a wide spectrum of corn pests, depending to some degree on region.

About 90% of terbufos (pounds) use on field corn is accounted for by the following states: Colorado, Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Nebraska, North Carolina, Ohio, South Dakota, Texas, and Wisconsin. There is significant variation in rainfall and other climatic variables within this region. Some regions of high ground water vulnerability may be affected by terbufos use on corn. Runoff events causing surface water contamination are expected to be less frequent in the more arid, western parts of the corn growing region.

Grain sorghum cultivation overlaps very broadly with cultivation of corn. However, sorghum is somewhat more tolerant of low moisture. Consequently terbufos use on sorghum may result in less surface water contamination than terbufos use on corn. Sorghum production is particularly concentrated in Kansas and the Texas and Oklahoma panhandles. Most of terbufos use on grain sorghum (by pounds) is accounted for by Kansas and Texas.

Terbufos use on sugar beets is localized in the mountain and northern plains states of the Western U.S. About 95% of terbufos use (pounds) on sugar beets is accounted for by Idaho, Minnesota, Montana, North Dakota, and Wyoming. Close to half of terbufos use (pounds) on sugar beets is in Minnesota and North Dakota. This use is probably accounted for largely by use in the Valley of the Red River, along the border of North Dakota and Minnesota. Terbufos is not registered for use in California, a state with significant sugar beet production.

The following information on use rates has been provided by the registrant (Fax from John Wrubel, 9/16/97). (See page following.) The rates in the table following are in lb/A. Assessment of risk to terrestrial wildlife requires rates in pounds per 1000 feet of row. Such rates are specified separately on the labels (see RQ tables in terrestrial risk assessment).

Application procedures for terbufos involve varying degrees of soil incorporation. Banded and in-furrow application procedures involve relatively less complete incorporation. In the terrestrial nontarget risk assessment EFED has assumed that 15% of granules are available to wildlife for banded application, versus 1% with other incorporation procedures.

**Use information for Terbufos**

| Crop | Max rate ai/A (typical ai/A) | Application technique | Percent of total use | Notes |
|---|---|---|---|---|
| Corn (field,sweet,pop) | 1.3 lb ai/A (1.1 lb ai/A) | **At planting**: In-furrow or in a 7-inch band lightly incorporated with drag chains or tines.<br>**Post-emergent:** Apply granules in a band over the row early in the growing season (1-6 leaf stage) and lightly incorporate with suitable implements.<br>**At cultivation**: Apply granules to the base (or over the top) of plants and cover with soil using cultivation shovels. | 95% of COUNTER on corn is applied at planting and 85% of that use is banded. | •Only one application (either at planting, post emergent, or at cultivation) per season.<br>•A reduced rate (0.75 lb ai/A) can be used on "first year" corn.<br>•Light incorporation places granules no deeper than 1 inch. |
| Grain sorghum | 3.9 lb ai/A for knifed-in only (0.75 lb ai/A)<br><br>2.0 lb ai/A for banded applications (0.75 lb ai/A) | **At bedding**: Knifed in at 1-4" below the seed or 1-4" below the seed and up to 5" to the side.<br><br>**At planting**: Knifed in 1-4" below the seed or 1-4" below the seed and up to 5" to the side or applied in a 7" band incorporated with drag chains or tines. | Greater than 95% of granules are applied in a band. | •Only one application (either at bedding or at planting) per season.<br>•Light incorporation places granules no deeper than 1". |

| | | | | |
|---|---|---|---|---|
| Sugar beets | 3.9 lb ai/A for knifed in only (1.1 lb ai/A)<br><br>2.0 lb ai/A for banded & in furrow (1.1 lb ai/A) | **At planting**: Knifed in 2" to the side and 2-4" below the seed; or 5-7" banded and lightly incorporated; or in-furrow.<br>**Post emergent**: Banded over the row and lightly incorporated with cultivation shovels. | 60% of the granules applied at planting are banded and 40% are applied in furrow. | •Only one application (either at planting or post emergent)per season.<br><br>•Light incorporation places granules no deeper than 1". |



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## 2. Environmental Fate

### a. Environmental Fate Assessment

The acceptable data and published literature give a consistent understanding of terbufos dissipation in the environment.

Hydrolysis and biodegradation are the primary dissipation processes for terbufos in the environment when terbufos is incorporated into soil. Under conditions favorable to microbial growth, the metabolic half-life in aerobic soil is approximately 27 days and in anaerobic soil is 72 days. Under abiotic conditions, the hydrolysis half-life is 15 days in the typical range of environmental pH values (pHs 5, 7, and 9).

The important metabolites terbufos sulfoxide and terbufos sulfone are more mobile and persistent than parent terbufos, and may be equally toxic. The sulfoxide and sulfone have half-lives in aerobic soil of 150 and 210 days, respectively. These metabolites are also mobile in all tested soils with Freundlich $K_{ads}$ values ranging from 0.40 - 2.93, and may reach ground water when terbufos is used in a location where irrigation or rain water moves through the soil profile to groundwater. In addition, terbufos and its metabolites may enter surface water as a result of run-off events.

Terbufos is unstable in irradiated water with a half-life of only 1 day. Photolysis does not become an important means of dissipation in the field, however, because terbufos is soil-incorporated. Also, in most bodies of water light penetration is not expected to be sufficient for photolysis to be considered a significant route of dissipation.

Volatilization may be a major dissipation route for the portion of parent terbufos that remains on the surface of soil after incorporation. The relatively high vapor pressure ($3.16 \times 10^{4}$ mm Hg) and observed Henry's Law Constant ($6.58 \times 10^{3}$) suggest that some of the parent compound will dissipate by diffusion into the atmosphere, but the amount that may volatilize will vary depending on the use site conditions and the mode of application. Since terbufos is soil-incorporated, volatilization from soil is not expected to be a significant route of dissipation in the environment.

### b. Environmental Fate and Transport

#### i. Degradation

**Hydrolysis** (161-1)--Terbufos degraded with a half-life of 15 days in pH 5, 7, and 9 buffer solutions. The primary degradation product was formaldehyde, which accounted for 50-69% of the applied dose at 4 weeks. (Formaldehyde has only been observed as a terbufos metabolite in sterile media. When formaldehyde forms in the environment, it is not expected to persist.)



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Terbufos sulfoxide and terbufos sulfone, terbufoxon sulfoxide and sulfone (CL 94,365; phosphorodithioic acid, S-(t-butylsulfonyl) methyl,0,0-diethyl ester), CL 94,293 [(t-Butylthio) methanethiol], and three unknowns were minor metabolites (<3% of applied). (MRID #00087694)

Bowman and Sans (1982) reported that terbufos degraded in aqueous solutions (pH 6 and 8.8) in darkness with half-lives of 3.2-3.5 days. The metabolite terbufos sulfoxide degraded with half-lives of 33-41 days in pH 8.8 water, but degraded only slightly in distilled water (pH 6) with a half-life of 347 days. The sulfone metabolite was also pH-sensitive, with similar half-lives (277 days in pH 6 water and 18-32 days in pH 8.8 water).

**Photolysis in water** (161-2)--Terbufos degraded with a half-life of 1.2 days (28 hours) days in pH 7 buffer solutions. Formaldehyde was 72% and 62% of the applied dose after 6 days of continuous irradiation. Terbufos sulfoxide and terbufos sulfone were minor (<10% of the applied) metabolites. (MRID #00161567)

**Aerobic soil metabolism** (162-1)--Terbufos degraded with a half-life of 27 days in a silt loam soil. The major metabolites were terbufos sulfoxide, terbufos sulfone, and $CO_2$. The maximum concentrations of these metabolites were 52, 20, and 46%, respectively. (MRID #00156853)

Felsot et al. (1982) reported that temperature is an important factor in terbufos degradation in aerobic soil. The reported $DT_{50}$ values were 100, 22, and 16 days in Flanagan silt loam at 6, 25, and 35 °C, respectively. The reported $DT_{50}$ values were 38, 9, and 6 days in Gilford-Hoopeston-Ade sandy loam sandy loam at 6, 25, and 35 °C, respectively. Terbufos persistence in Flanagan silt loam at 25 °C was apparently unrelated to soil moisture contents of 12, 24, and 40% because the degradation rates were very similar throughout the study (Felsot, et al., 1982).

**Anaerobic soil metabolism** (162-2)--Terbufos degraded with an anaerobic half-life of 10.0 days in 72 days in nonsterile flooded silt loam soil that was incubated under a nitrogen atmosphere for 60 days following 9 days of aerobic incubation. Parent terbufos was 26.1% of the applied dose at 60 days of anaerobic conditions. The major metabolite was $CO_2$, which reached a maximum of 35% of the applied dose. The metabolites terbufos sulfone and sulfoxide, and terbufoxon sulfone and sulfoxide were <2.6% of the applied dose throughout the study. The volatile residues increased with time to 38.6% at 60 days. The soil-extractable and water residues decreased with increasing anaerobic time, and the soil residues were approximately 3-4X those of the flood water. (MRID #41749801)

**Laboratory volatility** (163-2)--Although the vapor pressure value would trigger the need for a laboratory volatility study, this study is not required at the present time because terbufos is soil incorporated and because the Agency is requiring additional data on the dissipation of terbufos in the field.

### ii. Mobility

**Mobility/Adsorption/Desorption** (163-1)--Based on the above batch equilibrium study, parent terbufos is moderately mobile in an Arkansas loamy sand ($K_{ads}$ = 5.42), and essentially immobile in an Indiana silt loam, New Jersey sandy loam, and Wisconsin loam soils ($K_{ads}$ = 11.4-14.6). Freundlich $K_{des}$ values ranged from 3.7-8.2 for the above soils, which was probably due to degradation. The Freundlich $K_{ads}$ values for terbufos sulfoxide and terbufos sulfone were 2.8-2.9 for the Indiana silt loam (1.8% organic carbon), but only ranged from 0.4-0.86 for the other soils (0.29-1.39% OC). Adsorption of parent terbufos appears to be highly related to soil organic carbon content and somewhat related to soil texture. (MRID #41373604)

### iii. Accumulation

**Accumulation in Laboratory Fish** (165-4)--Terbufos bioaccumulated in bluegill sunfish with maximum bioaccumulation factors of 320, 940, and 680X in edible tissues (body, muscle, skin), non-edible tissue tissues (fins, head, internal organs), and whole fish, respectively, during 28 days of exposure to $^{14}C$-terbufos residues at 0.05 ug/L in a flow through system. Maximum levels of $^{14}C$-residues were 16 ug/L in edible tissues, 58 ug/L in nonedible tissues, and 34 ug/L in whole fish. After 14 days of depuration, $^{14}C$-residues in edible and nonedible tissues and whole fish were 2.5 ug/L, 3.5 ug/L, and 2.3 ug/L, respectively. The main residues in water and in fish were parent terbufos, terbufoxone (CL 94,221), and a methane-related derivative (CL 202,474; t-butylsulfinyl(methylsulfinyl)-methane). (MRID 41373603, 41373605)

The reported BCFs for terbufos (320X to 940X) indicate that terbufos has only a moderate potential for bioaccumulation.

### iv. Field Dissipation

**Terrestrial field dissipation (164-1)**. The terrestrial field data reviewed to date were considered upgradeable pending submission of storage stability data. Upgradeable data indicated that terbufos dissipated in the field with half-lives of 24 days in loam soil (2.1 % OM) in California and 14-40 days in loamy and sandy loam soils in Illinois and Colorado. Approximately 85% of the applied terbufos degraded between 14 and 30 days when moisture was applied to the field in California. These half-lives are comparable to the aerobic soil metabolism half-life of 27 days. Only trace levels of the metabolite terbufos sulfoxide was detected below 6 inches of depth. The lack of vertical mobility in the registrant's studies may be explained by the higher organic matter content of the loam soil in California (2.1 %) and the lack of precipitation early in the studies.

Felsot et al. (1987) reported half-lives of 11-16 days for parent terbufos and total toxic residue half-lives of 25-28 days in silt loam and silty clay loam soils in the field when terbufos (Counter 15G™) was applied at 1 lb. ai/A to moldboard plowed, chisel plowed, and no tillage plots. Mobility was not evaluated in this literature study.

