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

OFFICE OF PREVENTION,
PESTICIDES AND TOXIC SUBSTANCES

MEMORANDUM

FROM: David Farrar, Statistician, Terbufos RED task leader
James Breithaupt, Agronomist
James Carleton, Chemist
Environmental Fate and Effects Division (7507C)

THRU: Pat Jennings, Acting Branch Chief
Environmental Risk Branch II
Environmental Fate and Effects Division (7507C)

TO: Pam Noyes, Chemical Review Manager
Special Review and Reregistration Division

SUBJECT: **Terbufos:**
Revised EFED RED chapter;
Revision of Fate and Transport and Water Resources

DP BARCODE: D257287, D253363, D247455

DATE: Aug. 26, 1999

The purpose of this communication is to provide an updated copy of the EFED RED chapter for Terbufos to be placed in the Terbufos docket. (The updated RED chapter is attached.) The RED chapter has been significantly revised to address items submitted for the Terbufos docket and to make use of new information on the fate and transport properties of Terbufos and the sulfone and sulfoxide metabolites of Terbufos. Estimated concentrations in surface and ground water have been re-calculated for parent Terbufos and for the combined concentration of parent, sulfoxide, and sulfone, using the most recent model versions and using all available information on fate and transport properties.

Comments received by EFED and addressed in the chapter attached. The previous EFED RED chapter (11/4/98) was already revised to address comments received by EFED, with the following exceptions:

- Comments from Martha Philbeck submitted for the Terbufos docket
- Comments from American Cyanamid submitted 2/16/98

These comments have now been addressed in the RED chapter attached. In addition, each of these items is the subject of a separate communication. We responded to the comments from Ms. Philbeck on 8/5/99. The material submitted by Ms. Philbeck provides important perspectives on aquatic incidents caused by Terbufos. (See also our 4/11/99 communication on the significance of incidents in farm ponds.) On 8/20/99 we provided a separate communications addressing comments from Cyanamid. Each item has resulted in some revision of the RED chapter, as described in the separate communications.

Modification of the Environmental Fate Assessment. The Environmental fate assessment in the chapter attached notes that formaldehyde was found to be a degradation product in studies of hydrolysis, aqueous photolysis, and aerobic aquatic metabolism.

Modifications of the Ecological Risk Assessment and Risk Characterization. We have removed references to rainfall from the records of individual incidents in the Appendix to Section C of the chapter. It is understood that some rainfall is ordinarily required to move the pesticide to surface water. Inclusion of rainfall information for specific incidents would require further review and might require more rigorous documentation, for example daily records from rain gauges situated near to where the incidents occurred. The RED states that for many incidents the primary source of information is reports submitted by American Cyanamid.

Revision of surface water EECs. The surface water EECs reported in the attached RED chapter differ significantly from values EFED has reported previously. The differences are due the following modifications:

- The EECs for knifed-in applications to sugar beets take into account a recent reduction of about 50% in the maximum label rate.
- Whereas previous EECs represent parent Terbufos only, we have calculated EECs representing the decline of parent Terbufos and the formation and decline rates of Terbufos sulfoxide and sulfone in the field and off the field.
- EFED used the previously-submitted and reviewed aerobic soil metabolism study for PRZM and the new pond water degradation study for Terbufos for EXAMS.
- The newer PRZM model has more soil incorporation options than the older PRZM model. Use of these options resulted in significant changes in the EECs.

For all three labeled crops the model results suggest negligible exposure for application procedures other than T-band application. However, EFED is concerned that incorporation options in the most recent PRZM version may not adequately represent the availability of the chemical for runoff. The Agency has received reports of aquatic incidents for corn, for all application procedures including in-furrow application. EFED believes that in-furrow application can be associated with significant runoff for any of the three labelled crops. While we believe that application procedures can have a large influence on runoff, we do not have field information confirming differences as dramatic as those suggested by the model results for Terbufos.

OUTLINE OF SECTION C. ENVIRONMENTAL ASSESSMENT

4879

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-emergent 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.

Information on use rates, and estimates of relative importance of different application procedures, are displayed on the page following. The information is primarily from a Fax communication from J. Wrubel (9/16/97). A recent reduction in maximum rates for knifed-in applications to sugar beets and sorghum has been incorporated.

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.

6879

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. **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. **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. •A reduced rate (0.75 lb ai/A) can be used on "first year" corn. •Light incorporation places granules no deeper than 1 inch.
Grain sorghum	2 lb ai/A for knifed-in only (0.75 lb ai/A) 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. **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. •Light incorporation places granules no deeper than 1".
Sugar beets	2 lb ai/A for knifed in only (1.1 lb ai/A) 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. **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. •Light incorporation places granules no deeper than 1".

7879

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 linear metabolic half-life in aerobic soil is approximately 27 days (5.6 days for non-linear) and in anaerobic soil is 67 days (21 days for non-linear). Under abiotic conditions, the hydrolysis half-life is 12.3-13.7 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 EFED is assuming they are equally toxic. The sulfoxide and sulfone have non-linear half-lives of 116 and 96 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 (3.16×10^{-4} mm Hg) and observed Henry's Law Constant (6.58×10^{-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.

b. Environmental Fate and Transport

I. Degradation

Hydrolysis of Parent Terbufos (161-1)--Terbufos degraded with half-lives of 12.3, 12.8, and 13.8 days in pH 5, 7, and 9 buffer solutions, respectively. The primary degradation product was formaldehyde, which accounted for 50-69% of the applied dose at 4 weeks (end of study). 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)

8879

methanethiol], and three unknowns were minor metabolites (<3% of applied). (MRID #00087694)

Hydrolysis of Parent Terbufos and Terbufos Sulfoxide and Sulfone (161-1)The study was conducted using different temperatures for parent compound (10, 20, and 30 °C) than those used for Terbufos sulfoxide and sulfone. In addition, the registrant conducted the pH 5 and 7 studies for Terbufos sulfoxide and sulfone at 40, 50, and 60 °C and pH 9 metabolite studies at 20, 30, and 40 °C. This study design generally indicates that the compounds degrade faster at higher temperatures, regardless of pH. (MRID 44862501)

EFED did not use this study for risk assessment since the registrant provided the aerobic aquatic pond water study (MRID 44862502, 162-4) described below. The aerobic aquatic pond water study provided useful inputs for the EXAMS model.

Bowman and Sans (Open literature, 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) 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 in a silt loam soil with a half life of 27 days calculated using linear regression (log concentration against time), and with a half life of 6 days calculated by fitting the first-order degradation model using nonlinear regression, with untransformed concentration measurements. The 27-day half-life was originally calculated in previous documents, but EFED recalculated this half-life using non-linear regression because formation and decline analysis was used for modeling purposes. The major metabolites were Terbufos sulfoxide, Terbufos sulfone, and CO_2. Half-lives for these metabolites were 116 and 96 days, respectively, calculated using nonlinear regression. 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 a linear anaerobic half-life of 67 days (21 days for non-linear analysis) in nonsterile flooded silt loam soil that was incubated under a nitrogen atmosphere for 60 days following 9 days of aerobic incubation. The half-lives for terbufos sulfoxide were 14 days (linear) and 7 days (non-linear). 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 sulfoxide and sulfone, 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. Because the conditions were aerobic initially, the calculated anaerobic half-life is probably an underestimation of the true anaerobic soil half-life. (MRID #41749801)

Aerobic Aquatic Metabolism (162-4)–This study is acceptable and provides useful information on the degradation of parent Terbufos. However, the registrant submitted the aerobic aquatic pond water study below that incorporated the metabolites sulfoxide and sulfone. Therefore, EFED did not use this study as a model input into EXAMS.

Sand Sediment

The half-life in the sand sediment:water system was 27 days. Terbufos residues in water decreased from 44 % of applied at 6 hours to non-detectable levels by 50 days. Terbufos residues in sediment decreased from a maximum of 59 % at day zero to <10 % by 14 days. Terbufos in the glycol traps (volatile Terbufos) and NaOH traps (CO_2) increased as the levels in sediment and water decreased, reaching 21-45 % and 32 %, respectively.

Loam Sediment

The half-life in the sand sediment:water system was 41 days. Terbufos residues in water decreased from 16-17 % of applied at 6 hours to non-detectable levels by 7-14 days. Terbufos residues in sediment decreased from a maximum of 59 % at 6 hours to 11 % by 100 days (end of study). Terbufos in the glycol traps (volatile Terbufos) and NaOH traps (CO_2) increased as the levels in sediment and water decreased, reaching 9-31 % and 52 %, respectively. (MRID #44672004)

Aerobic Aquatic Metabolism in Pond Water Only (162-4)–The pond water study is acceptable and provides useful information for modeling purposes. EFED used these data in EXAMS to determine the persistence of parent Terbufos, Terbufos sulfoxide, and Terbufos sulfone, the formation rate of Terbufos sulfoxide from applied parent, and the formation rate of Terbufos sulfone from applied sulfoxide. Terbufos degraded with an aerobic half-life of 1.5 days (upper 90th confidence bound on mean of two replicates) using non-linear analysis in nonsterile pond water that was incubated for 30 days. Parent Terbufos reached non-detectable levels by 7 days. Applied Terbufos sulfoxide degraded with a half-life of 68 days (upper 90th

confidence bound on mean of two replicates) and declined to 50-62 % by 30 days (end of study). Applied Terbufos sulfone degraded with a calculated half-life of 32 days (upper 90th confidence bound on mean of two replicates) and declined to 39-43 % of applied by 30 days. The major metabolite was formaldehyde, indicating that hydrolyis proceeded faster than metabolism that would produce sulfoxide and sulfone metabolites. (MRID #44862502)

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 (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 exposure to aquatic organisms and to humans by drinking water. Also provided is a *description of environmental 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.

