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Attachment 8

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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OFFICE OF PREVENTION, PESTICIDES AND TOXIC SUBSTANCES

MEMORANDUM: **Drinking Water Assessment for Terbufos**

TO: William Hazel, Division Coordinator
Reregistration Branch I
Health Effects Division (7509C)

FROM: James Breithaupt
Agronomist, Environmental Risk Branch II
Environmental Fate and Ground Water Branch (7507C)

James Breithaupt 9/30/97

THRU : Elizabeth Leovey, Ph.D., Branch Chief
Environmental Risk Branch II
Environmental Fate and Effects Division (7507C)

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General Conclusions

This assessment contains a general Environmental Fate Assessment, and a review of monitoring data and modeling for both surface and ground water for parent terbufos. For ground water, EFED has also estimated concentrations of the oxidative metabolites, terbufos sulfoxide and sulfone. Table 1 presents the maximum acute and chronic **surface water** concentrations from PRZM 2.3 modeling and monitoring data for parent terbufos only. **Surface water** modeling for the oxidative metabolites terbufos sulfoxide and sulfone was not conducted because of a lack of fate data. Table 2 presents the maximum acute and chronic **ground water** concentrations from both modeling and monitoring data, including the modeling of the oxidative metabolites, terbufos sulfoxide and sulfone using the SCI-GROW model. Table 3 presents the maximum and typical estimated concentrations of parent terbufos in **surface water** using PRZM 2.3. Table 4 presents the maximum and typical estimated acute and chronic **ground water** concentrations for parent terbufos and the oxidative metabolites terbufos sulfoxide and sulfone using the SCI-GROW model.

For the corn use, concentrations from monitoring data should be used in place of modeling estimates for terbufos because data were available for concentrations in drinking water (Tables 1 and 2) except to estimate levels for chronic risk. Since there was inadequate monitoring data for terbufos sulfoxide and sulfone, modeling estimates for **ground water** using SCI-GROW should be used for these metabolites. Since there was no monitoring data available for the grain sorghum and sugar beet uses for both **ground water and surface water**, the estimated concentrations in Tables 1 and 2 should be used in dietary risk assessment.

Table 1. Acute and Chronic Concentrations[1] in Surface Water using PRZM 2.3 and EXAMS 2.94.

Compound	Crop	Acute (ug/L)	Source of Information	Chronic (ug/L)	Source of Information
Parent terbufos	Corn	2.25	Monitoring	0.8	Monitoring
Parent terbufos)	Grain Sorghum	21.7[2]	PRZM 2.3	3.6[2]	PRZM 2.3
Parent terbufos	Sugar Beets	6.7	PRZM 2.3	1.3	PRZM 2.3
Terbufos sulfoxide and sulfone	Corn, Grain Sorghum, and Sugar Beets	No data (not enough fate data to model)		No data (not enough fate data to model)	

[1] The acute values are the maximum EEC's for parent terbufos considering the different application methods for each crop. Chronic values are the 90-day estimated concentrations. The maximum and chronic surface water EEC's for these and other application methods may be found in Table 3.

[2] These EEC's for parent terbufos were obtained using a 2.0 lbs ai/A rate of terbufos applied in a band and incorporated to 1 inch of depth. 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.

Table 2. Acute and Chronic Concentrations of Parent Terbufos in Ground Water.

Compound	Crop	Acute (ug/L)	Source of Information	Chronic (ug/L)	Source of Information
Ground Water (parent terbufos)	Corn	11.0	Iowa Ground Water Monitoring Study	.041	SCI-GROW
Ground Water (parent terbufos)	Grain Sorghum	0.123	SCI-GROW	0.123	SCI-GROW
Ground Water (parent terbufos)	Sugar Beets	0.123	SCI-GROW	0.123	SCI-GROW
Ground Water (terbufos sulfoxide)	Corn	2.60	SCI-GROW	2.60	SCI-GROW
Ground Water (terbufos sulfoxide)	Grain Sorghum	7.90	SCI-GROW	7.90	SCI-GROW
Ground Water (terbufos sulfoxide)	Sugar Beets	7.90	SCI-GROW	7.90	SCI-GROW
Ground Water (terbufos sulfone)	Corn	2.90	SCI-GROW	2.90	SCI-GROW
Ground Water (terbufos sulfone)	Grain Sorghum	8.7	SCI-GROW	8.7	SCI-GROW
Ground Water (terbufos sulfone)	Sugar Beets	8.7	SCI-GROW	8.7	SCI-GROW