### 3. Water Resources

This section provides *estimated concentrations of terbufos and terbufos metabolites* in surface water and ground water for use in assessing drinking water exposure and exposure to aquatic organisms. Also provided is a *description of environment fate properties* of terbufos and terbufos metabolites as they relate to the potential for effects on the quality of surface and ground water. The major concerns raised by the use of terbufos are potential leaching of terbufos sulfoxide and terbufos sulfone to ground water and potential runoff of parent terbufos and these metabolites to surface water.

#### a. Ground Water

Because of their chemical characteristics, the two major metabolites of terbufos, terbufos sulfone and terbufos sulfoxide, have more potential to leach to ground water in vulnerable areas than the parent. Terbufos parent is not as likely to leach but, as shown by the monitoring data below, it too can move to ground water as a result of normal field use. Because an MCL has not been established for terbufos and its metabolites, no monitoring is required under the Safe Drinking Water Act.

**Occurrence of terbufos in ground water.** This section presents summaries of individual sources of information focusing on terbufos and terbufos metabolites in ground water (summarized in Table 1). The information is from several sources including registrant-conducted studies, U.S. Geological Survey (USGS) monitoring, state monitoring information, and EPA's Pesticides in Ground Water Database. Results of ground water monitoring studies are displayed in Table 1 below.

This data represents 4,563 samples from 13 states. It contains 20 detections of parent terbufos with an additional 7 apparent detections in Iowa that are questionable or unconfirmed. Thirteen wells were also sampled in Iowa for terbufos sulfone, but no residues were detected.

**Ground water monitoring studies**. Overall, monitoring efforts for terbufos have been limited. Monitoring has been conducted in some of the states within the terbufos major use area. Terbufos parent has been detected in one well in Missouri at a concentration of 0.06 ppb, from suspected normal field use. One well in Nebraska contained parent terbufos at a concentration of 0.02 ppb. In South Dakota, terbufos was one of the most commonly detected pesticides in one study and was found at concentrations ranging from 0.011 to 0.050 ppb. Terbufos was detected in Indiana at 12.0 ppb in one domestic well and at 20 ppb in a spring. In Iowa, terbufos parent was reported in ground water from public water supply wells. However, these detections in Iowa are questionable.

In general, the available monitoring studies are not adequate to assess the potential for terbufos to reach ground water because the terbufos metabolites were not analyzed. The minimum detection limits for terbufos were occasionally higher than the terbufos HA (Illinois, Indiana, Mississippi), and there is no clear connection between terbufos use areas and the sampled wells. Results from these studies are inconclusive because the terbufos use areas did not necessarily coincide with monitoring sites. In addition, most studies were conducted on public water supply wells that draw large amounts of water from several depths within one or more aquifers. The age of the water in these aquifers may not relate to any of the terbufos applications made in the area.

**State-by-State Summaries of Ground Water Monitoring Results.**

Georgia. Barber, et al., (1984), Davis and Turlington (1985), and Davis and Turlington (1986) sampled ground water in Georgia for parent terbufos (76 samples total). The limit of detection was 3 ug/L, which is above the Health Advisory of 0.9 ug/L. There were no detections, and there is no apparent use of terbufos in Georgia.

Illinois. Felsot (1984) sampled the inside faucets from 25 sand point wells. No pesticides were detected above 1 ppb and in particular terbufos and terbufos metabolites were not detected above that level. However, the results were inconclusive because of the sampling technique, the types of wells used, and the inability to characterize "spurious" peaks on the chromatogram.

Sinnott (1987) and Cobb and Sinnott (1988?) sampled public water supply wells for terbufos parent. Parent terbufos was not detected, but no metabolites were analyzed for in the studies.

Indiana. In 1986, the Indiana Department of Natural Resources and the Department of Environment Management sampled 24 private wells for terbufos and other pesticides (IN DEM, 1988). Using a detection limit of 0.50 ppb for parent terbufos, no residues were detected. No metabolites were analyzed.

Ground-water monitoring data for pesticides from 1986 to 1990 in Indiana was compiled in a report by Risch (1994). A combination of public community, non-community water supply wells, monitoring wells, and rural domestic wells were sampled during several studies for a total of 206 wells. Many of the sampled areas were considered vulnerable. Several detection limits ranging from 0.03 to 1.5 ppb were used for parent terbufos. Parent terbufos was detected in one domestic well and one spring at concentrations of 12.0 and 20.0 ppb, respectively. Both of these detections exceeded the HA of 0.9 ug/L. Resampling was conducted approximately six weeks later and no residues were found. No information about the origin of the terbufos residues in ground water was given. No metabolites were analyzed.

Statewide inferences about the occurrence of pesticides in ground water in Indiana cannot be based solely on this data compilation. The results were not due to a single statistical design, but instead were derived from a combination of many data sets. Among the studies, there was bias or variation in the selection of sample sites, in the timing and frequency of sample collection, and in the selection and minimum reporting limits of analytes.

Iowa. Samples have been collected from 787 wells in Iowa and analyzed for terbufos residues in studies between 1984 and 1989. Iowa had seven of the 27 reported terbufos detections in ground water nationwide, all of which came from five municipal well systems (public drinking water supply systems).

The registrant has disputed the detections of terbufos in Iowa municipal wells [Susan Wayland of EPA to William A. Stellar of Cyanamid, 10 Jan. 89], concluding that the findings were either not-confirmed or were attributed to point sources. The registrant provided a copy of the report, in which the study authors themselves believe that the lab may have misidentified terbufos in the 1985 Little Souix study (Kelly, Iowa Department of Natural Resources, 9/18/98 fax). It was suggested that the problem with the detections may be related to the EPA contract lab methodology. Upon consideration of the additional information, EFED cannot draw any conclusions from the data concerning the detections of terbufos in Iowa.

Minnesota. In 1986 and 1987, the Minnesota Department of Health (MDH) sampled public water supply wells across the state in areas susceptible to pesticide contamination (Klaseus et al., 1988). Samples were analyzed for parent terbufos only; no metabolites were analyzed. No detections of parent terbufos were found.

In another study, MDH and the Minnesota Pollution Control Agency sampled private drinking water supply wells in vulnerable areas (Klaseus and Hines, 1989). Resampling was done for a subset of these wells and also for three public drinking water wells. Terbufos parent was analyzed; no residues were found. No metabolites were analyzed.

Missouri. From 1986 to 1987, samples were taken from domestic, irrigation, and public water supply wells in the Mississippi River Valley alluvial aquifer (Mesko and Carlson, 1988). Only terbufos parent was analyzed; terbufos was detected in one well at a concentration of 0.06 ppb from suspected normal field use.

In another study from 1987 through 1990, the Missouri Department of Natural Resources sampled rural drinking water wells in the State (Sievers and Fulhage, 1991). Terbufos parent was not detected; metabolites were not analyzed.

Mississippi. In Mississippi, a statewide ground-water monitoring survey was designed to sample for pesticides in major crops such as cotton and soybeans. Both drinking water and irrigation wells are sampled (Landreth, 1996). Although terbufos has not been used in the State, it is one of the chemicals in the suite of analytes that is reported. No residues have been detected using a detection limit of 2.4 ppb. It is not clear if terbufos sulfoxide and sulfone were analyzed for in the studies.

Montana. From 1984 to 1988, a combination of domestic drinking water, livestock, and irrigation wells were sampled for pesticide residues by the Montana Department of Agriculture (DeLuca et al, 1989). Thirteen wells were sampled for terbufos parent; no residues were detected. No metabolites were analyzed.

Nebraska. Pesticide data available before 1989 were collected and published by Exner and Spalding (1990). Data were collected by the Nebraska Department of Health, the Nebraska Department of Environmental Control, the Lincoln-Lancaster County Health Department, U.S. Geological Survey and others. Five types of wells are included in the assessment including domestic (greatest number), irrigation, public supply and municipal, stock, and monitoring. One well contained parent terbufos at 0.02 ppb; no metabolites were analyzed.

Pennsylvania. Ground water from 22 wells and two springs in the Mahantango Watershed was analyzed for several pesticides that were heavily used in the watershed (Pionke et al., 1988; Pionke and Glofelty, 1989). All wells were located in unconfined aquifers. No terbufos parent was detected; no metabolites were analyzed.

Rhode Island. Twenty-four private drinking water wells were sampled for terbufos in corn-growing areas. Terbufos parent was not detected; metabolites were not analyzed (RI DEM, 1990).

South Dakota. Forty-one monitoring wells in three aquifers were sampled by the Department of Environment and Natural Resources from 1988 to 1992 (SD DENR, 1993). Terbufos was one of the most commonly detected pesticides and was found in 16 wells in all three aquifers. Concentrations in the Parker-Centerville aquifer ranged from 0.011 to 0.050 ppb in 1992. No metabolites were analyzed.

**Table 1.** Ground Water Monitoring Data for Terbufos

| Study | Well Type | Number of Wells Sampled | Minimum Detection Limit (ppb) | Number of Wells with Detections | Concentration Range (ppb) |
|---|---|---|---|---|---|
| Georgia (1984-1986) | community and non-community water systems | 76 | 3.0 | 0 | 0 |
| Little Sioux River, IA (1984-86) | public water supply, monitoring | 103 | 0.1 (parent) (sulfone; analyzed in 8 wells) | 7 | 0.3-20.0 (parent)* |
| Iowa monitoring (1984-89) | public water supply (drinking water) | 684 | 0.1 (parent) | 0 | 0 |
| Illinois monitoring (1985-88) | sand point; public water supply | 466 | 1.0, 0.05 (parent) 0.05 (metabolites) | 0 | 0 |
| Indiana (1986-90) | drinking water; community water supply | 206 | 0.03-1.5 (parent) | 2 | 12.0-20.0 |

| | | | | | |
|---|---|---|---|---|---|
| Minnesota (1986-90) | public water supply, private drinking water | 649 | 0.2 (parent) | 0 | 0 |
| Missouri (1986-90) | public water supply, private drinking water, irrigation | 325 | 0.05, 0.1, 0.3 (parent) | 1 | 0.06 |
| Mississippi (1989-96) | drinking water, irrigation | 459 | 2.4 (parent) | 0 | 0 |
| aMontana (1984-88) | livestock, domestic drinking water, irrigation | 13 | 1.0 (parent) | 0 | 0 |
| Nebraska (<1989) | domestic, irrigation, public supply and municipal, stock, monitoring | 1435 | 0.25 (parent) | 1 | 0.02 |
| Pennsylvania (1985-87) | monitoring? | 24 | 0.003-0.01 (parent) | 0 | 0 |
| Rhode Island (1986) | private drinking water | 24 | ? | 0 | 0 |
| South Dakota (1988-92) | monitoring | 99 | 0.010 (parent) | 16 | 0.011-0.050 |

*The detections of terbufos in the Little Sioux River public water supply study are in question and may be due to laboratory problems.

**Estimated concentrations in ground Water (SCI-GROW).** Table 2 presents estimates of terbufos and terbufos metabolites in ground water based on the SCI-GROW model (Barrett, 1997). The SCI-GROW model (Screening Concentrations in Ground Water) is a model for estimating "upper bound" concentrations of pesticides in ground water. SCI-GROW provides a screening concentration; an estimate of likely ground water concentrations if the pesticide is used at the maximum allowed label rate in areas with ground water exceptionally vulnerable to contamination. In most cases, a majority of the use area will have ground water that is less vulnerable to contamination than the areas used to derive the SCI-GROW estimate.

The SCI-GROW model is based on scaled ground water concentrations from ground water monitoring studies, environmental fate properties (aerobic soil half-lives and organic carbon partitioning coefficients-Koc's) and application rates.

**Table 2.** Estimates of Ground Water Concentrations of Parent Terbufos, Terbufos Sulfoxide, and Terbufos Sulfone based on the SCI-GROW model.

| Application Rate (lb ai/A) | Parent Terbufos (ug/L) | Terbufos Sulfoxide[1] (ug/L) | Terbufos Sulfone[1] (ug/L) |
|---|---|---|---|
| 1.3[2] | 0.041 | 2.60 | 2.90 |
| 2.0[3] | 0.06 | 4.1 | 4.5 |
| 3.9[4] | 0.123 | 7.90 | 8.70 |

[1] This assumes the maximum labeled application rates and 100 % conversion from parent through the sulfoxide metabolite to the sulfone metabolite by sequential oxidation.