These data represent 4,563 samples from 13 states, including 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 inconclusive because there appeared to be problems with the analytical method.

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 Health Advisory (Illinois, Indiana, Mississippi), and there is no clear connection between Terbufos use areas and the wells sampled. Therefore, 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 use of water from different aquifers drawn from a single well may indicate that the water may not have originated during periods when Terbufos was in use. Therefore, a non-detection may not be meaningful.

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; however, EFED has not confirmed whether or not there was use of Terbufos in Georgia during the period of sampling.

Illinois. Felsot (1984) sampled the inside faucets from 25 sand point wells. No Terbufos, Terbufos metabolites, or other pesticides were detected above 1 ppb. 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. Terbufos metabolites were analyzed for, but not detected.

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 Terbufos metabolites were analyzed.

Ground-water monitoring data for pesticides from 1986 to 1990 in Indiana were compiled in a report by Risch (1994). A combination of public community wells, 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 achievable 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 exceed the Health Advisory (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 provided. No Terbufos metabolites were analyzed for.

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, and EPA has concluding that the findings were either not-confirmed or were attributed to point sources [Susan Wayland of EPA to William A. Stellar of Cyanamid, 10 Jan. 89]. 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 based on the results of the Iowa study.

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). A subset of these wells and three public drinking water wells were resampled. Terbufos parent was analyzed; no residues were found. No metabolites were analyzed for.

14879

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 and was thought to be present as a result of normal use of Terbufos.

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. Because of the lack of use in the state, the lack of detections is not significant.

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 for.

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 including Terbufos 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 for.

15879

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.

16879

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 vulnerable to contamination. In most cases, a majority of the pesticide 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. The SCI-GROW model does not make use of information on application procedures.

The EECs and some of the discussion from a 1/5/99 memorandum on drinking water have been included in this section. EFED has estimated total toxic concentrations of Terbufos since adequate environmental fate data on degradates are available as inputs for the SCI-GROW model. EFED has also provided EECs for parent Terbufos for comparison purposes. Table 2 below presents the maximum acute and chronic **ground water** EECs for the total toxic residues of Terbufos using the SCI-GROW model. These EECs are appropriate for the dietary exposure assessment. The residues of parent Terbufos, Terbufos sulfoxide, and Terbufos sulfone in the aerobic soil metabolism study (MRID 00156853) were added for each sampling interval, and the half-life was calculated by linear regression of the log of the summed concentration against time.

Table 2. Acute and Chronic Concentrations of Total Toxic Residues of Terbufos in Ground Water using the Tier 1 Model SCI-GROW.[1]

Crop and Application Rate	Acute and Chronic (ug/L)
Corn (Parent only, 1.3 lbs ai/A maximum rate)[2]	0.007
Corn (Total toxic residue, 1.3 lb ai/A maximum rate)[2]	4.8
Grain Sorghum (Parent only, 2 lbs ai/a maximum rate)[3]	0.01
Grain Sorghum (Total toxic residue, 2 lbs ai/a maximum rate)[3]	7.4
Sugar Beets (Parent only, 2 lbs ai/A maximum rate)[4]	0.01
Sugar Beets (Total toxic residue, 2 lbs ai/A maximum rate)[4]	7.4

[1] This assumes the total toxic residue (parent + sulfoxide + sulfone) half-life from the aerobic soil metabolism study (MRID 00156853) of 129 days and the lowest K_{oc} of Terbufos sulfoxide and sulfone of 58 ml/g for an estimate of mobility. This K_{oc} value was chosen because the adsorption of these metabolites was highly related to soil pH (r^2=0.96-0.98). The different rates in this table are based on the label and the 9/16/97 fax from John Wrubel of American Cyanamid. For parent Terbufos only, EFED assumed a Koc of 633 and a half-life of 5.6 days from the same studies

[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 for each application procedure.

[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. These numbers take into account the recent label amendment for a maximum rate of knifed-in Terbufos to 2 lbs ai/A from 3.9 lbs ai/A.

[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). These numbers take into account the recent label amendment for a maximum rate of knifed-in Terbufos to 2 lbs ai/A from 3.9 lbs ai/A.

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 (pH values of 5, 7, and 9), aerobic soil metabolism and anaerobic aquatic metabolism were 12.3-13.7, 5.6, and 67 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 presence of the chemical below the photic zone. The reported vapor pressure (3.16×10^{-4} mm Hg), Henry's Law Constant of 6.58×10^{-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 modeling, EFED did not calculate the amount of Terbufos residues in sediment. This is because the metabolites are very mobile and would likely be associated with the water column.

In soil, parent Terbufos transforms 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 116 and 96 days, respectively) than parent Terbufos ($T_{1/2}$ of 5.6 days). 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 and in water suggest that the metabolites may also be more persistent in surface water than Terbufos.

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 STORET database also contained USGS NAWQA data from 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

19879

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. No data were available from these studies on the concentrations of the sulfoxide or sulfone metabolites in water bodies sampled.

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. The data EFED has received consist of 214 samples.

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.

Limitations of NAWQA Data

The NAWQA program was designed to describe the status and trends of a representative portion of the nation's water quality and to provide a sound scientific understanding of the primary natural and human factors affecting the water quality (Hirsch et al., 1988). The program is not targeted to reflect concentrations of pesticide resulting from use within the sampled watersheds.

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)

21879

EPA has received reports of 85 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 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 could 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 field corn in Ohio, grain sorghum in Kansas, and sugar beets in Minnesota, using PRZM 3.12 and EXAMS 2.975. (Previous modeling used PRZM 2.3 and EXAMS 2.94 and for corn, and an Iowa scenario was modeled.) EFED is also using a recently-approved label that reduces the maximum rate for knifed-in applications of terbufos for sugar beets and grain sorghum (3.9 lbs ai/a to 2 lbs ai/a). EFED has also calculated EECs for surface water for total toxic residues of those Terbufos residues that are observed in environmental fate studies (parent, Terbufos sulfoxide and sulfone). 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 average 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. This can also be expressed as an expectation that water concentrations will exceed EECs once every 10 years.

This revised RED Chapter contains updated EECs from modeling for both surface and ground water. This RED Chapter supersedes the memoranda dated 9/30/97 and 1/5/99 since it contains updated water concentrations. Since the previous memoranda, EFED has conducted additional modeling to estimate levels of parent terbufos and the oxidative metabolites terbufos sulfoxide and sulfone in surface water. EECs for these metabolites were not included in the 9/30/97 memorandum for either surface or ground water. This updated RED Chapter also contains the estimated environmental concentrations (EECs) for terbufos and the above oxidative metabolites in ground water from the 1/5/99 memorandum.

Since the previous water memoranda, EFED has received data on the abiotic hydrolysis of parent terbufos and the oxidative metabolites terbufos sulfoxide and sulfone. We have also received aerobic aquatic data for the above compounds in aerobic natural pond water. These data were submitted in response to the 11/24/98 memorandum which concluded that using the PRZM-EXAMS model to estimate surface water concentrations for these metabolites would not provide meaningful information at this time due to lack of data for either hydrolysis or aquatic metabolism.

The aerobic aquatic metabolism study (MRID 44672004) was screened and found to contain useful information for parent terbufos only. Therefore, EFED did not use the results from this study as a model input.

EFED did not use the abiotic hydrolysis data for surface water because the aerobic aquatic metabolism data are more relevant. For ground water, the hydrolysis data provide useful information on the persistence and degradation products if terbufos residues were to reach ground water.

Tier II upper tenth percentile EECs for parent Terbufos and the sulfoxide and sulfone metabolites are displayed in Table 4. Tables 5, 6, and 7 below present the Environmental Fate parameters used as inputs in the model for these compounds, respectively.

For the in-furrow and knifed-in uses, the model actually underpredicted the EECs that would likely be observed. Extremely low levels of parent terbufos and metabolites were predicted for all simulated in-furrow or knifed-in applications. PRZM does not move pesticides upward from a fixed depth even though this can occur in the field in finer-textured soils through capillary action. Some fish-kill incidents have been associated with in-furrow applications of terbufos.

23879

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						
Parent only Corn at 1.3 lbs ai/A T-banded (85 % in top 2 cm)	2.2	1.2	0.3	0.1	0.07	0.02
Total toxic residue Corn at 1.3 lbs ai/A T-banded (85 % in top 2 cm)	5.4	5.0	4.6	4.3	3.9	1.9
Parent Only Corn In-furrow (all at 1.0 inch of depth)	No residues were predicted to leave the field. This is a limitation of the model (See limitations discussion below).					
Total toxic residue Corn In-furrow (all at 1.0 inch of depth)	No residues were predicted to leave the field. This is a limitation of the model (See limitations discussion below).					

24879

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* ($\mu g \cdot L^{-1}$)
Grain Sorghum						
Parent Only Grain Sorghum T-banded (85 % in top 2 cm)	4.5	2.2	0.6	0.2	0.2	0.04
Total toxic residue Grain Sorghum T-banded (85 % in top 2 cm)	13.3	12.7	12.1	11.0	9.9	5.5
Parent Only Grain Sorghum In-furrow (all at 1 inch of depth)	No residues were predicted to leave the field. This is a limitation of the model (See limitations discussion below).					
Total toxic residue Grain Sorghum In-furrow (all at 1 inch of depth)	No residues were predicted to leave the field. This is a limitation of the model (See limitations discussion below).					