Environmental Fate

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 in the field may not be important since terbufos is incorporated or knifed in to a depth where sunlight does not contribute to its degradation.

Information from environmental fate studies indicates that parent terbufos will be moderately persistent in surface waters. The reported half-lives for hydrolysis (same for pH values of 5, 7, and 9), aerobic soil metabolism and anaerobic aquatic metabolism were 15, 27, and 73 days, respectively. The reported half-life for photodegradation in water was 1 day. However, photodegradation in water is not expected to significantly decrease surface water concentrations because of potential suspended sediments and shading. The reported vapor pressure (2.8 x 10^{-4} mm Hg), Henry's Law Constant of 1.7 x 10^{-6} Atm M^3 /Mol, and the solubility in water (15 ppm) indicate that parent terbufos has moderate volatility potential in surface water environments. This would potentially lower terbufos residues in surface water. Based on the Freundlich adsorption coefficient (K_d's of 7.8-27, K_{oc}'s of 633-2441) from an acceptable soil mobility study, parent terbufos can be transported in surface runoff waters, where it will be more associated with the sediment than the water column.

In soil, parent terbufos degrades into the oxidative metabolites terbufos sulfoxide and sulfone. These metabolites are more mobile (Freundlich K_{ads} values of 0.4-2.8 and 0.55-2.93, respectively) and more persistent ($T_{1/2}$'s of 150 and 210 days, respectively) than parent terbufos. These metabolites are more likely than parent terbufos to reach higher levels in water resources because they are more persistent and mobile.

Surface Water

Tier II - PRZM\EXAMS Modeling for Parent Terbufos

Tier II estimated environmental concentrations (EECs) for parent terbufos applied to grain sorghum in Kansas, field corn in Iowa, and sugar beets in Minnesota were calculated to generate aquatic exposure estimates for use in the ecological risk and human health risk assessments for terbufos as part of the reregistration process. The Tier II upper tenth percentile EECs are listed in Table 3.

Limitations of This Analysis

There are certain limitations imposed when Tier II EEC's are used for drinking water exposure estimates. Obviously, a single 10 hectare field with a 1 hectare pond does not accurately reflect the dynamics in a watershed large enough to support a drinking water facility. A basin of this size would certainly not be planted completely to a single crop nor be completely treated with a pesticide. Additionally, treatment with the pesticide would likely occur over several days or weeks, rather than all on a single day. This would reduce the magnitude of the concentration peaks, but also make them broader, reducing the acute exposure but perhaps increasing the chronic exposure. The fact that the simulated pond has no outlet is also a limitation as water bodies in this size range would have at least some flow through (rivers) or turnover (reservoirs). In spite of these limitations, a Tier II EEC can provide a reasonable upper bound on the concentration found in drinking water if not an accurate assessment of the real concentration. The EECs have been calculated so that in any given year, there is a 10% probability that the maximum average concentration of that duration in that year will equal or exceed the EEC at the site. Risk assessment using Tier II values can capably be used as refined screens to demonstrate that the risk is below the level of concern.

A Tier II EEC uses a single site which represents a high exposure scenario for the use of the pesticide on a particular crop or non-crop use site. The weather and agricultural practices are simulated at the site over multiple (in all cases, 36) years so that the probability of an EEC occurring at that site can be estimated.

Table 3. Tier II upper tenth percentile EEC's for Parent Terbufos for simulated crops using PRZM 2.3 and EXAMS 2.94.