[2] For corn. The 9/16/97 fax from John Wrubel of American Cyanamid stated that the typical application rate for corn was 1.1 lbs ai/A.

[3] For grain sorghum and sugar beets. The 9/16/97 fax from John Wrubel of American Cyanamid stated that the maximum labeled application rate for in-furrow and banded uses of terbufos is 2.0 lbs ai/A, and that >95 % of terbufos use on these crops is banded or used in-furrow.

[4] For grain sorghum and sugar beets. This is a high exposure case because most (>95 %) of terbufos use is banded or in-furrow at a maximum labeled rate of 2.0 lbs ai/A. The typical use rate for grain sorghum is 0.75 lb ai/A and the typical use rate for sugar beets is 1.1 lbs ai/A. (9/16/97 fax)

### b. Surface Water

**Fate and Transport Properties.** Hydrolysis and microbial degradation appear to be the most important means of terbufos dissipation in the environment. Terbufos is very unstable to photolysis in water, but photolysis may not be important because light penetration in surface water is often limited. In the terrestrial environment terbufos is incorporated or knifed in to a depth where sunlight does not contribute to its degradation.

Information from environmental fate studies indicates that parent terbufos will be moderately persistent in surface waters. The reported half-lives for hydrolysis (same for pH values of 5, 7, and 9), aerobic soil metabolism and anaerobic aquatic metabolism were 15, 27, and 73 days, respectively. The reported half-life for photodegradation in water was 1 day. However, photodegradation in water is not expected to significantly decrease surface water concentrations because of potential suspended sediments and shading. The reported vapor pressure ($3.16 \times 10^{-4}$ mm Hg), Henry's Law Constant of $6.58 \times 10^{4}$ atm m$^3$ / mol, and the solubility in water (5 ppm) indicate that parent terbufos has moderate volatility potential in surface water. This would potentially lower terbufos residues in surface water.

In the simulated pond in PRZM-EXAMS, between 46 and 88% of terbufos was in the dissolved phase for all crops. With the exception of the simulated sugar beet use where terbufos was knifed-in, the dissolved residues exceeded the bound residues.

In soil, parent terbufos degrades into the oxidative metabolites terbufos sulfoxide and terbufos sulfone. These metabolites are more mobile (Freundlich $K_{ads}$ values of 0.4-2.8 and 0.55-2.93, respectively) and more persistent ($T_{1/2}$'s of 150 and 210 days, respectively) than parent terbufos. Consequently, they should be available for runoff for a longer period of time than parent terbufos, and should have higher fractions dissolved in runoff water and in the water column than parent terbufos. The available data on soil suggest that the metabolites may also be more persistent in surface water than terbufos. However, there are no data available on the abiotic hydrolysis, direct photolysis or volatilization of the metabolites which could confirm that.

**Terbufos Occurrence in Surface Water**. According to pre-1988 listings in STORET, terbufos was detected in 134 of 2,016 surface water samples at an 85th percentile of detections of 0.1 ug/L and a maximum concentration of 2.25 ug/L. Baker (1988) sampled 8 tributaries of Lake Erie from April 15-August 15 of 1983 through 1985. He reported April 15-August 15, time weighted means for terbufos ranging from < 0.001 to 0.096 ug/L and averaging 0.008 ug/L. Maximum concentrations ranged from below a detection limit of 0.01 ug/L to 2.25 ug/L and averaged 0.21 ug/L. The State of Illinois (Moyer and Cross 1990) sampled 30 surface water sites for pesticides at various times from October 1985 through October 1988. Although substantial use in Illinois was a criterion for pesticides being included in the analyses, total terbufos was not detected in any of the samples at or above the detection limit of 0.05 ug/L. The USGS sampled 8 widely spread locations within the Mississippi Basin at frequent intervals from April 1991 to April 1992. Terbufos was detected at concentrations between 0.01 and 0.1 ug/L in one of the 47 samples collected from the Platte River and in one of the 45 samples collected from the Illinois River. Terbufos was not detected above a detection limit of 0.02 ug/L in any of the samples collected from the other 6 locations. EFED does not have any data on the concentrations of the sulfoxide or sulfone metabolites in water.

The USGS (Kimbrough and Litke 1995) has sampled the South Platte River in Colorado, the Platte River in Central Nebraska, the White River in Indiana, the Rio Grande River in Texas, New Mexico, and Colorado, the San Joaquin River in California, and the Albemarle-Pamlico River in Virginia and North Carolina for parent terbufos. With a detection limit of 0.013 ug/L, detected residues of parent terbufos ranged from 0.013-0.56 ug/L. These watersheds are locations where corn, grain sorghum, and sugar beets are grown. EFED counted 214 samples. USGS monitoring is designed to measure water quality in a watershed with an area of 10-2,000 square miles. It is not specifically designed to measure drinking water exposure.

The monitoring information in the previous paragraph is broken down below. There are 17 detections of parent terbufos in 5,198 samples in the USGS NAWQA database for surface water. One estimated detection (pending QA/QC) of 0.01 ppb was observed in the Albermarle-Pamlico River. There also 16 confirmed detections ranging from 0.013-0.56 ppb. (See Table 3 below for details). In the South Platte River, there were 6 detections of parent terbufos ranging from 0.03 to 0.56 ug/L. The higher detections were found in May and early June, when application would be expected, while the lower detections were in July. In the Central Nebraska

River, there were 3 detections ranging from 0.023-0.27 ug/L. The higher detections were observed in May, when application would be expected, while the 0.023 detection was found in August. In the San Joaquin River in California, there were 2 detections of 0.1 and 0.024 ug/L. In the Lower Susquehanna River Basin in Pennsylvania and Maryland (LSUS), the White River in Indiana, the Rio Grande River in Colorado, New Mexico, and Texas, and Georgia-Florida Rivers, there were 6 combined detections ranging from 0.013-0.03 ug/L.

Table 3. NAWQA Surface Water Data for Terbufos

| Study Location | Number of Samples | Number of Detections | Range of Concentrations (ug/L) | % of Samples with Detections by Location |
|---|---|---|---|---|
| Appalachicola-Chattahoochie-Flint River Basin | 432 | 0 | -- | 0 |
| Albermarle-Pamlico | 256 | 1 | 0.01 (estimated) | 0.39 |
| Central Columbia Plateau | 231 | 0 | -- | 0 |
| Central Nebraska | 157 | 3 | 0.023-0.27 | 1.9 |
| Connecticut | 141 | 0 | -- | 0 |
| Georgia-Florida | 384 | 1 | 0.018 | 0.26 |
| Hudson | 264 | 0 | -- | 0 |
| Lower Susquehanna River Basin | 408 | 1 | 0.03 | 0.25 |
| Nevada | 134 | 0 | -- | 0 |
| Ozark | 157 | 0 | -- | 0 |
| Potomac | 288 | 0 | -- | 0 |
| Red River of the North | 216 | 0 | -- | 0 |
| Rio Grande | 178 | 1 | 0.016 | 0.56 |
| San Joaquin | 437 | 2 | 0.024-0.1 | 0.46 |
| South Platte | 157 | 6 | 0.03-0.56 | 3.8 |
| Trinity | 331 | 0 | -- | 0 |

| | | | | |
|---|---|---|---|---|
| Upper Snake River Basin | 150 | 0 | -- | 0 |
| White | 544 | 2 | 0.013-0.16 | 0.37 |
| Williamette | 184 | 0 | -- | 0 |
| Western Lake Michigan Drainage | 149 | 0 | -- | 0 |
| Total | 5,198 | 17 | | 0.33 % (overall) |

EPA has received a reports of over 30 fish kill incidents associated with terbufos use. Most of these have been in farm ponds. However, large fish kill incidents have occurred in lakes and other bodies of water after rainfall events that have occurred 10-28 days after terbufos application. Up to 50,000-90,000 fish have died in a single incident. Therefore, it is apparent that residues of terbufos or terbufos metabolites can reach levels toxic to fish over an extended period of time. Humans would also be exposed to similar levels in untreated water.

**Tier II Estimated Surface Water Concentrations.** Tier II estimated environmental concentrations (EECs) have been calculated for parent terbufos applied to grain sorghum in Kansas, field corn in Iowa, and sugar beets in Minnesota, using PRZM 2.3 and EXAMS 2.94. Tier II EECs are used to assess drinking water exposure and exposure to aquatic organisms for surface water. A Tier II EEC for a particular crop or use is based on a single site that represents a high exposure scenario for the crop or use. Weather and agricultural practices are simulated at the site for 36 years to estimate the probability of exceeding a given concentration (maximum concentration or average concentration) in a single year. Maximum EECs are calculated so that there is a 10% probability that the maximum concentration in a given year will exceed the EEC at the site; 4-day, 21-day, 60-day, and 90-day EECs are calculated so that there is a 10% probability that the maximum average concentration for a given duration (4-day, 21-day, etc.) will equal or exceed the EEC at the site.

Tier II upper tenth percentile EECs for parent terbufos are displayed in Table 4. Table 5 presents the Environmental Fate parameters used as inputs in the model. Tier II EECs are also used in developing drinking water exposure estimates (Table 6) for sugar beet and sorghum uses. (For the corn use, drinking water exposure estimates are based on monitoring data.)

**Table 4.** Tier II upper tenth percentile EEC's for Parent Terbufos

| Application | Maximum ($\mu g \cdot L^{-1}$) | 4 Day ($\mu g \cdot L^{-1}$) | 21 Day ($\mu g \cdot L^{-1}$) | 60 Day ($\mu g \cdot L^{-1}$) | 90 Day ($\mu g \cdot L^{-1}$) | Annual Mean* ($\mu g \cdot L^{-1}$) |
|---|---|---|---|---|---|---|
| **Corn** | | | | | | |
| 1.3 lbs ai/A in-furrow to 1.25 inches of depth at planting | 4.3 | 3.6 | 2.1 | 1.1 | 0.8 | 0.2 |
| 1.3 lbs ai/A to 1 inch of depth in 7-inch band at planting | 5.3 | 4.5 | 2.7 | 1.4 | 1.0 | 0.3 |
| **Grain Sorghum** | | | | | | |
| 3.9 lbs ai/A knifed to 5 inches of depth at planting | 8.3 | 7.2 | 4.2 | 2.0 | 1.4 | 0.3 |
| 2.0 lbs ai/A incorporated to 1 inch of depth at planting | 21.7 | 18.4 | 10.1 | 4.9 | 3.6 | 0.9 |
| **Sugar Beets** | | | | | | |
| 3.9 lbs ai/A knifed to 5 inches of depth at planting) | 4.1 | 3.4 | 2.3 | 1.2 | 0.9 | 0.2 |
| 2.0 lbs ai/A incorporated to 1 inch of depth at planting | 6.7 | 5.8 | 3.6 | 1.8 | 1.3 | 0.3 |

* Upper 90% confidence bound on the 36 year mean with variance calculated from annual means.

Table 5. **Environmental Fate Parameters used in PRZM-EXAMS Modeling.**

| Parameter | Value | Source (MRID unless specified) | Uncertainty Factor[1] | PRZM-EXAMS Value | Rate Constants (K-value) |
|---|---|---|---|---|---|
| Freundlich $K_{ads}$ (ml/g) | 633 | 41373604 | Not Applicable | 633 ml/g | Not Applicable |
| Aerobic Soil Metabolism $T_{1/2}$ (days) | 27 | 00156853 | 3 | 81 days | $8.56 \times 10^{-3}$ day$^{-1}$ |
| Aerobic Aquatic Metabolism $T_{1/2}$ (days) | 73 | 41749801 | 6 | 438 days | $6.7 \times 10^{-5}$ hour$^{-1}$ |
| Anaerobic Aquatic Metabolism $T_{1/2}$ (days) | 73 | 41749801 | 6 | 438 days | $6.7 \times 10^{-5}$ hour$^{-1}$ |
| Water solubility (mg/L) | 15 | One-Liner | Not Applicable | 15 mg/L | 15 mg/L |
| Hydrolysis $T_{1/2}$ (days), (pH 5) | 15 | 00087694 | Not Applicable | 15 days | $1.87 \times 10^{-3}$ hour$^{-1}$ |
| Hydrolysis $T_{1/2}$ (days), (pH 7) | 15 | 00087694 | Not Applicable | 15 days | $1.87 \times 10^{-3}$ hour$^{-1}$ |
| Hydrolysis $T_{1/2}$ (days), (pH 9) | 15 | 00087694 | Not Applicable | 15 days | $1.87 \times 10^{-3}$ hour$^{-1}$ |
| Aqueous Photolysis $T_{1/2}$ (days) | 1 | 00161567 | Not Applicable | 1 day | $2.89 \times 10^{-2}$ hour$^{-1}$ |

[1] For laboratory metabolism studies, EFED multiplies a single metabolism study half-life by 3 to account for the uncertainty of having only one half-life. Since there was no aerobic or anaerobic aquatic metabolism data, EFED multiplied the anaerobic soil metabolism half-life of 73 days by an additional factor of 2 to account for a change in media for a total uncertainty factor of 6. This is based on official guidance from both ACPA and EFED.