25879

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* ($\mu g \cdot L^{-1}$)
Sugar Beets						
Parent Only Sugar Beets T-banded (85 % in top 2 cm)	1.6	0.8	0.2	0.06	0.04	0.009
Total toxic residue Sugar Beets T-banded (85 % in top 2 cm)	4.3	3.8	3.4	3.0	2.8	1.3
Parent Only Sugar Beets Knifed In (all at 2 inches of depth)	No residues were predicted to leave the field. This is a limitation of the model (See limitations discussion below).					
Total toxic residue Sugar Beets Knifed In (all at 2 inches of depth)	No residues were predicted to leave the field. This is a limitation of the model (See limitations discussion below).					

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

26879

Table 5. **Environmental Fate Parameters used in PRZM-EXAMS Modeling for Parent Terbufos, Terbufos sulfoxide, and Terbufos sulfone.**

Parameter	**Value**	**Source (MRID unless specified)**	**Uncertainty Factor**[1]	**Rate Constants (K-value)**
Parent Terbufos				
Freundlich K_{oc}	633 ml/g	41373604	Not Applicable	Not Applicable
Aerobic Soil Metabolism $T_{1/2}$	5.6 days[2]	00156853	None	1.24×10^{-1} day^{-1}
Aerobic Aquatic Metabolism $T_{1/2}$ (KBACW)	1.50 days[2]	44862502	None	4.65×10^{-1} hour^{-1}
Anaerobic Aquatic Metabolism $T_{1/2}$ (KBACS)	11.7 days[2]	41749801	None	2.5×10^{-3} hour^{-1}
Terbufos sulfoxide				
Freundlich K_{oc}	58 ml/g/	41373604	Not Applicable	Not Applicable
Aerobic Soil Metabolism $T_{1/2}$	117 days[2]	00156853	None	5.9×10^{-3} day^{-1}
Aerobic Aquatic Metabolism $T_{1/2}$ (KBACW)	68 days[2]	44862502	None	$4.22. \times 10^{-4}$ hour^{-1}
Anaerobic Aquatic Metabolism $T_{1/2}$ (KBACS)	116 days[2]	00156853	2	1.24×10^{-4} hour^{-1}
Terbufos Sulfone				
Freundlich K_{oc}	58 ml/g	41373604	Not Applicable	Not Applicable
Aerobic Soil Metabolism $T_{1/2}$	96 days[2]	00156853	None	7.22×10^{-3} day^{-1}
Aerobic Aquatic Metabolism $T_{1/2}$ (KBACW)	32 days[2]	44862502	None	8.92×10^{-4} hour^{-1}
Anaerobic Aquatic Metabolism $T_{1/2}$ (KBACS)	96 days[2]	00156853	2	1.49×10^{-4} hour^{-1}

[1] For laboratory metabolism studies, EFED normally multiplies a single metabolism study $T_{1/2}$ by 3 to account for the uncertainty of having only one half-life. Since EFED conducted a formation and decline analysis, no uncertainty factors were included, and the value given in Column 2 has been used in PRZM-EXAMS modeling, after conversion to a rate constant (Column 5).

27879

[2] $T_{1/2}$ values used for PRZM-EXAMS modeling were calculated by fitting the first-order dissipation model using nonlinear regression with untransformed concentration measurements. For the KBACS (pond sediment) rate value in EXAMS, EFED used the aerobic soil half-life of terbufos sulfoxide (116 days) and sulfone (96 days), multiplied by 2 for a change in media, and converted this daily rate to an hourly rate.

Comparison of Modeling and Monitoring Results for Terbufos.

Maximum concentrations of parent Terbufos from PRZM 3.12 modeling were 1.6 ug/L for sugar beets, 2.2 ug/L for corn, and 4.5 ug/L for grain sorghum. Maximum concentrations of total toxic residues of Terbufos from PRZM 3.12 modeling were 4.3 ug/L for sugar beets, 5.4 ug/L for corn, and 13.3 ug/L for grain sorghum. Instead of the monitoring or modeling concentrations that take into account only parent terbufos, EFED recommends using the t-banded PRZM-EXAMS EECs for total toxic residues for each crop for both acute and chronic dietary exposure assessment.

Parent Terbufos was not found above 2.25 ug/L in monitoring data from the Midwest. However, the monitoring data are limited and often not associated with periods or areas of Terbufos use, and the quality for some data is unknown. Since they represent parent terbufos only, the monitoring data are useful for only a lower bound of environmental concentrations for parent terbufos only. However, the monitoring data do show that the PRZM-EXAMS modeling provides realistic estimates of exposure through drinking water, based on the similarity of the data. Based on the persistence and mobility of the sulfoxide and sulfone metabolites, monitoring data may actually exceed the EECs produced from PRZM-EXAMS.

c. Drinking Water Assessment

The major drinking water concerns associated with Terbufos use are potential leaching to ground water (only for the metabolites, terbufos sulfoxide and terbufos sulfone) and runoff to surface water (for parent terbufos as well as terbufos sulfoxide and terbufos sulfone). It is EFED's understands that the tolerance expression established for mammalian toxicity includes parent Terbufos, the metabolites Terbufos sulfoxide and sulfone, Terbufos oxon, and oxon sulfoxide and sulfone. Parent EECs were provided as well as total toxic residues that include parent Terbufos, Terbufos sulfoxide, and sulfone. These were the only Terbufos compounds with the organophosphate functional group that were observed in environmental fate laboratory studies in significant quantities.

Ground water concentrations for drinking water exposure assessment. Table 2 (above) displays estimated concentrations for ground water for use in dietary risk assessment, for parent Terbufos and the metabolites Terbufos sulfoxide and Terbufos sulfone, based on the SCI-GROW model. EFED recommends using the EECs for total toxic residues for each combination of crop and application method. EFED has presented EECs for parent Terbufos for purposes of comparison.

28871

Uncertainties in estimating ground water concentrations. The SCI-GROW model is based on small-scale ground water monitoring studies conducted for aquifers beneath 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. Table 4 above contains surface water concentrations of total residues (parent terbufos+terbufos sulfoxide+terbufos sulfone) for use in dietary risk assessment, based on modeling with PRZM-EXAMS. Terbufos sulfoxide and terbufos sulfone are the only Terbufos metabolites having the organophosphate functional group that have been observed in significant quantities in fate studies. EFED recommends using the EECs for total residues for each crop and application method combination. EFED has provided the EECs for parent Terbufos for purposes of comparison. The water monitoring data are very limited for parent Terbufos, and no monitoring information for the Terbufos metabolites is available to EFED for surface water.

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, 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). However, PRZM cannot simulate the upward movement of residues due to capillary transport that may occur in finer-textured soils. Therefore, PRZM may underpredict EECs when simulating applications such as knifed-in and in-furrow applications. Supporting evidence for underprediction is provided by the fish kill incidents.

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.

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 (95% CI 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. (# FEOTER02)

The acceptable avian subacute dietary studies are listed below:

Avian Subacute Dietary Toxicity Findings

Species	% AI	LC_{50} (ppm)	Conclusions
Mallard Duck	86	520 (95% CI 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 00035120, 00087717, 00160387)

30879

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 NOAEL 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, FEOTER01)

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 BAOTER01)

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 (95% CI 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:

33879

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

Species	% AI	LC_{50} (ppb) LC_{50} (ppb ai)	Toxicity category	Study classification
Bluegill sunfish	15	12.3 (95% CI 9.8-15.2) 1.8 (1.5-2.3)	very highly toxic	core
Rainbow trout	15	59.7 (48.1-74.3) 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 NOAEL was 1.4 ppb, the highest concentration tested. 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)

34879

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 (95% CI 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] from Mayer and Ellersieck, 1986. 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	NOAEC 30 ppt; LOAEC 76 ppt 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

35879

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)

Chronic toxicity information is not available for marine and estuarine animals.

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

36879

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 LOAEC (for birds, fish, and aquatic invertebrates), NOAEC (for birds, fish and aquatic invertebrates), and MATC (for fish and aquatic invertebrates). The NOAEC 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 NOAEC and LOAEC) is the chronic toxicity measurement used for fish and aquatic invertebrates. However, the NOAEC 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/NOAEC	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/NOAEC	1

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

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

37879

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 NOAEC	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 NOAEC	1
Aquatic Plants		
Acute High Risk	EEC[2]/EC50	1
Acute Endangered Species	EEC/EC05 or NOAEC	1

[1] EEC = lb ai/A
[2] EEC = concentration 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:

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

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

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

Tables in Appendix C.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.

$$\frac{\text{Granules}}{\text{ft}^2} \;/\; \frac{\text{Granules}}{\text{LD}_{50}} = \frac{\text{LD}_{50}}{\text{ft}^2}$$

39879

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, or adhering to the surface of 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.

Risk quotients for birds and mammals are displayed on the pages following. 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. For all uses, the level of concern is exceeded for Terbufos, for both birds and mammals. Tables below show the avian risk quotients for the various uses and application methods of Terbufos. Banded application of Terbufos the RQs tend to be somewhat greater due to the less efficient soil incorporation. For The complete calculations are displayed in tables provided in Appendix C.1.