Crop	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 ($\mu g \cdot L^{-1}$)	Long-term Mean* ($\mu g \cdot L^{-1}$)
Corn (1.3 lbs ai/A in-furrow to 1.25 inches of depth at planting)	4.3	3.6	2.1	1.1	0.8	0.2
Corn (1.3 lbs ai/A to 1 inch of depth in 7-inch band at planting)	5.3	4.5	2.7	1.4	1.0	0.3
Grain Sorghum (3.9 lbs ai/A knifed to 5 inches of depth at planting)	8.3	7.2	4.2	2.0	1.4	0.3
Grain Sorghum (2.0 lbs ai/A incorporated to 1 inch of depth at planting)	21.7	18.4	10.1	4.9	3.6	0.9
Sugar Beets (3.9 lbs ai/A knifed to 5 inches of depth at planting)	4.1	3.4	2.3	1.2	0.9	0.2
Sugar Beets (2.0 lbs ai/A incorporated to 1 inch of depth at planting)	6.7	5.8	3.6	1.8	1.3	0.3
	* Upper 90% confidence bound on the 36 year mean with the variance calculated from the annual means.					

Monitoring Data

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 criteria for pesticides being included in the analyses, total terbufos was not detected in any of the samples at or above the detection limit of 0.05 ug/L. The USGS sampled 8 widely spread locations within the Mississippi Basin at frequent intervals from April 1991 to April 1992. Terbufos was detected at concentrations between 0.01 and 0.1 ug/L in one of the 47 samples collected from the Platte River and in one of the 45 samples collected from the Illinois River. Terbufos was not detected above a detection limit of 0.02 ug/L in any of the samples collected from the other 6 locations. EFED does not have any data on the concentrations of the sulfoxide or sulfone metabolites in water.

Comparison of Modeling versus Monitoring

Maximum concentrations of parent terbufos from PRZM 2.3 modeling were 4.1 ug/L for sugar beets, 5.3 ug/L for corn, and 21.7 ug/L for grain sorghum. In surface water bodies with dilution from outflow, these estimated concentrations would be lower. Parent terbufos is moderately persistent in water, and the estimated chronic concentrations for corn were approximately 1.0 ug/L from PRZM 2.3 modeling. Parent terbufos was not found above 2.25 ug/L in monitoring data from the Midwest. Therefore the monitoring and modeling data are in reasonable agreement for the corn use. For the dietary assessment, an acute EEC of 2.25 ug/L and a chronic EEC of 0.21 ug/L should be used for corn. For grain sorghum and sugar beets, the PRZM-EXAMS values should be used due to the lack of monitoring data.

Fish Kill Incidents

EPA has received a total of 32 fish kill incidents as of 12/13/94 (EFED EEB Science Chapter). Most of these have been in farm ponds. However, large fish kill incidents have occurred in lakes and other bodies of water after rainfall events that have occurred 10-28 days after terbufos application. Up to 50,000-90,000 fish have died in a single incident. Therefore, it is apparent that terbufos residues can reach levels (LC_{50}'s of 0.77-20 ug/L) toxic to fish over an extended period of time. Humans would also be exposed to similar levels in untreated water.

Ground Water

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

Modeled concentrations of parent terbufos, terbufos sulfoxide, and terbufos sulfone in ground water are 0.123, 7.9, and 8.7 ug/L (See **Tables 3** and **4** below). Ground water monitoring data from Indiana reported a spring with a concentration of parent terbufos of 20 ug/L, and a domestic well with 11 ug/L. A well-designed public drinking water supply study from Iowa reported seven detections of parent terbufos ranging from 0.3-11 ug/L. Therefore, an acute measured concentration of 11.0 ug/L and a chronic EEC of 0.041 ug/L should be used for parent terbufos for the corn use in the dietary assessment. Based on the use pattern, it is reasonable to assume that the detections in Iowa were due to corn use. The SCI-GROW modeling results should be used for terbufos sulfoxide and sulfone in assessing corn and to estimate all terbufos residues in grain sorghum and sugar beets.