**Comparison of Modeling and Monitoring.** Maximum concentrations of parent terbufos from PRZM 2.3 modeling were 4.1 ug/L for sugar beets, 5.3 ug/L for corn, and 21.7 ug/L for grain sorghum. In surface water bodies with dilution from outflow, these estimated concentrations would be lower. Parent terbufos is moderately persistent in water, and the estimated chronic concentrations for corn were approximately 1.0 ug/L from PRZM 2.3 modeling. Parent terbufos was not found above 2.25 ug/L in monitoring data from the Midwest. However, the monitoring data are limited, and the quality is unknown for some of the data. Therefore, for the dietary assessment, the PRZM-EXAMS EEC's should be used for all crops for both acute and chronic EEC's.

### c. Drinking Water Assessment

The major concerns raised by the use of terbufos are potential leaching of terbufos sulfoxide and terbufos sulfone to ground water and potential runoff of parent terbufos and these metabolites to surface water. It is EFED's understanding that the tolerance expression established for mammalian toxicity includes parent terbufos and the metabolites terbufos sulfoxide, sulfone, and oxon.

**Ground water concentrations for drinking water exposure assessment.** Table 6 below displays drinking water estimates from ground water for parent terbufos and the metabolites terbufos sulfoxide and terbufos sulfone using the SCI-GROW model.

**Table 6. Ground Water** Concentrations for Drinking Water Assessment based on modeling with SCI-GROW.

| Compound | Crop | Acute (ug/L) | Chronic (ug/L) |
|---|---|---|---|
| Parent terbufos | Corn | 0.041 | 0.041 |
| | Grain Sorghum | 0.123 | 0.123 |
| | Sugar Beets | 0.123 | 0.123 |
| Terbufos sulfoxide | Corn | 2.6 | 2.60 |
| | Grain Sorghum | 7.9 | 7.90 |
| | Sugar Beets | 7.9 | 7.90 |
| Terbufos sulfone | Corn | 2.9 | 2.90 |
| | Grain Sorghum | 8.7 | 8.7 |
| | Sugar Beets | 8.7 | 8.7 |

Modeled concentrations of parent terbufos, terbufos sulfoxide, and terbufos sulfone in ground water are 0.123, 7.9, and 8.7 ug/L (See Table 2). Monitoring data from Indiana reported a spring with a concentration of parent terbufos of 20 ug/L, and a domestic well with 11 ug/L. A well-designed public drinking water supply study from Iowa reported seven detections of parent terbufos. The detections in Indiana do not appear to be typical concentrations found in ground water, and the detections in Iowa are questionable. The SCI-GROW modeling results should be used for parent terbufos, terbufos sulfoxide and terbufos sulfone in assessing corn, grain sorghum and sugar beets.

Terbufos sulfoxide and terbufos sulfone are more persistent and more mobile than parent terbufos and are therefore more likely to reach ground water. Therefore, they are expected to reach higher levels than parent terbufos. Detections of terbufos residues in ground water are limited, because the parent compound was the only analyte in most monitoring studies. The sulfoxide and sulfone metabolites, EFED's greatest concern, are not usually included in analysis of ground water samples.

**Uncertainties in estimating ground water concentrations**. The SCI-GROW model is based on small-scale ground water monitoring studies conducted on highly vulnerable sandy soils with shallow ground water (10-30 ft in depth). Uncertainties in the SCI-GROW model are: 1) The model does not consider site specific factors regarding hydrology, soil properties, climatic conditions, and agronomic practices; 2) The model does not account for volatilization, and 3) Predicted ground water concentrations are linearly extrapolated from the application rates. This model is based on actual field data from "upper bound" ground water monitoring studies conducted on sandy soils and with heavy irrigation. Therefore the results should be considered to be an "upper bound" for terbufos and its residues in ground water.

**Surface water concentrations for drinking water exposure assessment**. The Table 7 below contains surface water concentrations of *parent terbufos* for use in a dietary risk assessment, based on modeling with PRZM-EXAMS. Surface water monitoring was very limited for parent terbufos, and there was no monitoring for the terbufos metabolites.

Environmental concentrations have not been estimated for *terbufos metabolites* in surface water because of a lack of monitoring information and lack of information on inputs for modeling.

**Table 7. Surface Water** Concentrations for Drinking Water Exposure Assessment.

| Compound | Crop | Acute[1] (ug/L) | Source of Information | Chronic[2] (ug/L) | Source of Information |
|---|---|---|---|---|---|
| Parent terbufos | Corn | 5.3 | PRZM 2.3 | 1.0 | PRZM 2.3 |
| | Grain Sorghum | 21.7[3] | PRZM 2.3 | 3.6[3] | PRZM 2.3 |
| | Sugar Beets | 6.7 | PRZM 2.3 | 1.3 | PRZM 2.3 |
| Terbufos sulfoxide and sulfone | All | Not estimated | | Not estimated | |

[1] The acute values are the maximum EEC's for parent terbufos considering the different application methods for each crop. Model results are from Table 4.

[2] Chronic values are the 90-day estimated concentrations. Model results are from Table 4.

[3] These EEC's for parent terbufos were obtained using a 2.0 lbs ai/A rate of terbufos applied in a band and incorporated to 1 inch of depth. Based on communication 9/16/97 from John Wrubel of American Cyanamid the maximum labeled application rate for in-furrow and banded uses of terbufos is 2.0 lbs ai/A, and >95 % of terbufos use on these crops is banded or used in-furrow.



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**Limitations of Tier II Surface Drinking Water Assessment.** Obviously, a single 10 hectare field with a 1 hectare pond does not accurately reflect the dynamics in a watershed large enough to support a drinking water facility. A basin of this size would certainly not be planted completely to a single crop nor be completely treated with a pesticide. Additionally, treatment with the pesticide would likely occur over several days or weeks, rather than all on a single day. This would reduce the magnitude of the concentration peaks, but also make them broader, reducing the acute exposure but perhaps increasing the chronic exposure. The fact that the simulated pond has no outlet is also a limitation as water bodies in this size range would have at least some flow through (rivers) or turnover (reservoirs).

In spite of these limitations, a Tier II EEC can provide a reasonable upper bound on the concentration found in drinking water if not an accurate assessment of the real concentration. The EECs have been calculated so that in any given year, there is a 10% probability that the maximum average concentration of that duration in that year will equal or exceed the EEC at the site. Risk assessment using Tier II values can reasonably be used as refined screens to demonstrate that the risk is below the level of concern.

**Water Treatment.** If parent terbufos reaches water, it is expected to be primarily associated with the sediment than the water column. If the terbufos sulfoxide and sulfone metabolites reach water or are formed in water, they will be primarily associated with the dissolved phase of the water column because of their low adsorption coefficients. Standard coagulation-flocculation and sedimentation processes used in water treatment will be more effective in removing parent terbufos than the sulfoxide and sulfone metabolites from drinking water. The use of GAC (Granular Activated Carbon) will also be more effective in removing parent terbufos than its metabolites because of higher binding affinity to organic carbon.

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### 4. Ecological Toxicity Data

The Agency has adequate data to assess the toxicity of *parent* terbufos to nontarget organisms. The Agency has no information on toxicity of terbufos *metabolites*.

#### a. Toxicity to Terrestrial Animals

##### i. Birds, Acute and Subacute

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

- An avian single-dose $LD_{50}$ 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 $LC_{50}$ tests, one with a species of waterfowl, preferably the mallard, and one with a species of upland gamebird, preferably the bobwhite (section 71-2).

The acceptable avian acute oral toxicity studies are listed below:

**Avian Acute Oral Toxicity Findings**

| Species | % AI | $LD_{50}$ (mg/kg) | Conclusions |
|---|---|---|---|
| Bobwhite quail | 89.6 | 29 (22-57) | highly toxic |
| | tech | 15 (12-19) | highly toxic |

These results show that terbufos is highly toxic to birds. The guideline requirement for the avian acute oral $LD_{50}$ study is fulfilled. (MRID# FATHER)

The acceptable avian subacute dietary studies are listed below:

**Avian Subacute Dietary Toxicity Findings**

| Species | % AI | $LC_{50}$ (ppm) | Conclusions |
|---|---|---|---|
| Mallard Duck | 86 | 520 (400-676) | moderately toxic |
| | 86 | 160 (131-195) | highly toxic |
| Bobwhite Quail | 87.8 | 157 (125-201) | highly toxic |
| | 86 | 140 (107-183) | highly toxic |

On a subacute dietary basis, terbufos is moderately to highly toxic to birds. The guideline requirement is fulfilled. (MRID #s 00035120, 00087717, 00160387)

### ii. Birds, Chronic

Avian reproduction studies are required because terbufos is expected to persist in soil with a half life greater than four days. In order to establish the chronic toxicity of terbufos to birds, the data required on the technical material are:

Two avian reproduction studies (71-4), 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.

**Avian Reproduction Findings**

| Species | % A.I. | Conclusions |
|---|---|---|
| Mallard Duck | tech | No significant impairment at 2-20ppm dietary levels, but approaching significance at 20ppm. |
| Bobwhite Quail | tech | No significant impairment at 2-20ppm dietary levels. |
| Mallard Duck | tech | Possible but not statistically significant effects on embryo viability at 15 ppm. |
| Bobwhite Quail | tech | No effects at up to 30ppm. |

These studies indicate that the NOEL is approximately 15 ppm, based on embryo viability in the mallard. The guideline requirements for avian reproduction studies have been fulfilled. (MRID 00097892, 00161574, 00191573)

### iii. Mammals

Wild mammal testing is required on a case-by-case basis, depending on the results of lower tier laboratory mammalian studies, intended use pattern and pertinent environmental fate characteristics. In most cases, and for terbufos in particular, rodent toxicity values obtained from the Agency's Health Effects Division (HED) substitute for wild mammal testing. Mammalian toxicity results are listed below.

**Mammalian Acute Oral Toxicity Findings**

| Species | % AI | $LD_{50}$ male; female (mg/kg) | Conclusions |
|---|---|---|---|
| Rat | 96.7 | 4.5; 9.0 | very highly toxic |
| Rat | 86.0 | 1.74; 1.57 | very highly toxic |
| Dog | 96.7 | 4.5; 6.3 | very highly toxic |
| Mouse | 97.7 | 3.5; 9.2 | very highly toxic |

These tests show that terbufos is very highly toxic to mammals.

### iv. Simulated and/or Actual Field Tests

Simulated or actual field tests are required on a case-by-case basis to support the registration of an end-use product intended for outdoor application. These tests 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 agricultural land treated with terbufos.

Results of field studies (71-5) with terbufos are summarized below.

*Terrestrial Field Study*. 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. (MRID 00085178, 00085180, 00087726). The study partially fulfills the data requirement.

*Simulated Field Study, exposure to treated soil*. 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 in soil 22 days after initial exposure. 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. The study is not required to fulfill the data requirement. (MRID 00085179,00085183, FETTER01)

*Terrestrial Field Study*. 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 a cornfield in Maryland. Following the at planting application several species of wildlife were observed exhibiting signs 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. The study fulfills the data requirement. (MRID BATTER01)

*Terrestrial Field Study*. 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 relatively 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. The study fulfills the data requirement. (MRID 409855-01, 414758-01)

*Simulated Field Study*. A study was conducted to compare the effects of Counter 15G to Counter 20CR on bobwhite quail and brown-headed cowbirds. Terbufos was applied at time of corn planting 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. The study is not required. (MRID 415088-01, 41849201)

### b. Toxicity to Aquatic Animals

#### i. Freshwater Fish

**Fish Acute with Technical.** In order to establish the toxicity of a pesticide to freshwater fish, the minimum data required on the technical grade of the active ingredient are two freshwater fish toxicity studies (72-1). One study should use a coldwater species (preferably the rainbow trout), and the other should use a warmwater species (preferably the bluegill sunfish).