Avian Risk Quotients and LOC's for Terbufos 20 CR formulation

USE/APPLICATION METHOD	APPLICATION RATE/oz. per 1000 ft of row	RISK QUOTIENT LD_{50}/FT2	
		27 G BIRD	170 G BIRD
FIELD CORN, POPCORN & SWEET CORN			
BANDED AT PLANTING	1.2	21	3.3
IN-FURROW AT PLANTING	1.2	8.4	1.3
BANDED POST EMERGENCE INCORPORATED	1.8	32	5.0
BANDED, AT CULTIVATION	1.2	21	3.3
GRAIN SORGHUM			
KNIFED-IN AT BEDDING	1.2	8.6	1.4
KNIFED-IN AT PLANTING	0.62	11	1.7
SUGARBEETS			
BANDED AT PLANTING	1.2	21	3.3
KNIFED-IN AT PLANTING	1.2	8.6	1.4
MODIFIED IN-FURROW AT PLANTING	1.2	8.4	1.3
BANDED POST EMERGENCE	1.2	21	3.3

Avian Risk Quotients and LOC's for Terbufos 15G formulation

Application Method	Formulation/ Use Rate	Risk Quotient LD_{50}/ft2	
		27 g Bird	170 g Bird
Field corn, popcorn & sweet corn			
Banded at planting	1.2 oz/1000 ft row	21	3.3
In-furrow at planting	1.2 oz/1000 ft row	8.4	1.3
Grain sorghum			
Banded at planting	1.2 oz/1000 ft row	21	3.3
Sugarbeets			
Banded at planting	1.2 oz/1000 ft row	21	3.3
In-furrow at planting	1.2 oz/1000 ft row	8.4	1.3
Post emergence banded	1.2 oz/1000 ft row	21	3.3

Note: the calculations are documented in an Addendum. RQ values are assumed according to the following criteria:

High Risk > 0.5
Restricted use > 0.2
Endangered Species > 0.1

41879

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	1 kg Mammal
FIELD CORN, POPCORN & SWEET CORN			
BANDED AT PLANTING	1.2	217	5.4
IN-FURROW AT PLANTING	1.2	87	2.2
BANDED POST EMERGENCE INCORPORATED	1.8	327	8.2
BANDED, AT CULTIVATION	1.2	217	5.4
GRAIN SORGHUM			
KNIFED-IN AT BEDDING	1.2	89	2.2
KNIFED-IN AT PLANTING	0.62	111	2.8
SUGARBEETS			
BANDED AT PLANTING	1.2	217	5.4
KNIFED-IN AT PLANTING	1.2	89	2.2
MODIFIED IN-FURROW AT PLANTING	1.2	87	2.2
BANDED POST EMERGENCE	1.2	217	5.4

Mammal Acute Risk Quotients and LOC's for 15 G

Application Method	Use Rate (oz/1000 ft of row)	Risk Quotient LD_{50}/ft2	
		25 g Mammal	1 KG Mammal
Field corn, popcorn & sweet corn			
Banded at planting	1.2	216	5.4
In-furrow at planting	1.2	87	2.2
Grain sorghum			
Banded at planting	1.2	216	5.4
Sugarbeets			
Banded at planting	1.2	216	5.4
In-furrow at planting	1.2	87	2.2
Post emergence banded	1.2	216	5.4

Note: the calculations are documented in an Addendum. RQ values are assumed according to the following criteria:

High Risk > 0.5
Restricted use > 0.2
Endangered Species > 0.1

42879

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 NOAEL of 15 ppm may be derived. A three generation rat reproduction study with technical Terbufos reported a NOAEL of 0.25 ppm and a LOAEL of 1 ppm. The major effect observed was an increase in offspring deaths as compared to controls.

ii. Aquatic LOC assessments

Standard procedures for determination concerns for adverse effects are based on risk quotients (RQs), which compare estimated environmental concentrations (EECs) to laboratory toxicity measurements. Risk quotients are displayed on the following two pages for all categories of aquatic animals (fish/invertebrate, acute/chronic, freshwater/marine/estuarine).

To estimate exposure, weather and agricultural practices were simulated based on 36 years of meteorological data. To obtain an acute risk quotient, an LC50 is divided is divided by the "peak EEC, which is the estimated concentration exceeded my the maximum yearly concentration, for 10% of years. To calculate a chronic risk quotient, the EEC calculation involves averaging concentration over a time interval comparable to the length of the toxicity study. For example a a 4-day EEC is the concentration exceed by at least one 4-day average, in 10% of years. The calculation of EECs is described in greater detail in Section C.1.c ("Water Resources").

EECs and RQs have been calculated for Terbufos in two ways (see tables on the pages following): The first set of results is for parent Terbufos; the second set represents the combined concentration of parent Terbufos, Terbufos sulfoxide, and Terbufos sulfone ("total OP residue").

The RQs on the following pages can be summarized as follows. For T-band applications to all three crops (application rates 1.3 - 2 lb ai/A) the following ranges of RQs are obtained using total OP residue:

- for fish/acute, RQ 3-17;
- for fish/chronic, RQ 2-8;
- for invert/acute, RQ 14-60;
- for invert/chronic, RQ 113-403.

These acute RQs all exceed acute high risk levels of concern, i.e., RQ>0.5, and the chronic RQs all exceed the level of concern, i.e., RQ>1. We find that consideration of the total OP residue raises acute EECs and RQs by a factor of 2.5 - 3X and raises chronic EECs and RQs by a factor of 15 - 50X, relative to results for parent Terbufos. The greater factor increase for the chronic results is presumed to be due to the persistence of metabolites. For application

43379

procedures other than T-band, the estimated exposures are equal to zero. However, incident data involving fish kills demonstrates ecological risk with in-furrow applications to corn. The Agency believes that significant runoff can be associated with in-furrow applications for all three crops. We are concerned that incorporation options in the most recent PRZM version may not adequately represent the availability of the chemical for runoff.

Risk quotients for aquatic animals based on estimated concentration of parent Terbufos

Crop (lb ai/A)	Application Procedure	Estimated Environmental Concentration (EEC, ppb)			Risk Quotients by Crop, rate etc.					
					freshwater				marine /estuarine	
					fish		invertebrate		fish	invert.
					acute	chronic	acute	chronic	acute	acute
					Toxic concentration (LC50 or NOAEC, ppb)[1]					
					0.77	1.43	0.31	0.03	1.6	0.22
					Exposure column for EEC					
		Peak	21 day	60 day	peak	60 day	peak	21 day	peak	peak
corn 1.3 lb/A	T-band, 85% in top 2 cm	2.2	0.3	0.1	2.9	0.071	7.1	10	1.4	10
	In-Furrow, 100% at 1.25 in	[Estimated exposure = zero [2]]								
grain sorghum 2 lb/A	T-band, 85% in top 2 cm	4.5	0.6	0.2	6	0	15	20	2.8	20
	In-Furrow, 100% at 1 in	[Estimated exposure = zero [2]]								
sugar beets 2 lb/A	T-band, 85% in top 2 cm	1.6	0.2	0.06	2.1	0.043	5.2	6.7	1.0	7.3
	Knifed-in, 100% at 2 in	[Estimated exposure = zero [2]]								

[1] Toxicity Measurements: FW fish acute = LC50 for bluegill sunfish; FW fish chronic = NOAEC from rainbow trout life cycle. The NOAEC was taken to be the highest concentration tested because no level tested resulted in an adverse affect. (Guidelines require the chemical to be tested at a level high enough to adversely affect some life stage.) FW invert. acute = LC50 for *Daphnia magna* (Crustacea); FW invert. chronic = LOAEC for *D. magna*. M/E fish acute = LC50 for sheepshead minnow. M/E invert. acute = LC50 for mysid (Crustacea). Chronic toxicity measurements are not available for M/E fish and invertebrates.

[2] See discussion of model limitations in the environmental fate assessment. Incorporation options in the current version of the PRZM model may not adequately represent the availability of the chemical for runoff.

45879

Risk quotients for aquatic animals based on estimated combined concentration of parent Terbufos, Terbufos sulfone, and Terbufos sulfoxide

Crop	Rate etc.	Estimated Environmental Concentration (EEC, ppb)			Risk Quotients by Crop, rate etc.					
					freshwater				marine /estuarine	
					fish		invertebrate		fish	invert.
					acute	chronic	acute	chronic	acute	acute
					Toxic concentration (ppb) (LC50 or NOAEC) [1]					
					0.77	1.43	0.31	0.03	1.6	0.22
					Exposure column for EEC					
		Peak	21 day	60 day	peak	60 day	peak	21 day	peak	peak
corn 1.3 lb/A	T-band, 85% in top 2 cm	5.4	4.6	4.3	7.0	3.1	17	153	3	25
	In-Furrow, 100% at 1.25 in	[Estimated exposure = zero [2]]								
grain sorghum 2 lb/A	T-band, 85% in top 2 cm	13.3	12.1	11	17	8	43	403	8.3	60
	In-Furrow, 100% at 1 in	[Estimated exposure = zero [2]]								
sugar beets 2 lb/A	T-band, 85% in top 2 cm	4.3	3.4	3	5.6	2.1	14	113	2.7	20
	Knifed-in, 100% at 2 in	[Estimated exposure = zero [2]]								

[1]Toxicity measurements here are from studies with parent Terbufos and are documented further in the preceding table.

[2] See discussion of model limitations in the environmental fate assessment. Incorporation options in the current version of the PRZM model may not adequately represent the availability of the chemical for runoff.

46879

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.

Few studies have been completed that evaluate the effects of Terbufos on nontarget wildlife species under field conditions, and those that have been completed are somewhat limited in scope and sensitivity. Nevertheless, the available studies indicate acute hazard and show some indication of potential chronic problems. For the 15G formulation effects appears to be limited to relatively few species. Data are relatively scant for the 20CR formulation but there are no grounds for considering that formulation less hazardous than the 15G formulation. Granules of the 20 CR formulation are expected to be more durable than those of the 15G formulation, and a few granules can be lethal to wildlife.