Table 4. Estimates of Ground Water Concentrations of Parent Terbufos, Terbufos Sulfoxide, and Terbufos Sulfone.

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

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

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

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

[4] For grain sorghum and sugar beets. This is a worst-case analysis since 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)

Method for Estimating Concentrations in Ground Water

The SCI-GROW model (Screening Concentrations in Ground Water) is a model for estimating concentrations of pesticides in ground water under "worst case" conditions. SCI-GROW provides a screening concentration, an estimate of likely ground water concentrations if the pesticide is used at the maximum allowed label rate in areas with ground water exceptionally vulnerable to contamination. In most cases, a majority of the use area will have ground water that is less vulnerable to contamination than the areas used to derive the SCI-GROW estimate.

The SCI-GROW model is based on scaled ground water concentration from ground water monitoring studies, environmental fate properties (aerobic soil half-lives and organic carbon partitioning coefficients-Koc's) and application rates. The model is based on permeable soils that are vulnerable to leaching and on shallow ground water (10-30 feet).

Results from the SCI-GROW screening model predict that the maximum chronic concentration of parent terbufos in shallow ground water is not expected to exceed 0.123 ug/L for the labeled use sites. The concentrations of the metabolites terbufos sulfoxide and sulfone are estimated to reach 7.9 and 8.7 ug/L, respectively. This was modeled using a 3.9 lb ai/acre/season application to grain sorghum and should be considered a "worst case" or "upper bound." The estimated concentrations in ground water will be proportionally lower in relation to the amount applied.

Ground Water Monitoring Data

EPA's "Pesticides in Ground Water Database" reports 4,224 samples in 12 states for parent terbufos. Four states reported detections in a total of 11 wells ranging from 0.02-20 ug/L. Eight of the 11 detections exceeded the lifetime HA of 0.9 ug/L. Six of these eight exceedences were in Iowa. The two additional detections exceeding the HA were located in Indiana. Thirteen wells were also sampled in Iowa for terbufos sulfone, but no residues were detected.

Reference: Kelley, Richard and Monica Wnuk. Little Sioux River Synthetic Organic Compound Municipal Well Sampling. Iowa Department of Water, Air, and Waste Management (IDWAWM)), Des Moines, Iowa. March 1986.

Iowa sampled 787 wells for terbufos residues. Iowa had seven of the 11 reported terbufos detections, all of which came from five municipal well systems (public drinking water supply systems). Six of the seven detections exceeded the HA with residues ranging from 1.2-11.0 ug/L.

This study was well-designed. Water samples were collected from 25 wells at the well head before any treatment. At least one well sample was obtained from each of the 12 municipal water supply systems in the Little Souix River Basin. Twelve of the 25 wells were shallow alluvial and pleistocene wells under 100 feet in depth, closely reflecting the overall distribution of well depth for all municipal water supplies in Northwestern Iowa. EFED concluded that this study is representative of small municipal drinking water supply systems in the terbufos use area.

Reference:

Risch, Martin R. A Summary of Pesticides in Ground Water Data Collected by Government Agencies in Indiana, December 1985 to April 1991. USGS Open File Report 93-133. USGS Water Resources Division, Indiana District, Indianapolis, IN, 1994.

The Indiana studies sampled 206 wells for terbufos residues. Indiana reported two detections of terbufos both which exceeded the HA. The first detection, and highest in the U.S., was from a spring in Indiana with 20 ug/L, and the second was from a domestic well with 11 ug/L.

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.

Comparison of Modeling and Monitoring for Ground Water

Modeling using SCI-Grow and monitoring data from the Pesticides in Ground Water Database (PGWDB) are in good agreement. The concentrations were very similar using both methods, and the high quality of the monitoring data adds certainty to this assessment. The Iowa study was well -designed and measured actual drinking water. Therefore, the actual concentration of 11.0 ug/L from the Iowa study should be used for dietary risk assessment.

<u>Water Treatment</u>

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