**Freshwater Fish Acute Toxicity Findings (Technical)**

| Species | % AI | $LC_{50}$ (ppb) | Conclusions |
|---|---|---|---|
| Bluegill sunfish | 86.0 | 0.77 (0.72-0.83) | very highly toxic |
| Bluegill sunfish | 86.3 | 3.8 (2.8-4.9) | very highly toxic |
| Bluegill sunfish | 88.6 | 0.87 (0.77-1.0) | very highly toxic |
| Brown trout | 86.0 | 20 (12.6-34.3) | very highly toxic |
| Rainbow trout | 86.3 | 9.4 (7.7-11.4) | very highly toxic |
| Channel catfish | 88.6 | 9.6 (8.5-11.1) | very highly toxic |

The results of four of the 96-hour acute toxicity studies indicate that terbufos is very highly toxic to both cold and warm water fish. The guideline requirement for acute toxicity testing of the technical on freshwater fish is fulfilled. (MRID #s 00087718, 00037483, 00085176)

**Fish Acute with End Use Product.** Two 96-hr $LC_{50}$ fish studies using the 15% granular formulation may be needed for hazard evaluation of terbufos if the $LC_{50}$ 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 $LC_{50}$ tests conducted with the 15 % granular formulation of terbufos are listed below:

**Freshwater Fish Acute Toxicity Findings (End Use/15 G formulation)**

| Species | % AI | $LC_{50}$ (ppb)<br>$LC_{50}$ (ppb ai) | Toxicity category | Study classification |
|---|---|---|---|---|
| Bluegill sunfish | 15 | 12.3 (9.8-15.2)<br>1.8 (1.5-2.3) | very highly toxic | core |
| Rainbow trout | 15 | 59.7 (48.1-74.3)<br>9.0 (7.2-11) | very highly toxic | core |

These results show that the 15% granular formulation of terbufos is very highly toxic to freshwater fish. Results are comparable to results with technical terbufos, on a ppb ai basis. (MRID #s FEOTER04, FEOTER05)

**Fish Early Life Stage Test with Technical.** A fish early life-stage test (72-4) is required because the toxicity of terbufos to fish is less than 1 mg/kg. Results of the fish early life-stage test on terbufos are given below.

**Freshwater Fish Early Life Stage (Technical)**

| Species | % AI | Conclusions |
|---|---|---|
| Rainbow trout | 98.5 | The NOEL was 1.4 ppb, the highest concentration tested.<br>The MATC could not be calculated. |

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." Chronic effects are anticipated at concentrations of >1.4 ppb and lower than levels causing acute effects (rainbow trout acute 96 hr LC50 about 10 ppb). (MRID #40009301)

### ii. Freshwater Invertebrates

**Acute toxicity**. The minimum testing required to assess the hazard of a pesticide is a 48-hour freshwater aquatic invertebrate toxicity test with the technical (72-2), preferably using first instar *Daphnia magna* or early instar amphipods, stoneflies, mayflies, or midges.

**Freshwater Invertebrate Toxicity Findings**

| Species | % AI | $LC_{50}$ (ppb) | Conclusions |
|---|---|---|---|
| *Daphnia magna* (crustacea) | 88.6 | 0.31 (0.27-0.36) | very highly toxic |
| Crayfish (crustacea) | 88.6 | 8.0 (6.9-10.2) | very highly toxic |
| *Gammarus pseudolimnaeus*(1)(2) (crustacea) | 88 | 0.2 (0.1-0.3) | very highly toxic |
| *Chironomus plumosus* (Diptera)(1) | 88 | 1.4 (1-2) | very highly toxic |

(1) F.L. Mayer and M.R. Ellersieck. 1986. Manual of acute toxicity: interpretation and data base for 4510 chemicals and 66 species of freshwater animals. USFWS Resource publ. 160. Static studies.
(2) 96-hour measurement

There is sufficient information to characterize terbufos as very highly toxic to aquatic invertebrates. The guideline requirement is fulfilled although tests with crayfish are considered supplemental. (MRID FEOTER03, 00085176)

**Chronic toxicity**. An aquatic invertebrate life cycle test (72-4) is required because the acute 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 $LC_{50}$; the hydrolytic half-life is greater than 4 days, and terbufos has broad use on corn. An aquatic invertebrate reproductive test with the water flea (*Daphnia magna*) is required to establish the chronic toxicity to aquatic invertebrates. Results from an acceptable study are displayed below:

**Freshwater Invertebrate Life Cycle Findings**

| Species | % AI | MATC | Conclusions |
|---|---|---|---|
| *Daphnia magna* | 98.4 | NOEC 30 ppt; LOEC 76 ppt<br>MATC 48 ppt | very highly toxic |

This test indicates that terbufos causes chronic toxic effects to freshwater invertebrates at extremely low levels. (MRID 00162525)

### iii. Estuarine and Marine Animals

Acute toxicity testing with estuarine and marine organisms (72-3) is required when an end-use product is intended for direct application to the marine/estuarine environment or is expected to reach this environment in significant concentrations. The corn and sorghum uses of terbufos may result in exposure to the estuarine environment.

The requirements under this category include a 96-hour $LC_{50}$ for an estuarine fish, a 96-hour $LC_{50}$ for shrimp, and either a 48-hour embryo-larvae study or a 96-hour shell deposition study with oysters (72-3a, c, b).

**Estuarine/Marine Acute Toxicity Findings**

| Species | % Test Material (TGAI) | $LC_{50}$/$EC_{50}$ | Conclusions |
|---|---|---|---|
| Eastern oyster (shell growth) | 89.2 | $EC_{50}$=0.20mg ai/l | highly toxic |
| Mysid | 98.4 | $LC_{50}$=0.22ppb | very highly toxic |
| | 98 | 0.40ppb | very highly toxic |
| Sheepshead minnow | 98 | 3.2ppb | very highly toxic |
| | 98.4 | 1.6ppb | very highly toxic |

There is sufficient information to characterize terbufos as very highly toxic to estuarine/marine organisms and highly toxic to the Eastern oyster. The guideline requirement is fulfilled. (MRID 42381501, 00162523, 41373603, 41373602, 00162524)

## 5. Ecological Exposure and Risk Characterization

### a. Evaluation of LOC exceedances

This section describes the determination of concerns for ecological effects based on the quotient method. Description of field information (incidents, field studies) is found in a subsequent section.

$$\text{Risk quotient} = \frac{\text{Exposure}}{\text{Toxicity}}$$

Following the quotient method, a risk quotient (RQ) is calculated based on an estimate of exposure and an estimate of toxicity: A finding of a concern results when the value of a RQ exceeds a Level of Concern (LOC). The values of LOCs are displayed in the table below. The value of the LOC depends on the category of nontarget organisms and also on the following categories of concern: (1) *acute high risk* - potential for acute risk is high and regulatory action may be warranted in addition to restricted use classification; (2) *acute/restricted use* - the potential for acute risk is high but may be mitigated through restricted use classification; (3) *acute/endangered species* - the potential for acute risk to endangered species is high and regulatory action may be warranted, and (4) *chronic risk* - the potential for chronic risk is high and regulatory action may be warranted.

Currently, EFED does not perform assessments for chronic risk to plants, acute or chronic risks to nontarget insects, or chronic risk from granular/bait formulations to mammalian or avian species.

The toxicity measurements used in the denominators of risk quotients are derived from required ecological effects studies. Examples of toxicity measurements from relatively short-term laboratory studies, used to assess *acute* concerns are $LC_{50}$ (for fish and birds), $LD_{50}$ (for birds and mammals, $EC_{50}$ (for aquatic plants and aquatic invertebrates), and $EC_{25}$ (for terrestrial plants). Examples of toxicity measurements from relatively longer-term studies, used to assess *chronic* effects are LOEC (for birds, fish, and aquatic invertebrates), NOEC (for birds, fish and aquatic invertebrates), and MATC (for fish and aquatic invertebrates). The NOEC is used to assess chronic concerns for birds and mammals. Other values may be used when justified. Generally, the MATC (defined as the geometric mean of the NOEC and LOEC) is the chronic toxicity measurement used for fish and aquatic invertebrates. However, the NOEC is used if the measurement end point is survival or production of offspring.

Formulae for risk quotients are given below, along with corresponding LOCs and risk presumptions.

## Risk Presumptions for Terrestrial Animals

| Risk Presumption | RQ | LOC |
|---|---|---|
| **Birds** | | |
| Acute High Risk | EEC[1]/LC50 or LD50/sqft[2] or LD50/day[3] | 0.5 |
| Acute Restricted Use | EEC/LC50 or LD50/sqft or LD50/day (or LD50 < 50 mg/kg) | 0.2 |
| Acute Endangered Species | EEC/LC50 or LD50/sqft or LD50/day | 0.1 |
| Chronic Risk | EEC/NOEC | 1 |
| **Wild Mammals** | | |
| Acute High Risk | EEC/LC50 or LD50/sqft or LD50/day | 0.5 |
| Acute Restricted Use | EEC/LC50 or LD50/sqft or LD50/day (or LD50 < 50 mg/kg) | 0.2 |
| Acute Endangered Species | EEC/LC50 or LD50/sqft or LD50/day | 0.1 |
| Chronic Risk | EEC/NOEC | 1 |

[1] abbreviation for Estimated Environmental Concentration (ppm) on avian/mammalian food items

[2] $\frac{mg/ft^2}{LD50 * wt. of bird}$ [3] $\frac{mg of toxicant consumed/day}{LD50 * wt. of bird}$

## Risk Presumptions for Aquatic Animals

| Risk Presumption | RQ | LOC |
|---|---|---|
| Acute High Risk | EEC[1]/LC50 or EC50 | 0.5 |
| Acute Restricted Use | EEC/LC50 or EC50 | 0.1 |
| Acute Endangered Species | EEC/LC50 or EC50 | 0.05 |
| Chronic Risk | EEC/MATC or NOEC | 1 |

[1] EEC = concentration in water (ppm or ppb)

## Risk Presumptions for Plants

| Risk Presumption | RQ | LOC |
|---|---|---|
| **Terrestrial and Semi-Aquatic Plants** | | |
| Acute High Risk | EEC[1]/EC25 | 1 |
| Acute Endangered Species | EEC/EC05 or NOEC | 1 |
| **Aquatic Plants** | | |
| Acute High Risk | EEC[2]/EC50 | 1 |
| Acute Endangered Species | EEC/EC05 or NOEC | 1 |

[1] EEC = lb ai/A

[2] EEC = conceentration in water (ppm or ppb)

### i. Terrestrial LOC assessments

Granular pesticide products such as terbufos represent a 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 contaminated 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 for granular formulations than that used for foliar application. Granular exposure is estimated by the Agency based on the amount of toxicant exposed per square foot of treated area.

Soil 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 reduce the number of exposed granules, but do not eliminate potential exposure to non-targets. Varying numbers of exposed granules may therefore 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 used the following mean estimates:

**Percentage of COUNTER granules remaining exposed after application and incorporation**

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

1Because 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. An attempt to account for the greater percentage of granules exposed at the row ends would result in risk quotients somewhat larger than the values reported here.

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

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

Exposed ai (mg)/$ft^2$ = ai (mg)/$ft^2$ * % unincorporated

Exposed granules / $ft^2$ = Exposed mg ai/$ft^2$ / (%ai * granule weight)

Tables in Addendum 1 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 body 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.

The Agency uses the calculation of risk quotients that are based on the amount of toxicant per unit area for identifying granular pesticides which pose high risk. These pesticides then warrant closer examination to evaluate if modifications of use are required to reduce concerns. The risk quotient is 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 quotient used by the Agency to indicate potential effects to non-target terrestrial organisms.

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

Risk quotients greater than 0.5 $LD_{50}/ft^2$ (level of concern) are considered to indicate the potential for high risk to non-target terrestrial organisms.