The record of terrestrial incidents for Terbufos (including the misuse incidents) is displayed in tables on the pages following. The most notable terrestrial incident occurred in 1996 in King County Texas. About 20 migrating Swainson's hawks were killed by Terbufos 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 (Bennett et al.) 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.

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, FEOTER01)

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 BAOTER01)

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)

6. *Terrestrial Field Study*. Knapton and Mineau (1995) studied effects of Terbufos (Counter 15G) and Fonofos (Dyfonate 20G) in corn fields in southwestern Ontario. Birds were color banded before application and then tracked. There were nine control fields, six fields treated with Fonofos, and 5 fields treated with Terbufos. 228 song sparrows (*Melospiza melodia*) were

48879

marked. Territorial individuals were observed to spend some time foraging on cornfields. The study authors concluded that there was no evidence that either insecticide affected survivorship of song sparrows, and there were no dramatic impacts in other bird species (horned lark, savannah sparrow, vesper sparrow). Reproductive success of song sparrows was evaluated based on 91 nests. No adverse effects were detected despite observation of parents collecting food for their young from corn fields.

In order to place the results in perspective, it is important to note that fields studies ordinarily involve limited data collection and high variability, even with the additional precision from following marked individuals. In the Knapton and Mineau study, the largest number of marked birds were song sparrows (*M. melodia*). Of 96 song sparrows marked in control plots, 13 (or 13.5%) were lost to tracking; in treated plots 12 of 69 marked song sparrows (17.4%) were lost to tracking. If it is assumed that there may be some difference in the disappearance rates between treated and control groups, the ratio 17.4/13.5=1.28 (a 'risk ratio') can be used to estimate the magnitude of the difference. (However, a chi-square test performed by the study authors indicates that treated and control groups are not statistically different.) Using standard formulae for a confidence interval for a risk ratio (Kleinbaum et al., 1982, Ch. 15), the risk ratio is between 0.62 and 2.6 with 95% confidence. The results for species other than song sparrows would be consistent with an even wider range of risk ratios because of fewer data for those species.

49879

Terbufos Terrestrial Incidents

Crop	Year	State	Number Affected	Species Affected	Certainty Index, Use Pattern, Residue and CHE Analysis, (Reference)
corn	1997	DE	2	Canada geese	**Highly Probable** Incident occurred in Felton, DE (Kent County) on May 27, 1997 in a 7 acre stand of field corn. The geese were feeding in the newly planted corn which had been treated with Counter 15G. There were heavy rains prior to the incident. Analysis of the stomach contents revealed 75 ppm of Terbufos (I007372-001).
misuse	1996	CD	NR	eagles	**Probable/Misuse.** Carcasses baited with Terbufos for coyote control in Saskatoon area of Canada (I004605-1; references newspaper article in Star Phoenix)
corn	1996	TX	20	Swainsons hawks	**Highly Probable/Misapplication.** An incident in occurred on April 27, 1996 near Dumas, Texas (King County) 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 (larvae of the Southern masked chafer) exposed in a newly plowed field. Stomach contents were found to contain soil, grubs, and Terbufos residues ranging from 6.5 to 16 ppm. 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. In much of the field, the corn seed and the Terbufos granules were deposited on to the soil surface instead of inside the furrow. The dead hawks were discovered 7 days after planting. The conclusion of the report is that the incident occurred under an unusual set of conditions. (I003498-001; I006435C).
corn?	1995	WI	2	red-tailed hawk	**Highly Probable** An adult female and a hatchling red-tailed hawk were found at the base of a tree in Madison, WI. Meat taken from the crops of the hawks contained 12 and 13 ppm Terbufos. The investigator speculated that the prey of the hawks had been a rodent from a nearby corn field (I002993-012; I002733-043, USF&WS case file 2300).

50879

Terbufos Terrestrial Incidents

Crop	Year	State	Number Affected	Species Affected	Certainty Index, Use Pattern, Residue and CHE Analysis, (Reference)
misuse?	1994	CD	4	bald eagles	**Highly Probable/Possible Misuse** An incident occurred in Vancouver, British Columbia involving 4 eagles. Analysis of the contents of the crop and stomach confirmed the presence of Terbufos and its oxidative degradates at levels that could have caused the death of the eagles. Because the eagles were found many months after the normal application time for Terbufos and the significant amounts of parent Terbufos (relative to the amounts of oxidative degradates) misuse is suspected (I002486).
Misuse	1994	NC	2	red wolf	**Highly Probable/Misuse** Two dead red wolves were found near a farm in NC in the Fall of 1994. Analysis of the stomach contents revealed "large quantities" of Terbufos (38 ppm), rabbit flesh, and shotgun pellets. The presence of these 3 items in the gut strongly supported a case of intentional poisoning. The wolves had been introduced by the U.S. Fish and Wildlife Service against the wishes of the owners of the farm (I002484).
sugar beets?	1992	OR	5-10	Bald eagles	**Highly Probable/Possible Misuse** Five bald eagle carcasses were collected in March, 1992 near Toulee Lake in the Klamath Basin Game Preserve, north of Klamath Falls OR. Analysis of the gut contents revealed Terbufos residues. The gut contents was mainly waterfowl. The source of the Terbufos was not known. The report noted that sugar beets are grown in the Klamath Falls area and Terbufos is registered on sugar beets. Ingestion of Terbufos laced bovine meat as a poison bait was also speculated since the incident occurred prior to planting of sugar beets and the registrant does not have any records of sale in this area.. (I000089, I000089-001, B0000-300-39; Bennett and Williams, 1996)

51879

ii. Aquatic Incidents

No aquatic field studies are available to the Agency for Terbufos, but numerous aquatic incidents have been associated with Terbufos. These incidents confirm that Terbufos parent and/or Terbufos metabolites do often reach aquatic environments in concentrations lethal to aquatic organisms.

The incidents record for Terbufos was reviewed most recently on March 11, 1999, by D. Brassard, acting incident coordinator for EFED (memo D. Farrar, D. Brassard, and J. Breithaupt to P. Noyes). A table of incidents is provided in Appendix C.2. The incidents provide useful information for risk characterization, as considered in greater detail C.5.c below (ecological risk characterization).

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 terrestrial 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. While some earlier drafts of the EFED RED chapter stated that the field studies available consistently document an acute hazard, the study by Knapton and Mineau (1995) did not provide evidence of acute or reproductive field effects, based on comparison of five fields treated with Counter 15G to nine control fields. However, it is always important to take note of the inherent limitations of field studies (see discussion in Section C.5.b.) In particular, field studies generally involve limited replication and high variability, potential for confounding with uncontrolled variables affecting survival, and a narrow range of field conditions investigated. Because of these limitations, it can be concluded that significant die-offs did not occurr, but the study does not establish that Terbufos does not pose a significant risk to birds.

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.

52879

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.

53879

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 processes 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-lives* range from 6 to 27 days in aerobic soil and 67 days in anaerobic soil. The *hydrolytic half lives* range from 12 to 14 days under abiotic conditions and typical environmental pHs.

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.

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 116 and 96 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 toxicity information for parent Terbufos only, 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 (see EFEDs one-liner toxicity database).

54879

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.

EFED expects that Terbufos sufloxide and Terbufos sulfone will reach higher concentrations than parent Terbufos in water. However, there are inadequate monitoring data for these metabolites.

Effects of application procedure on estimated surface water concentrations. Modeling results obtained using PRZM and EXAMS suggest that application procedures can have a dramatic effect on surface water concentrations. For all three labeled crops the model results suggest negligible exposure for application procedures other than T-band application. However, EFED is concerned that incorporation options in the most recent PRZM version may not adequately represent the availability of the chemical for runoff. The Agency has received reports of aquatic incidents for corn, for all application procedures including in-furrow application. EFED believes that in-furrow application can be associated with significant runoff for any of the three labelled crops. While EFED believes that application procedures can have a large influence on routes of dissipation in the field, no data are available to support the dramatic difference in environmental concentrations suggested by the Terbufos modeling results..

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 affect 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 concentrations from 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 usually measured.

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.

Characterization of Terbufos aquatic incidents. During the period from 1989 to 1998, seventy-eight fish mortality incidents have been reported involving Terbufos. Incidents reported annually ranged from 1 in 1996 to18 in 1990. The average rate of incidents is 8 per year.

Based on the information available to the Agency for these incidents, we can draw the following generalizations:

- For each reported incidents there was some evidence to associate the incident with use on corn.
- Eighty percent of incidents occurred in 5 corn belt states (IA, IN, IL, NE, OH)
- Incidents involved mortality of from 30 fish to 90,000 fish.
- All application methods for corn (band, t-band, and in furrow) caused incidents.
- All formulations (15G and 20CR) caused incidents.
- Large grassy buffer strips (350-1000 feet) did not prevent incidents in some cases.
- Incidents generally occurred from 2 days to 3 weeks after application.

For many incidents, the primary source of information is 6(a)2 reports submitted by American Cyanamid. In reports submitted by Cyanamid, it is usually asserted that incidents follow periods of heavy rainfall and often a specific value is given (e.g., ">3 inches"). However, no documentation is given to support the estimate and in at least some cases where records are available from nearby stations, values given by Cyanamid have not been supported: For a cluster of three incidents in Indiana, associated with Terbufos use by a single applicator in 1998 (I007924-006, I007795-002, I007795-001), the available rainfall information is data reported by the state of Indiana, from the Indiana Climate Page. Whereas Cyanamid reports >2 inches for one of these incidents and >5 inches for the other two, the available information indicates that rainfall did not exceed about half an inch for any day of the week preceding either incident. The information available to the Agency is consistent with incidents being caused by normal springtime rainfall. Similarly, claims that incidents occur on highly erodible soils or soil with high runoff potential are not substantiated.