**Birds**. Tables below show the avian risk quotients for the various uses and application methods of terbufos.

For terbufos for both formulations, 15G and the 20CR, the risk quotients range 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 quotients range from 2.67 to 21.01. For banded application of terbufos the quotient range is somewhat greater due to the less efficient soil incorporation accomplished with this method of application. Quotients 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 quotient 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. In other words, *for all uses, the level of concern is exceeded.* It should be noted that these quotient 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 quotients.



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The tables below give the risk quotients and LOC exceedance findings for acute risk to birds. The complete calculations are displayed in tables provided in an addendum. [Note to CRM: you may wish to assign a number to the addendum.]

## Avian Risk Quotients and LOC's for <u>20 CR</u>

| USE/APPLICATION METHOD | APPLICATION RATE/oz. per 1000 ft of row | RISK QUOTIENT $LD_{50}$/FT2 | | LOC |
|---|---|---|---|---|
| | | 27 G BIRD | 170 G BIRD | |
| **FIELD CORN, POPCORN & SWEET CORN** | | | | |
| BANDED AT PLANTING | 1.2 | 21.01 | 3.33 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| IN-FURROW AT PLANTING | 1.2 | 8.40 | 1.33 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| BANDED POST EMERGENCE INCORPORATED | 1.8 | 31.63 | 5.02 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| BANDED, AT CULTIVATION | 1.2 | 21.01 | 3.33 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| **GRAIN SORGHUM** | | | | |
| KNIFED-IN AT BEDDING | 2.4 | 16.81 | 2.67 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| KNIFED-IN AT PLANTING | 1.2 | 21.01 | 3.33 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| **SUGARBEETS** | | | | |
| BANDED AT PLANTING | 1.2 | 21.01 | 3.33 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| KNIFED-IN AT PLANTING | 2.4 | 16.81 | 2.67 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| MODIFIED IN-FURROW AT PLANTING | 1.2 | 8.40 | 1.33 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| BANDED POST EMERGENCE | 1.2 | 21.01 | 3.33 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |

Note: the calculations are documented in tables in Addendum.

## Avian Risk Quotients and LOC's for 15 G

| Application Method | Formulation/ Use Rate | Risk Quotient $LD_{50}$/ft2 | | LOC |
|---|---|---|---|---|
| | | 27 g Bird | 170 g Bird | |
| **Field corn, popcorn & sweet corn** | | | | |
| Banded at planting | 15 g<br>1.2 oz/1000 ft of row | 20.99 | 3.33 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| In-furrow at planting | 15 g<br>1.2 oz/1000 ft of row | 8.39 | 1.33 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| **Grain sorghum** | | | | |
| Banded at planting | 15 g<br>1.2 oz/1000 ft of row | 20.99 | 3.33 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| **Sugarbeets** | | | | |
| Banded at planting | 15 g<br>1.2 oz/1000 ft of row | 20.99 | 3.33 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| In-furrow at planting | 15 g<br>1.2 oz/1000 ft of row | 8.39 | 1.33 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| Post emergence banded | 15 g<br>1.2 oz/1000 ft of row | 20.99 | 3.33 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |

Note: the calculations are documented in an Addendum

**Mammals.** Mammals appear to be somewhat more sensitive to terbufos than birds. Testing of the technical grade material resulted in $LD_{50}$ 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 $LC_{50}$ value of 26 ppm for the rat. 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 from 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 or contaminated soil. As with birds, the Agency uses a risk quotient based on the number of $LD_{50}$ per $ft^2$ exposed on or near the soil surface to indicate the potential to impact nontarget mammals.

Tables below show the mammalian risk quotients for the various uses and application methods of terbufos.

For terbufos for both formulations, 15G and the 20CR, the risk quotients range 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 quotients range from 4.33 for a 1 kg mammal to 173.9 for a 25 gram mammal. For banded application of terbufos the quotient range is somewhat greater due to the less efficient soil incorporation accomplished with this method of application. Quotients 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 quotient suggests that terbufos presents an acute hazard to mammalian species for both formulations and for all use rates and application methods, with banded application resulting in somewhat higher exposure. In other words, *for all uses, the level of concern is exceeded.* It should be noted that these quotient 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 quotients.

## Mammal Acute Risk Quotients and LOC's for Terbufos 20 CR

| APPLICATION METHOD | APPLICATION RATE oz/1000 ft of row | RISK QUOTIENT $LD_{50}/FT^2$ 25 G Mammal | RISK QUOTIENT $LD_{50}/FT^2$ 1 kg Mammal | LOC |
|---|---|---|---|---|
| **FIELD CORN, POPCORN & SWEET CORN** | | | | |
| BANDED AT PLANTING | 1.2 | 217.39 | 5.41 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| IN-FURROW AT PLANTING | 1.2 | 86.96 | 2.16 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| BANDED POST EMERGENCE INCORPORATED | 1.8 | 327.35 | 8.15 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| BANDED, AT CULTIVATION | 1.2 | 217.39 | 5.41 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| **GRAIN SORGHUM** | | | | |
| KNIFED-IN AT BEDDING | 2.4 | 173.91 | 4.33 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| KNIFED-IN AT PLANTING | 1.2 | 217.39 | 5.41 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| **SUGARBEETS** | | | | |
| BANDED AT PLANTING | 1.2 | 217.39 | 5.41 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| KNIFED-IN AT PLANTING | 2.4 | 173.91 | 4.33 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| MODIFIED IN-FURROW AT PLANTING | 1.2 | 86.96 | 2.16 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| BANDED POST EMERGENCE | 1.2 | 217.39 | 5.41 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |



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## Mammal Acute Risk Quotients and LOC's for 15 G

| Application Method | Use Rate (oz/1000 ft of row) | Risk Quotient $LD_{50}$/ft2 | | LOC |
|---|---|---|---|---|
| | | 25 g Mammal | 1 KG Mammal | |
| **Field corn, popcorn & sweet corn** | | | | |
| Banded at planting | 1.2 | 216.27 | 5.41 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| In-furrow at planting | 1.2 | 86.51 | 2.17 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| **Grain sorghum** | | | | |
| Banded at planting | 1.2 | 216.27 | 5.41 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| **Sugarbeets** | | | | |
| Banded at planting | 1.2 | 216.27 | 5.41 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| In-furrow at planting | 1.2 | 86.51 | 2.17 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |
| Post emergence banded | 1.2 | 216.27 | 5.41 | High Risk > 0.5<br>RU > 0.2<br>ES > 0.1 |

**Chronic Risk**. Laboratory studies indicate that terbufos may present chronic effects. Results of a 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. The major effect observed was an increase in offspring deaths as compared to controls.

### ii. Aquatic LOC assessments

This section assesses concerns for aquatic organisms and ecosystems based on the results of effects studies, and on environmental concentrations estimated using fate and transport models. Estimated environmental concentrations (EECs) have been calculated for terbufos using the models PRZM and EXAMS. The assumptions that have been used with these models for terbufos are described in greater detail in Section C.1.c ("Water Resources"). EECs have been calculated for parent terbufos applied to grain sorghum in Kansas, field corn in Iowa, and sugar beets in Minnesota. For each of these an EEC is based on a single site that would represent a high exposure scenario.

**Scenarios modelled for calculation of EECs**

| | |
|---|---|
| Corn | 1.3 lbs ai/A in-furrow to 1.25 inches of depth at planting<br>1.3 lbs ai/A to 1 inch of depth in 7-inch band at planting |
| Grain Sorghum | 3.9 lbs ai/A knifed to 5 inches of depth at planting<br>2.0 lbs ai/A incorporated to 1 inch of depth at planting |
| Sugar Beets | 3.9 lbs ai/A knifed to 5 inches of depth at planting<br>2.0 lbs ai/A incorporated to 1 inch of depth at planting |

Weather and agricultural practices were simulated for 36 years to estimate the probability of exceeding a given concentration in a single year. Peak, 4-day, 21-day, 60-day, and 90-day EECs were calculated. The *peak* (or instantaneous) EEC is the concentration exceeded by 10% of yearly *maximum* concentrations; 4-day, 21-day, 60-day, and 90-day EECs are concentations exceeded in 10% of years considering the maximum yearly 4-day averages, 21-day averages, etc.

The *acute* risk quotients were calculated by dividing the *maximum* EEC by the $LC_{50}$ for the most sensitive species. To assess *chronic* risk, risk quotients have been calculated based on the 21-day EECs for invertebrates and 60-day EECs for fish. The chronic risk to aquatic organisms was assessed by comparing the EEC to NOECs determined by life-cycle and early-life-stage tests for fish and aquatic invertebrates.

**Freshwater fish.** Acute and chronic risk quotients for freshwater fish are tabulated below.

(Based on $LC_{50}$ = 0.77 ppb for bluegill sunfish; NOEC=1.4 ppb[1] for rainbow trout)

| Site/ Application Method/ Rate in lbs ai/A (No. of Apps.) | EEC Initial/Peak (ppb) | EEC 60-Day Ave. (ppb) | Acute RQ (=EEC/LC50) | Chronic RQ (=EEC/NOEC) |
|---|---|---|---|---|
| **Corn** 1.3 lbs ai/A in-furrow | 4.3 | 1.1 | 5.6 | 0.8 |
| **Corn** 1.3 lbs ai/A banded | 5.3 | 1.4 | 6.9 | 1.0 |
| **Gr Sorghum** 3.9 lbs ai/A knifed in | 8.3 | 2 | 11 | 1.4 |
| **Gr Sorghum** 2.0 lbs ai/A incorp. | 21.7 | 4.9 | 28 | 3.5 |
| **Sugar Beets** 3.9 lbs ai/A knifed in | 4.1 | 1.2 | 5.3 | 0.9 |
| **Sugar Beets** 2.0 lbs ai/A incorp. | 6.7 | 1.8 | 8.7 | 1.3 |

1 Here the NOEC is the highest concentration tested in the rainbow trout life cycle test. The study failed to meet the guideline requirement that at least one test level must adversely affect a life stage.

Comparison of acute risk quotients to the EPA's LOC value of 0.5 for non-endangered species indicates concerns based on all uses evaluated. The chronic risk quotients are larger than or approximately equal to the LOC value of 1.

**Freshwater invertebrates.** Acute and chronic risk quotients for freshwater invertebrates are tabulated below.

(Based on $LC_{50}$ = 0.31 ppb, NOEC=0.03 ppb for *Daphnia magna*)

| Site/ Application Method/ Rate in lbs ai/A (No. of Apps.) | EEC Initial/Peak (ppb) | EEC 21-Day Ave. (ppb) | Acute RQ (=EEC/LC50) | Chronic RQ (=EEC/NOEC) |
|---|---|---|---|---|
| **Corn** 1.3 lbs ai/A in-furrow | 4.3 | 2.1 | 14 | 70 |
| **Corn** 1.3 lbs ai/A banded | 5.3 | 2.7 | 17 | 90 |
| **Gr Sorghum** 3.9 lbs ai/A knifed in | 8.3 | 4.2 | 27 | 140 |
| **Gr Sorghum** 2.0 lbs ai/A incorp. | 21.7 | 10.1 | 70 | 337 |
| **Sugar Beets** 3.9 lbs ai/A knifed in | 4.1 | 2.3 | 13 | 77 |
| **Sugar Beets** 2.0 lbs ai/A incorp. | 6.7 | 3.6 | 22 | 120 |

Comparison of these risk quotients to the EPA's acute LOC (0.5) and chronic LOC (1) indicate acute and chronic concerns for freshwater invertebrates.

**Marine/Estuarine fish.** Acute risk quotients for marine/estuarine fish are tabulated below.

(Based on $LC_{50}$ = 1.6 ppb for sheepshead minnow)

| Site/ Application Method/ Rate in lbs ai/A (No. of Apps.) | EEC Initial/Peak (ppb) | Acute RQ (=EEC/LC50) |
|---|---|---|
| **Corn** 1.3 lbs ai/A in-furrow | 4.3 | 2.7 |
| **Corn** 1.3 lbs ai/A banded | 5.3 | 3.3 |
| **Gr Sorghum** 3.9 lbs ai/A knifed in | 8.3 | 5.2 |
| **Gr Sorghum** 2.0 lbs ai/A incorp. | 22 | 14 |
| **Sugar Beets** 3.9 lbs ai/A knifed in | 4.1 | 2.6 |
| **Sugar Beets** 2.0 lbs ai/A incorp. | 6.7 | 4.2 |

Comparison to the LOC for non-endangered species (=0.5) indicates concern for *acute* effects on estuarine/marine fish. *Chronic* toxicity information is not available for marine/estuarine organisms.

**Marine/Estuarine invertebrates.** Acute risk quotients for marine/estuarine invertebrates are tabulated below.

(Based on $LC_{50}$ = 0.22 ppb for mysid)

| Site/ Application Method/ Rate in lbs ai/A (No. of Apps.) | EEC Initial/Peak (ppb) | Acute RQ (=EEC/LC50) |
|---|---|---|
| **Corn** 1.3 lbs ai/A in-furrow | 4.3 | 20 |
| **Corn** 1.3 lbs ai/A banded | 5.3 | 24 |
| **Gr Sorghum** 3.9 lbs ai/A knifed in | 8.3 | 38 |
| **Gr Sorghum** 2.0 lbs ai/A incorp. | 22 | 100 |
| **Sugar Beets** 3.9 lbs ai/A knifed in | 4.1 | 19 |
| **Sugar Beets** 2.0 lbs ai/A incorp. | 6.7 | 30 |

Comparison to the LOC for non-endangered species (=0.5) indicates concern for acute effects on estuarine/marine invertebrates. Chronic toxicity information is not available for marine/estuarine organisms.

### iii. 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, on an acute and chronic basis is exceeded for all uses of terbufos.

The Endangered Species Protection Program is expected to become final in the future. Limitations on terbufos use will be required to protect endangered and threatened species, but these limitations have not been defined and may be formulation specific. EPA anticipates that a consultation with the Fish and Wildlife Service will be conducted in accordance with the species-based priority approach described in the Program. After completion of consultation, registrants will be informed if label modifications are required. Such modifications would most likely consist of the generic label statement referring pesticide users to use limitations contained in county Bulletins.

## b. Incidents and Field Studies

### i. Terrestrial Incidents and Field Studies

The weight of available evidence provided by incidents and field studies suggests that terbufos, both the 20CR and 15G formulations, presents an acute as well as a chronic risk to non-target wildlife species.

Several studies of terbufos under field conditions are available. While data are scant for 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 to terrestrial wildlife. In general, 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. Nevertheless, these studies have consistently documented acute hazard and shown an indication of potential chronic problems. In the use of the 15 G formulation, however, the extent of the effects appears to be limited to a relatively small number of species.

An incident in occurred in 1996 in King Count Texas in which about 20 migrating Swainson's hawks were killed by terbufos (COUNTER 15G). The registrant commissioned a team of scientists to conduct an assessment of the incident. The unpublished report developed by that team has been reviewed by the Agency.

The report draws the following conclusions: The hawks were killed while gorging on grubs exposed in a newly plowed field. Stomach contents were found to contain soil as well as grubs. The exposure of the birds to terbufos resulted from failure to cover the furrows after plowing. The furrows were not properly covered because of equipment failure associated with plowing under unusually wet soil conditions. The conclusion of the report is that the incident occurred under an unusual set of conditions.

In a second incident, two hawks were reported killed. No evidence is available that would either exclude or establish that the incident resulted from misuse.

Simulated and/or actual field tests (71-5) on terbufos are summarized below.

1. *Terrestrial Field Study*. 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. (MRID 00085178, 00085180, 00087726).

2. *Simulated Field Study of exposure to treated soil*. 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. 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. (MRID 00085179,00085183, FETTER01)

3. *Terrestrial Field Study*. 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 signs 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. (MRID BATTER01)

4. *Terrestrial Field Study*. 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 relatively 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. (MRID 409855-01, 414758-01)

5. *Simulated Field Study*. 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. (MRID 415088-01, 41849201)

### ii. Aquatic Incidents

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 (mesocosm 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 conclusions that terbufos can reach aquatic environments at toxic levels.

The Agency has received over 30 fish kill incident reports for terbufos. Most have been related to use 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 are summarized below:

- 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 were 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-planting 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, the Agency 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 field 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).

• On May 10, 1991, a fish kill occurred in Onslow, North Carolina. The pesticides that were found were chlorpyrifos (Lorsban) and terbufos (Counter). The uses sites that were associated with the fish kill were corn and tobacco. A corrugated pipe connects the fields to a drainage ditch and a concrete pipe to connects the ditch and runs under the road to the pond. Apparently pesticide application was applied too close to water. (I000799-004; IR91-60 North Carolina Dept. of Agriculture)

• On October 21, 1991, the Texas Department of Agriculture submitted information on pesticide incidents from September 1, 1986 to through October 20, 1993 for terbufos. A fish incident (TDA incident No. 11-91-0017) was reported in Lamar, Texas. Apparently the kill was due to suspected runoff. (I00917-004)

• On August 15, 1994, FMC Corporation submitted a report of emergency phone calls related to pesticide incidents. An incident reported in Louisiana involved Counter and/or Pounce. According to the report "treated soil washed into drainage following a 12 inch rain." Counter was determined by the Louisiana Department of Agriculture to be major cause of fish kill. A small amount of Pounce was present. (I001179-020, I001849-003)

• On November 8, 1995, American Cyanamid submitted updates for terbufos and phorate fish kill incidents. They reported one fish kill in 1991, a dry year, in the corn belt. In 1993, a record wet year in the midwest, fish kills in 14 ponds were associated with terbufos. Seven farm pond incidents occurred in 1994, a moderately wet year. Four farm pond incidents occurred in 1995. (I002814)

• On April 19, 1993, the North Carolina Department of Agriculture investigated an incident in Simpson County. A fish kill in a small private pond may have involved runoff from a recently treated corn field. (I003654-003; IR93-37. North Carolina Department of Agriculture)

• On May 10, 1994, the North Carolina Department of Agriculture reported a fish kill incident involving approximately 100 fish, that occurred in a canal that fed into the Pasquotank River in Pasquotank County. Terbufos (Counter 20CR) had been applied to a corn field adjacent to the canal. The area received approximately 3 inches of rain. (I003654 003; IR94-51. North Carolina Department of Agriculture)

### c. Ecological Risk Characterization.

#### i. Terrestrial Risk Characterization

Standard LOC criteria indicate concerns for acute effects on birds and mammals for terbufos 15G and 20G applied at all rates evaluated (1.2 oz. per 1000 row feet and higher). This concern is supported by field studies. This section provides additional information for characterization of the scope and likelihood of adverse effects.

**Weight of evidence from field studies.** Several studies of terbufos under field conditions are available. While data are scant for 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 to terrestrial wildlife. In general, 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. Nevertheless, these studies have consistently documented acute hazard and shown an indication of potential chronic problems. In the use of the 15 G formulation, however, the extent of the effects appears to be limited to a relatively small number of species.

**Exposure of birds to granules.** Granular pesticides represent a unique risk to wildlife in that granules may be ingested directly by birds foraging for seed and grit at or below the soil surface. Birds and mammals may also ingest granules adhered to the surface of invertebrate prey items such as earthworms and grubs (implicated in an incident for terbufos), or through ingestion of water or food sources contaminated with pesticides. In addition, wildlife may receive dermal exposure through contact with treated soil.

Soil incorporation of granules reduces the number of exposed granules. Both band and in-furrow applications of granular pesticides with incorporation, using conventional commercial equipment, greatly reduce the number of exposed granules, but do not eliminate potential exposure to non-targets. For determination of LOC exceedances the Agency has assumed that 15% of granules are exposed and available to birds for banded applications, and 1% for in-furrow, drill, and knifed-in. However, varying numbers of exposed granules may result from each type of use specified on terbufos product labels.

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.

**Effect of granule characteristics on terrestrial exposure.** Factors that need to be considered when evaluating the potential for effects to nontarget wildlife 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 properties of the pesticide (e.g. persistence, bioaccumulation).

For avian species the similarity of the granular to natural forage or grit has been suggested as an important characteristic which may influence ingestion of granules. The likelihood of ingesting a lethal dose is related to the number of granules which contain an $LD_{50}$, and the number available. It seems logical, since most species will consume at least a few grit particles in the size range of terbufos granules, that the fewer the number of granules equal to a toxic dose, the greater the number of species at risk.

For Terbufos 20CR, 2 to 15 granules are estimated to be equivalent to an $LD_{50}$ depending on weight of the bird, suggesting the potential to impact a variety of species. (See calculations above and in addendum for terrestrial risk quotients.) That is, small birds would be expected to consume relatively 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 granules.

For the 15G formulation, 41 to 257 granules are estimated to be equivalent to an $LD_{50}$ depending on weight of the bird. This suggests that larger avian species are at lower risk due both to the relatively large number of granules needed to equal an $LC_{50}$ 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.

For the most part these factors have not been investigated to define their influence for the two formulations. Results of pen trials (simulated field studies with birds confined in pens) suggest that both formulations have the potential to impact non-target wildlife species. However, the data collected are insufficient to draw inferences about the relative hazard of the two formulations to non-target species under actual use conditions. (MRID #s 415088-01, 418492-01)

**Exposure of mammals**. 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 from 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 or contaminated soil.

**Persistence of terbufos in the terrestrial environment**. Because terbufos is incorporated the relevant degradation process are those that occur in soil. In soil terbufos will degrade primarily by *hydrolysis and microbial degradation*. Under conditions favorable to microbial growth the *soil metabolic half-life* is about 27 days in aerobic soil and about 72 days in anaerobic soil. The *hydrolytic half life* is 15 days under abiotic conditions and typical environmental pH.

Although terbufos is unstable in irradiated water, *photolysis* is not expected to be a significant route of degradation, assuming incorporation. *Volatilization* may be a major dissipation route for the portion of parent terbufos that remains on the surface of soil after incorporation. Information is needed on dissipation of terbufos under *field* conditions.

The predominant *metabolites*, terbufos sulfoxide and terbufos sulfone, are more mobile and persistent than parent terbufos, and may be equally toxic. The sulfoxide and sulfone have half-lives in aerobic soil of 150 and 210 days, respectively.

Additional details are given in the Environmental Fate Assessment.

### ii. Aquatic Risk Characterization

Concerns for adverse effects of parent terbufos and/or terbufos metabolites are strongly supported by widespread fish kill incidents.

These concerns are further supported by standard LOC criteria which indicate concerns for adverse effects on aquatic (fresh water, estuarine/marine) fish and invertebrates for terbufos 15G and 20G. The application of these criteria for terbufos are based on measurements of fate and effects properties of *parent* terbufos, whereas actual impacts may be due to a large degree to terbufos metabolites (terbufos sulfone and sulfoxide) that are longer-lived than parent terbufos. The Agency does not have ecological toxicity measurements for terbufos metabolites, but experience with other organophosphorus pesticides suggests that sulfone and sulfoxide metabolites tend to have toxicity comparable to the parent compound.

This section provides additional information for characterization of the scope and likelihood of adverse effects.

**Transport to surface water, persistence in surface water.** Terbufos and terbufos metabolites may be transported to surface water in runoff. Also, based on concentrations of parent terbufos observed in ground water, these compounds may be transported to surface water in biologically significant concentrations via ground water.

Substantial amounts of *parent* terbufos could be available for runoff to surface waters for several days to weeks post-application (aerobic soil metabolism and terrestrial field dissipation half-lives of 24 to <40 days). The intermediate soil/water partitioning of terbufos ($K_{oc}$ 300-1400) indicates that substantial fractions of terbufos runoff could occur as both dissolution in runoff water and adsorption to eroding soil. The susceptibility of parent terbufos to hydrolysis (half-life of 2.2 weeks at pHs 5-9), rapid direct photolysis in water (half-life of 1 day with xenon lamp), and somewhat intermediate volatilization potential (Henry's constant of $6.6 \times 10^{3}$ atm*m$^3$/mol) should limit persistence in surface waters. In aquatic ecosystems significant fractions of parent terbufos may exist both dissolved in the water column and adsorbed to suspended and bottom sediment, based on the intermediate soil/water and sediment/water partitioning.

The major *metabolites* (terbufos sulfoxide and terbufos sulfone) have somewhat lower soil/water partitioning ($K_{oc}$ 105-452 for the sulfoxide, 93-250 for the sulfone) than terbufos, and appear to be much more persistent in soil (half-lives on the order of 150 to 210 days). Consequently, these metabolites should be available for runoff for a substantially longer time than terbufos parent, and will probably have somewhat higher fractions dissolved in runoff water and in the water column than terbufos. The available data on soil suggest that the metabolites may also be more persistent in surface water than terbufos. However, there are no data available on the abiotic hydrolysis, direct photolysis or volatilization of the metabolites which could help confirm that.