57879

Summary of Terbufos Aquatic Incidents on Corn, by Year.

Year	possible incidents		probable incidents		total incidents	# of Mortalities		Comments
	no analysis	no residues	normal use	misuse		average	Total*	
1998		2	7		9	4500	36000	All 20 CR, 8 t-band, 1 in furrow, all in Indiana , rainfall averaged 5.8"
1997	5				5			
1996	1				1			
1995	4				4			
1994	7		2		9	743	1486	140 ppb Terbufos in NC canal, 3" rain
1993	14		1		15	30	--	
1992	3				3	--	--	
1991	3	1	6	1	11	1642 7	98564	1 possible incident showed both Terbufos and chlorpyrifos residues
1990	5		13		18	1978	29670	
1989			3		3	1004	3012	
1989-1998	**42**	**3**	**32**	**1**	**78**	**4114**	**168732**	
1976-1985	**5**	**2**			**7**	**510**	**1020**	
Total	**47**	**5**	**32**	**1**	**85**	**3600**	**169752**	

* total number of mortalities for year only from incidents reporting number mortalities.

58879

Significance of incidents in static water bodies. For the most part, Terbufos incidents occurred in static (lentic) water bodies such as farm ponds. EFED believes such incidents are significant for reasons that include (1) the value of managed fish in the farm ponds; (2) the value of natural populations that farm ponds support (e.g., with breeding habitat, food, or water); and (3) the value of farm pond incidents as indicators of impacts on other surface water, particularly other shallow water close to treated fields.

In addition to managed fish, farm ponds are significant habitat for naturally occurring vertebrates including frogs, salamanders, snakes, turtles, birds, and mammals. Many of these species migrate overland between farm ponds and other aquatic habitat so that farm ponds contribute to wildlife populations for natural water bodies. Many species of amphibians (frogs, toads, and salamanders) depend on farm ponds and other small or ephemeral waters as breeding grounds and nurseries for developing tadpoles.

Farm pond incidents serve as indicators for impacts to other aquatic areas such as small streams and creeks. Pesticide monitoring data has shown that pesticide residues in streams and creeks adjacent to agricultural areas can reach levels similar to those predicted for farm ponds. Residues of Terbufos and its sulfone and sulfoxide degradates are highly mobile and can readily move into streams and creeks. Therefore, if fish kills are occurring in farm ponds, it is reasonably certain that aquatic organisms are being killed in streams and creeks adjacent to treated fields. Fish kills in farm ponds are more likely to be noticed and reported than those occurring in natural water bodies.

Limitations of 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. Adverse ecological effects cannot be assumed to be reliably detected and reported. Before an incident can be reported, it must be observed 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.

Comparison of incident report frequencies. The Ecological Incident Information System (EIIS) is a repository of 2,915 ecological incidents submitted by state and federal agencies, diagnostic laboratories, and pesticide registrants. Review of the fish mortality from EIIS leads EFED to conclude that the use of Terbufos ranks fourth in pesticide-induced fish kill incidents in the United

59879

States (see Table below), and the leading cause of pesticide-related fish kill incidents from the use on field corn. Tefluthrin, with 10 incidents, ranks second in fish kill incidents on corn.

Top Four Pesticides Associated with Fish Kill Incidents in the United States (numbers of incidents from EIIS)

Active Ingredient	**# of incidents**	**Uses associated with majority of incidents**
Azinphos-methyl	172	sugarcane and cotton
chlorpyrifos	159	termiticides
endosulfan	94	agricultural areas, lettuce, tobacco, tomato, potato
Terbufos	62*	corn

* number of Terbufos incidents in EIIS; an additional 23 incidents were located in IDS that have not yet been entered into EIIS but were included in our analysis.

60379

References for Section C.

Austin, 1981. Land Resources Regions and Major Land Resource Areas of the United States. USDA Handbook 296, revised 1981. Washington, D.C. (Soil Conservation Service)

Barrett, M.R., December 3, 1997. Memorandum from Joe Merenda to Larry Dorsey of the Science Advisory Panel. U.S. EPA/OPP/EFED.

DeLuca, T., Larson, J., Torma, L. and G. Algard. 1989. A Survey of Groundwater Contamination by Pesticides in Montana, Montana Department of Agriculture, Technical Report 89-1, August 1989.

Detroy, M. 1985. Iowa Ground-Water-Quality Monitoring Program, U.S. Geological Survey, Open File Report 84-815, December 1985.

Detroy, M., Hunt, P., and M. Holub. 1988. Ground-Water-Quality Monitoring in Iowa: Nitrate and Pesticides in Shallow Aquifers, U.S. Geological Survey, Water Resources Investigations Report 88-4123.

Exner, M. and Roy Spalding. 1990. Occurrence of Pesticides and Nitrate in Nebraska's Ground Water, University of Nebraska, Institute of Agriculture and Natural Resources.

Felsot, A., L. Wei, and J. Wilson. 1982. Environmental chemodynamic studies with terbufos (Counter™) insecticide in soil under laboratory and field conditions. Journal of environmental science and health. Vol. B17(6), pp. 649-673.

Felsot, A., W.N. Bruce, and K.S. Steffey. 1987. Degradation of terbufos (Counter™) soil insecticide in corn fields under conservation tillage practices. Bulletin of Environmental Contamination and Toxicology Vol. 38:369-376.

Hirsch, R.M. Alley, W.M., and Wilbur, W.B. 1988. Concepts of National Water Quality Assessment Program. USGS Circular 1021.

Indiana Department of Environmental Management. 1988. Assessment of Nonpoint Source Pollution of Ground Water in Indiana, July 1988.

Kelley, R.. 1985. Synthetic Organic Compound Sampling Survey of Public Water Supplies, Iowa Department of Natural Resources, Des Moines, IA, April 1985.

Kelley, R. and Wnuk, M. 1986. Little Sioux River Synthetic Organic Compound Municipal Well Sampling Survey, Iowa Department of Natural Resources, Des Moines, IA, March 1986.

61879

Kelley, R. 1986. 1986 Little Sioux River Pesticide Monitoring Report, Iowa Department of Natural Resources, Des Moines, IA, March 1988.

Kelley, R. 1986. University of Iowa, Hygienic Laboratory, personal communication.

Klaseus, T., Buzicky, G. and E. Schneider. 1988. Pesticides and Ground Water: Surveys of Selected Minnesota Wells, Minnesota Department of Health and Minnesota Department of Agriculture, February 1988.

Klaseus, T. and Hines, J. 1989. Pesticides and Ground Water: Surveys of Selected Minnesota Wells, Minnesota Department of Health, August 1989.

Kleinbaum, D.G., L.L. Kupper, and H. Morgenstern. 1982. *Epidemiological Research.* Van Nostrand Reinhold.

Knapton, R.W., and P. Mineau. 1995. Effects of granular formulations of terbufos and fonofos applied to cornfields on mortality and reproductive success in songbirds. Ecotoxicology 4:138-153.

Lane, L. 1987. Mississippi Pesticide Hazard Assessment Project: Annual Progress Report No. 15, Mississippi State University, May 1987.

Mayer, F.L. and Ellersieck, M.R. 1986. Manual of acute toxicity: interpretation and data base for 4510 chemicals and 66 species of freshwater animals. USFWS Resource publ. 160.

Mesko, T. and Carlson, G. 1988. Occurrence of Pesticides, Nitrates, Organic Compounds, and Trace Elements in Ground Water and Streams, Southeastern Missouri, 1986-87, U.S. Geological Survey Open-File Report 88-495.

Rhode Island Department of Environmental Management. 1990. Rhode Island Private Well Survey Final Report.

Sievers, D. and Fulhage, C. 1991. Quality of Rural Well Water North Missouri and Quality of Missouri's Agricultural Groundwater Region II Sampling, University of Missouri, June 1991.

South Dakota Department of Environment and Natural Resources. 1993. 1992 Pesticide and Nitrogen Sampling Program and Five Year SumM., February 1993.

USEPA. 1992. Pesticides in Ground Water Database - A Compilation of Monitoring Studies: 1971 - 1991. Office of Prevention, Pesticides, and Toxic Substances. EPA 734-12-92-001. September 1992.

USEPA Office of Water. February 1996, Drinking Water Regulations and Health Advisories, EPA 822-R-96-001

63879

Appendix C.1. Calculations for determination of LOC exceedances for terrestrial wildlife

For knifed-in applications to sorghum and sugar beets, the calculations are here based on a maximum label rate of 3.9 lb/A although the maximum label rate for these uses was changed in 1999 to 2 lb/A. Given linearity of the formulae, exposure estimates for an arbitrary application rate can be re-calculated using the formula:

exposure(revised) = exposure(tabled here) * (rate assumed here) / (rate of interest)

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	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

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 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]	170 g bird[5]
	(%AI/100)	(mg)	(oz/1000 ft of row)	(ft)	(decimal)	(mg/ft^2)	(/ft^2)	granules	granules
Field Corn, Popcorn, & Sweet Corn									
Banded at planting	0.15	0.066	1.2	0.6	0.15	8.50	858.59	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/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

66879

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

68879

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

Application method	Formul-ation	Granule Wt.	App. Rate	Band Width	Percent Unincor-porated	Amount of Active Ingredient Exposed[1]	No. of Exposed Granules[2]	No. of Granules/ LD_{50}[3]	
								25 g mammal[4]	1 kg mammal
	(%AI/100)	(mg)	(oz/1000 ft of row)	(ft)	(decimal)	(mg/ft^2)	(/ft^2)	granules	granules
Field Corn, Popcorn, & Sweet Corn									
Banded at planting	0.15	0.066	1.2	0.6	0.15	8.50	858.59	3.97	158.59
In-furrow, at planting	0.15	0.066	1.2	0.1	0.01	3.40	343.43	3.97	158.59
Sugarbeets									
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/ft^2)/(% ai product/ granule wt)

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

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

69379

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	Formul-ation	Granule Wt.	App. Rate	Band Width	Percent Unincor-porated	Amount of Active Ingredient Exposed	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	0.20	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/ft^2	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/ft^2	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

72879

Appendix C.2. Terbufos Aquatic Ecological Incidents.

Crop	Year	State	Number Affected	Species Affected	Certainty Index, Use Pattern, Residue and CHE Analysis, (Reference)
corn	1998	IN	10,000 3,000 100 200	bluegill largemouth bass catfish walleye	**Possible.** The fish kill occurred on June 19, 1998 in a 15 acre, 20 foot deep, farm pond in Lagro, IN. The grower applied the 20CR formulation of terbufos as a T-band application at planting at the rate of 1.3 lbs ai/A to a 75 acre corn field. The "field drains into neighbor's farm pond and pond overflows into reported pond incident". Analysis of water samples revealed no evidence of terbufos residues. (I007795-002)
corn	1998	IN	2,000-3,000 500	bluegill largemouth bass	**Possible.** The fish kill occurred on June 19, 1998 in a farm pond in Lagro, IN. The grower applied the 20CR formulation of terbufos as a T-band application at planting at the rate of 1.3 lbs ai/A to a 75 acre corn field. The field drains via tile into the farm pond. There is also a 2 to 3 foot deep drainage ditch that carries runoff into the pond. Analysis of water samples revealed no evidence of terbufos residues. (I007795-001)
corn?	1998	IN	2,400 20 10 1	bluegill bass frogs carp	**Probable.** The fish kill occurred on June 18, 1998 in a farm pond in Huntington, IN. The grower applied the 20CR formulation of terbufos as a T-band application at planting at the rate of 1.3 lbs ai/A to a 46 acre field. Analysis of water samples revealed terbufos sulfoxide and terbufos sulfone residues. (I007676-001)
corn?	1998	IN	>5,000	bluegill bass catfish minnows crappie	**Probable.** The fish kill occurred on June 13, 1998 in a 2 acre farm pond in LaFountaine, IN. The grower applied the 20CR formulation of terbufos as a T-band application at planting at the rate of 1.3 lbs ai/A to a 76 acre field. Analysis of water samples revealed terbufos sulfoxide and terbufos sulfone residues. (I007924-006)
corn?	1998	IN	1400	fish	**Probable.** The fish kill occurred on June 13, 1998 in 2 farm ponds in Lewis, IN. The grower applied the 20CR formulation of terbufos as a t-banded application at planting at the labeled rate. Analysis of water samples revealed terbufos sulfoxide and terbufos sulfone residues. (I007924-005)
corn?	1998	IN	~1100 50-75 200	bluegill bass crappie	**Probable.** The fish kill occurred on June 14, 1998 in a 3 acre farm pond in Wabash, IN. The grower applied the 20CR formulation of terbufos as a T-band application at planting at the rate of 1.3 lbs ai/A. Mortality estimates for bluegill ranged from 1000-1200. Analysis of water samples revealed terbufos sulfoxide and terbufos sulfone residues. (I007924-004)

73879

Crop	Year	State	Number Affected	Species Affected	Certainty Index, Use Pattern, Residue and CHE Analysis, (Reference)
corn?	1998	IN	1000 100 50	bluegill bass walleye	**Probable.** The fish kill occurred on June 16, 1998 in a 2 acre farm pond in Wabash County, IN. The grower applied the 20CR formulation of terbufos as a T-band application at planting. Analysis of water samples revealed terbufos sulfoxide and terbufos sulfone residues. (I007924-003)
corn?	1998	IN	5,100 100	bluegill bass	**Probable.** The fish kill occurred on June 13, 1998 in 2 farm ponds in Chester, IN. The grower applied the 20CR formulation of terbufos as an in-furrow application at planting at the rate of 1.3 lbs ai/A to a 38.5 acre field. Analysis of water samples revealed terbufos sulfoxide and terbufos sulfone residues. (I007924-002)
corn?	1998	IN	60 32 1	bluegill bass catfish	**Probable.** The fish kill occurred on June 16, 1998 in a 0.8 acre farm pond in Wabash, IN. The grower applied the 20CR formulation of terbufos as a T-band application at planting at the rate of 1.3 lbs ai/A to a 74 acre field. Analysis of water samples revealed terbufos sulfoxide and terbufos sulfone residues. (I007924-001)
corn?	1997	corn belt	NR	fish	**Possible.** American Cyanamide reported 5 fish kill incidents involving farm ponds in Indiana, Nebraska, and possibly other corn belt states in 1997 (I006718-001)
corn?	1996	corn belt	NR	fish	**Possible.** American Cyanamide reported 1 fish kill incident in the corn belt in 1996 (I004607-001; I006718-001)
corn?	1995	corn belt	NR	fish	**Possible.** American Cyanamide reported 4 fish kill incidents involving farm ponds in the corn belt in 1995 (I002814-001, I006718-001)
corn?	1994	corn belt	NR	fish	**Possible.** American Cyanamide reported 7 fish kill incidents involving farm ponds in the corn belt in 1994 (I002814-001, I006718-001)
corn	1994	NC	100	bass bluegill crappie	**Probable.** 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. Residue analysis revealed 140 ppb of terbufos in the canal. (I003826-025; IR94-51; North Carolina Department of Agriculture)
corn	1994	LA	1386	fish	**Probable.** Terbufos and permethrin applied preplant to 3769 acres of corn. The Louisiana State University Medical Diagnostic Laboratory concluded that the fish were killed by terbufos and permethrin. (I001849-003; I001179-20)

14879

Crop	Year	State	Number Affected	Species Affected	Certainty Index, Use Pattern, Residue and CHE Analysis, (Reference)
corn?	1993	corn belt	NR	fish	**Possible.** American Cyanamide reported fish kill incidents at 14 farm ponds in the corn belt in 1993 (I002814-001, I006718-001)
corn	1993	NC	15 15	bass bream	**Highly Probable.** A fish kill occurred in Clinton, NC (Sampson County) on April 16 following application of atrazine and terbufos to a neighboring corn field approximately 365 feet away. Water samples taken a week later revealed 2 ppb of terbufos. No analyses were conducted on the dead fish. (I003654-003)
corn?	1992	corn belt	NR	fish	**Possible.** American Cyanamide reported 2 fish kill incidents in the corn belt in 1992 (I002814-001, I006718-001)
corn tobacco	1992	NC	small number	bluegill	**Possible.** A fish kill in a small pond adjacent to tobacco and corn fields in North Carolina on June 12, 1992. Terbufos, carbofuran, and aldicarb were applied to adjacent fields (I000165-052).
corn?	1991	IA	NR	fish	**Probable/Misuse** Grower in Fontanelle, Adair County, IA, reportedly left partially used bag of Counter® 15G eight feet from pond. (B000170-6; I002814-002)
corn	1991	IA	4,000-5,000	bluegill, crappie, small bass	**Probable.** This incident involved 6 ponds in Chariton, Lucas County, IA. Residue analysis 2 to 4 weeks after treatment showed 1-4 ppb terbufos sulfoxide in the pond. (B000170-4, I002814-002)
corn	1991	IA	large number	bluegill bass crappie catfish	**Probable.** Fish kill occurred on June 9 in several ponds east of Chariton, IA. The largest pond (3.5 acres) was surrounded by 300-1000 feet of pasture/grassy buffer strip. Terbufos was applied as a banded application on an adjacent farm. Terbufos residues (1 ppb) recovered from pond water on July 6. No analyses made on dead fish. (B000300-41)
corn	1991	IA	500 400 3	bluegill bass snapping turtle	**Probable.** Fish kill occurred in 2 ponds in Milo, Warren County, IA. Incident is related to a study by Wildlife International. Pond surrounded by grassy strips and steep sloped corn fields . Terbufos also caused a fish kill in these ponds in 1990. (B00170-005 I002814-002).
corn	1991	IA	NR	fish	**Possible.** Pond near corn field in Lucas County, IA experienced a fish kill in June, 1991. No residue analysis performed. (I000254-002: Submitted by Region VII)