**Accumulation.** The reported BCFs for terbufos (320X to 940X), based on bioaccumulation in bluegill sunfish, indicate that parent terbufos has only moderate potential for bioaccumulation.

**Measured environmental concentrations relative to aquatic toxicity.** Monitoring information indicates that concentrations of parent terbufos and terbufos metabolites sometimes reach levels that would adversely effect aquatic animals in laboratory toxicity studies. Parent terbufos has been found to be toxic to several species of aquatic animals at concentrations under 1 ppb. Specifically for acute effects on fish, three studies with bluegill sunfish gave 96 hour $LC_{50}$ values 0.8-3.8 ppb (geometric mean 1.4 ppb). (Note that some toxic effect is expected to occur below the $LC_{50}$.) There are several reports of parent terbufos at concentrations exceeding 1 ppb in surface and ground water. As noted in the water quality assessment a spring in Iowa was found to have parent terbufos at 20 ppb.

Attempts to evaluate the frequency of toxic levels based on monitoring studies would be subject to several difficulties including (1) monitoring data rarely captures the peak concentrations that are most significant for acute toxic effects; and (2) concentrations of terbufos metabolites are not necessarily monitored.

**The Tier II aquatic exposure scenario and alternative scenarios.** The Agency estimates aquatic exposure assuming a closed body of water similar in dimensions to a farm pond. Farm pond scenarios are relevant per se for reasons that include (1) the need of pond owners/managers to know if terbufos will be a hazard to the fish in their ponds; and (2) use of farm ponds by various wildlife not deliberately stocked in the ponds including snakes, turtles, amphibians, waterfowl, wading birds, and raccoons.

As a surrogate for other kinds of bodies of water, the scenario may be appropriate, under-protective, or over-protective. Important determinants of whether or not the scenario is protective include the potential for dilution, which depends on factors including the size of the water body, whether the body of water is static (lentic) or flowing (lotic), and the rapidity of mixing. The scenario is probably suitable as a screen for effects on larger fish that would tend to inhabit open water. The scenario may be appropriate for prairie potholes.

For some kinds of aquatic systems the scenario may actually underestimate exposure. These include many kinds of water bodies that may be particularly significant as habitat for fish and amphibians, including a variety of shallow and/or ephemeral bodies of water around fields, such as marshes, ditches, and ephemeral streams and pools. For some of these, the exposure may be similar to the concentration in undiluted runoff.

Even for bodies of water that have higher dilution than a farm pond overall, the assumption of instantaneous mixing may result in underestimation of exposure for the relatively slower-mixing zone close to shoreline. The zone close to shoreline is typically the zone of highest biological activity and may be particularly significant as habitat for early life stages of fish and for small species of fish and amphibians.

**Regional considerations.** Fish kill incidents caused by pesticides are most often associated with large rains, which produce pesticide-contaminated runoff. The frequency of rains large enough to cause incidents will be less in more arid regions. However, relatively arid regions experience occasional thunderstorms, and in fact thunderstorms may account for a large fraction of the limited summer rainfall. Also, the kinds of water bodies affected will vary among regions with regard to the amount of dilution that occurs after rainfall.

**Limitations in incident information.** For terbufos, incident information is important in confirming aquatic impacts. Incidents can provide useful information on the circumstances where impacts occur in the field and are therefore a valuable tool for risk characterization. However, reliance on the *frequency* of incidents may significantly underestimate the extent of the actual impacts. Incidents cannot be assumed to be reliably detected and reported. Before an incident can be reported, it must be observed, reported, and attributed to the pesticide. Reproductive effects or other sublethal effects, effects on eggs or small age classes, or impacts on relatively small species (invertebrates, amphibians, or small fish species) are likely to escape immediate detection. The only invertebrate species cited in terbufos related incidents are crayfish, which are relatively conspicuous invertebrates. The attribution of incidents to a particular pesticide is subject to both "false positives" and "false negatives." An incident actually caused by terbufos cannot be attributed to terbufos unless there is information that the pesticide has been used recently in the vicinity of the incident. This is perhaps unlikely if the incident occurs days after application.

## Addendum ####?. Calculations for determination of LOC exceedances for terrestrial wildlife

The risk quotients are compared to LOC values in the text of the RED.

**Table 1.** Estimated Number of Granules per Square Foot and Number of Granules per $LD_{50}$ Index For Terbufos **20 CR**

| Use/ application method | Formulation (%AI/100) | Granule Wt. (mg) | App. Rate (oz/1000 ft of row) | Band Width (ft) | Percent Unincorporated App. Rate (decimal) | Amount of Active Ingredient Exposed[1] (mg/ft²) | No. of Exposed Granules[2] (/ft²) | Num. Granules/ $LD_{50}$[3]: 27 g bird[4] granules | Num. Granules/ $LD_{50}$[3]: 170 g bird[4] granules |
|---|---|---|---|---|---|---|---|---|---|
| **Field Corn, Popcorn, & Sweet Corn** | | | | | | | | | |
| Banded at planting | 0.20 | 0.85 | 1.2 | 0.6 | 0.15 | 8.50 | 50.00 | 2.38 | 15.00 |
| In-furrow at planting | 0.20 | 0.85 | 1.2 | 0.1 | 0.01 | 3.40 | 20.00 | 2.38 | 15.00 |
| Banded Post Emergence-incorporated | 0.20 | 0.85 | 1.8 | 0.6 | 0.15 | 12.80 | 75.29 | 2.38 | 15.00 |
| Banded At cultivation | 0.20 | 0.85 | 1.2 | 0.6 | 0.15 | 8.50 | 50.00 | 2.38 | 15.00 |
| **Grain Sorghum** | | | | | | | | | |
| Knifed-in at bedding | 0.20 | 0.85 | 2.4 | 0.1 | 0.01 | 6.80 | 40.00 | 2.38 | 15.00 |
| Knifed-in at planting | 0.20 | 0.85 | 1.2 | 0.1 | 0.15 | 8.50 | 50.00 | 2.38 | 15.00 |
| **Sugarbeets** | | | | | | | | | |
| Banded at planting | 0.20 | 0.85 | 1.2 | 0.6 | 0.15 | 8.50 | 50.00 | 2.38 | 15.00 |
| Knifed-in at planting | 0.20 | 0.85 | 2.4 | 0.1 | 0.01 | 6.80 | 40.00 | 2.38 | 15.00 |
| Banded at planting | 0.20 | 0.85 | 1.2 | 0.6 | 0.15 | 8.50 | 50.00 | 2.38 | 15.00 |
| Modified in-furrow at planting | 0.20 | 0.85 | 1.2 | 0.1 | 0.01 | 3.40 | 20.00 | 2.38 | 15.00 |
| Banded Post-Emergence | 0.20 | 0.85 | 1.2 | 0.6 | 0.15 | 8.50 | 50.00 | 2.38 | 15.00 |



58 of [illegible]

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 2.** Estimated Number of Granules per Square Foot and Number of Granules per $LD_{50}$ Avian Index For Terbufos **15 G**

| 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] 27 g bird[4] | No. of Granules/$LD_{50}$[3] 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 3. 20 CR Acute Avian Risk Quotients

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

Table 4. 15 G Avian Acute Risk Quotients

| APPLICATION METHOD | NUM. EXPOSED GRANULES/FT$^2$ | NUM. GRANULES/ $LD_{50}$ | | RISK QUOTIENT $LD_{50}$ / FT$^2$ | |
|---|---|---|---|---|---|
| | | 27 G BIRD | 170 G BIRD | 27 G BIRD | 170 G BIRD |
| **FIELD CORN, POPCORN & SWEET CORN** | | | | | |
| BANDED AT PLANTING | 858.59 | 40.91 | 257.58 | 20.99 | 3.33 |
| IN-FURROW AT PLANTING | 343.43 | 40.91 | 257.58 | 8.39 | 1.33 |
| **GRAIN SORGHUM** | | | | | |
| BANDED AT PLANTING | 858.59 | 40.91 | 257.58 | 20.99 | 3.33 |
| **SUGARBEETS** | | | | | |
| BANDED AT PLANTING | 858.59 | 40.91 | 257.58 | 20.99 | 3.33 |
| IN-FURROW AT PLANTING | 343.43 | 40.91 | 257.58 | 8.39 | 1.33 |
| POST EMERGENCE BANDED | 858.59 | 40.91 | 257.58 | 20.99 | 3.33 |



62 g 7

**Table 7.** Estimated Number of Granules per Square Foot and Number of Granules per $LD_{50}$ Mammalian Index For Terbufos 15 G

| 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] | 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 | 0.15 | 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** | | | | | | | | | |
| Bnded 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/ft²)/(% ai product/ granule wt)

3. No. granules per $LD_{50}$ = ($LD_{50}$ * body wt.)/(%ai*100 * granule wt.)

4. Mouse size mammal with $LD_{50}$ = 3.5 mg/kg

**Table 8.** Estimated Number of Granules per Square Foot and Number of Granules per $LD_{50}$ Index For Terbufos **20 CR** for Mammals

| Application method | Formulation (%AI/100) | Granule Wt. (mg) | App. Rate (oz/1000 ft of row) | Band Width (ft) | Percent Unincorporated (decimal) | Amount of Active Ingredient Exposed (mg/ft²) | No. of Exposed Granules[2] (/ft²) | No. of Granules/ $LD_{50}$[3] 25 g mammal[4] (granules) | No. of Granules/ $LD_{50}$[3] 1 kg mammal (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

Table 9. 20 CR Mammal Acute Risk Quotients

| Application method | No. of exposed Granules/ft² | No. of Granules/$LD_{50}$ | | Risk Quotient $LD_{50}/ft^2$ | |
|---|---|---|---|---|---|
| | | 25 g Mammal | 1kg Mammal | 25 g Mammal | 1 kg Mammal |
| **Field Corn, Popcorn & Sweet Corn** | | | | | |
| Banded at Planting | 50.0 | 0.23 | 9.24 | 217.39 | 5.41 |
| In-furrow at Planting | 20.0 | 0.23 | 9.24 | 86.96 | 2.16 |
| Banded Post Emergence Incorporated | 75.29 | 0.23 | 9.24 | 327.35 | 8.15 |
| Banded, at Cultivation | 50.0 | 0.23 | 9.24 | 217.39 | 5.41 |
| **Grain Sorghum** | | | | | |
| Knifed-in at Bedding | 40.0 | 0.23 | 9.24 | 173.91 | 4.33 |
| Knifed-in at Planting | 50.0 | 0.23 | 9.24 | 217.39 | 5.41 |
| **Sugarbeets** | | | | | |
| Banded at Planting | 50.0 | 0.23 | 9.24 | 217.39 | 5.41 |
| Knifed-in at Planting | 40.0 | 0.23 | 9.24 | 173.91 | 4.33 |
| Modified In-furrow at Planting | 20.0 | 0.23 | 9.24 | 86.96 | 2.16 |
| Banded Post Emergence | 50.0 | 0.23 | 9.24 | 217.39 | 5.41 |

Table 10. 15 G Mammal Acute Risk Quotients

| Application method | No. of exposed Granules/ft² | No. of Granules/$LD_{50}$ | | Risk Quotient $LD_{50}/ft^2$ | |
|---|---|---|---|---|---|
| | | 25 g Mammal | 1kg Mammal | 25 g Mammal | 1kg mammal |
| **Field Corn, Popcorn & Sweet Corn** | | | | | |
| Banded at Planting | 858.59 | 3.97 | 158.59 | 216.27 | 5.41 |
| In-furrow at Planting | 343.43 | 3.97 | 158.59 | 86.51 | 2.17 |
| **Grain Sorghum** | | | | | |
| Banded at Planting | 858.59 | 3.97 | 158.59 | 216.27 | 5.41 |
| **Sugarbeets** | | | | | |
| Banded at Planting | 858.59 | 3.97 | 158.59 | 216.27 | 5.41 |
| In-furrow at Planting | 343.43 | 3.97 | 158.59 | 86.51 | 2.17 |
| Post Emergence Banded | 858.59 | 3.97 | 158.59 | 216.27 | 5.41 |

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