75879

Crop	Year	State	Number Affected	Species Affected	Certainty Index, Use Pattern, Residue and CHE Analysis, (Reference)
corn	1991	IA	NR	bluegill bass crappie catfish	**Highly Probable.** Pond near corn field in Lucas County, IA experienced fish kill in June, 1991. Residue analysis revealed terbufos in water following kill and 3 weeks later. Trifluralin and Bicep also applied. (I000254-001: Submitted by Region VII)
corn	1991	IL	1,000	bluegill	**Probable.** Pond in Nashville, Washington County, IL experienced a fish kill. An assay conducted 2 weeks after treatment revealed 3 ppb terbufos sulfoxide (I002814-002; I000170-001)
corn	1991	IL	41,800 38,000 6,318 4,343	bluegill bass sunfish crappie	**Highly Probable.** On May 4, 1991, terbufos was applied at a rate of 1.3 lb ai/A on a no-till corn field adjacent to Taylor Lake, in Victoria, IL (Knox County). Taylor Lake is a former strip mine. 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. The dead sunfish had the pectoral fin in the forward position across the head: which is considered to be a sign of OP toxicosis. An assay conducted 2 weeks after treatment revealed 2 to 9 ppb terbufos sulfoxide (I005002-003; B000166-001; I002814-002; I000170-2; Illinois Department of Conservation, 1991)
corn	1991	IN	1,500	bluegill crappie	**Possible.** Incident occurred in Whiteland, Brown County, IN involving 1500 bluegill and crappie fingerlings,. No assay was conducted. (I002814-002; I000170-003)
corn tobacco	1991	NC	200+	bluegill bass	**Possible** On May 10, 1991, a fish kill occurred in Onslow, North Carolina Terbufos, disulfoton, ethoprop, chlorpyrifos, atrazine, and napropamide were applied to adjacent corn and tobacco fields. Analysis of pond water and surrounding soils found terbufos, chlorpyrifos, napropamide, and atrazine residues. Because the chlorpyrifos and terbufos residues were higher than napropamide, and atrazine residues, they were considered more likely to have caused the kill. The crops that were associated with the fish kill were corn and tobacco. Terbufos was applied to the corn crop only. 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)
corn or sorghum	1991	TX	NR	fish	**Possible.** Incident occurred on April 19, 1991 in a lake adjacent to a 500 acre treated field in Lamar, Texas. Assay of water samples was negative. Crop listed in report as field crop/grain with the pest as greenbug. (I00917-004; TDA incident No. 11-91-0017)

Crop	Year	State	Number Affected	Species Affected	Certainty Index, Use Pattern, Residue and CHE Analysis, (Reference)
corn	1990	IA	300	bluegill	**Probable.** Event occurred in Audubon County, IA. Terbufos sulfoxide found in residue analysis. (B00168-002, I002814-003)
corn	1990	IA	200	bluegill	**Probable.** Event occurred in Audubon County, IA. Terbufos sulfoxide found in residue analysis. (B00168-001, I002814-003)
corn	1990	IA	200+	bluegill	**Probable.** Event occurred in Montgomery County, IA. Field sloping towards pond. Terbufos sulfoxide found in residue analysis. (B00168-003, I002814-003)
corn	1990	IA	200+	bluegill	**Probable.** Event occurred in Warren County, IA. Terbufos sulfoxide found in residue analysis. (B00168-006, I002814-003)
corn	1990	IA	200+	bluegill	**Probable.** Event occurred in Milo, Warren County, IA. Incident is related to a study by Wildlife International. Terbufos sulfoxide found in residue analysis. (B00168-005)
corn	1990	IA	500	bluegill	**Possible.** Event occurred in Washington County, IA. No residue samples taken (B000168-004, I002814-003)
corn	1990	IA	200+	bluegill	**Probable.** Event occurred in Warren County, IA. Terbufos sulfoxide found in residue analysis. (B00168-006, I002814-003)
corn	1990	IL	150	bluegill	**Possible.** Event occurred in Coles County, IL. No residue samples taken (B000168-013, I002814-003)
corn	1990	IL	10,000-15,000	fish	**Possible.** Event occurred in McHenry County, IL. No residue samples taken (B000168-014)
corn	1990	IL	NR	bluegill	**Probable.** Event occurred in Du Page County, IL. Terbufos found in residue analysis. (B00168-015)
corn	1990	IL	20	bluegill	**Probable.** Event occurred in St Clair County, IL. Terbufos sulfoxide found in residue analysis. (B00168-0016)
corn	1990	KS	300	fish	**Probable.** Event occurred in Leavenworth County, KS. Terbufos was applied in furrow. Terbufos sulfoxide found in residue analysis. (B00168-007)

7682

77979

Crop	Year	State	Number Affected	Species Affected	Certainty Index, Use Pattern, Residue and CHE Analysis, (Reference)
corn	1990	MI	500-600	bluegill	**Probable.** Event occurred in Hillsdale County, MI. Terbufos was applied as a banded application. Terbufos sulfoxide found in residue analysis. (B00168-008)
corn	1990	OH	100 % in 4-5 acre pond 1	bass, bluegill, catfish, crappie snake	**Probable.** On May 15, 1990, bass, bluegill, catfish, crappie, and a black snake were reported killed from the use of terbufos applied in-furrow at-planting on a corn field at a rate of 1.3 lb ai/A in Licking County, Ohio. The Ohio Department of Agriculture measured **terbufos residues of 10 ppb.** Ammonia, atrazine, and metalachlor residues were also found. The investigator concluded that the kill could have been caused by terbufos or ammonia. The total kill was reported for the 4 to 5-acre pond that was 5 to 6 feet deep (B000168-12; 422059-01; American Cyanamid, 1992).
corn	1990	OH	NR	bluegill	**Probable.** Event occurred in Clinton County, OH. Terbufos was applied as a banded application. Terbufos sulfoxide found in residue analysis. (B00168-010)
corn	1990	OH	1,500-1,800	bluegill	**Possible.** Event occurred in Darke County, OH. Terbufos was applied as a banded application. There was no residue analysis performed. (B00168-011)
corn	1990	OH	10,000-15,000	bluegill	**Probable.** Event occurred in Licking County, OH. Terbufos was applied as an in furrow application. Terbufos sulfoxide found in residue analysis. (B00168-009)
corn? sorghum ?	1990	TX	200	fish	**Probable.** Incident occurred in Bell County, Texas. Investigators suspect that runoff from the neighbors field into tank caused the fish to die. Samples of fish analyzed contained terbufos. Crop listed in report as field crop/grain. Corn and sorghum are the most likely crops to have been involved. Metalachlor, 2,4-D, atrazine, and picloram were also applied to adjacent fields. (I00917-003; TDA incident No. 05-90-0034)
corn	1989	NC	600 12	small fish crayfish	**Highly probable.** On May 5, 1989, a fish kill occurred from the use of Counter 15G on a nearby corn field in Sampson County, NC. About 600 small fish and 12 crayfish were found dead in an adjacent water body. The corn field was treated on April 20. The metabolite of terbufos, terbufos sulfone, was detected in the water samples (B000169-001; IR89-40. North Carolina Department of Agriculture, 1989).

Crop	Year	State	Number Affected	Species Affected	Certainty Index, Use Pattern, Residue and CHE Analysis, (Reference)
corn	1989	NC	2000+	fish	**Highly probable.** On April 30, 1989, thousands of fish were killed in a canal which feeds into the Alligator River following the application of terbufos 15G and alachlor to corn in Tyrell County, NC. By the time the fish kill was investigated on May 1, 1989, the fish had drifted into the Alligator River. Terbufos had been applied in-furrow at-planting and alachlor on top after planting. Terbufos sulfone, the metabolite of terbufos, was detected in soil samples (B000164-001; R89-37. North Carolina Department of Agriculture, 1989).
corn	1989	NC	400	fish	**Highly probable.** 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. An adjacent tobacco field had been treated with ethoprop and pebulate, but no measurable residues were detected for those chemicals (B000167-001; IR89-44. North Carolina Department of Agriculture, 1989).
corn	1985	NE	1000	fish	**Possible.** Terbufos was applied in a corn field in Butler County, NE on May 8, 1985. The water source for this pond was filtered overflow from a larger pond which had also suffered a fish kill at the same time. Terbufos (applied in-furrow to corn) and phorate (applied to sorghum) had recently been used in nearby fields above the pond. (I000598-001A; Nebraska Game and Parks Commission, 1985).
corn?	1985	NE	"many"	fish	**Possible.** In 1985, terbufos was applied in a field near a pond in Richardson County, NE. (I000598-007. Nebraska Game and Parks Commission).
corn	1984	SC	100 100	bass bream	**Possible.** On April 2, 1984 a fish kill was reported in Williamsburg County, SC. Terbufos, atrazine, and metalochlor were used on the adjacent corn field 2 to 3 days before the kill. Analysis of a water sample showed no terbufos residues but tested positive for atrazine and metalochlor. (B000163-001)
corn	1981	MO	not reported	fish	**Possible.** Fish kill occurred on May 29, 1981 in Krueger Pond, Lafayette County, MO (near the town of Alma). A one acre pond was affected. Butylate and atrazine were also applied to the corn field (B000165-001; I000636-032).
corn	1981	MO	not reported	small bluegill few crappie	**Possible** On June 3, 1981, terbufos was implicated in a Missouri fish kill with multiple pesticide use (atrazine, Sutan and terbufos). Many small bluegill and a few crappie reportedly were affected from the use on corn (Missouri Department of Conservation, 1981).

78279

79879

Crop	Year	State	Number Affected	Species Affected	Certainty Index, Use Pattern, Residue and CHE Analysis, (Reference)
corn	1978	IA	many	fish	**Possible** Terbufos was applied in a corn field in Iowa in 1978. Runoff into a farm pond drained about ½ acre of the treated corn field. Many dead fish were found in the pond (Pesticide Incident Monitoring System, 1981.).
NR	1976	IL	20	bluegill	**Possible.** Around April 1976, terbufos was applied to a field across the road from a 0.8 acre pond in Illinois. About 20 dead bluegill were found. Laboratory work did not confirm the presence of terbufos (Pesticide Incident Monitoring System, 1981).

NR = Not reported
CI = certainty index

Notes: hundreds interpreted as 200+
thousands as 2,000+
soil incorporated interpreted as in-furrow application
surface application interpreted as banded application