8/19/94

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

OFFICE OF
PREVENTION, PESTICIDES AND
TOXIC SUBSTANCES

MEMORANDUM

SUBJECT: Transmittal of EFED List A Summary Report for Linuron
(Chemical # 035506) Case # 0047

FROM: Betsy Grim Betsy Grim 8/19/94
Science Analysis and Coordination Staff
Environmental Fate and Effects Division

THRU: for Evert K. Byington, Chief Mary Frankenberry 8/19/94
Science Analysis & Coordination Staff,
Environmental Fate and Effects Division

TO: Esther Saito, Acting Chief
Reregistration Branch,
Special Review & Reregistration Division

Attached please find the following documents for the completed EFED summary report of Linuron.

1. EFGWB Science Chapter
2. EEB Science Chapter
3. SACS Reregistration Summary Report
4. DERs

Linuron exceeds levels of concern for ecological effects and ground-water quality. In addition, data gaps were identified that have prevented EFED from making a complete environmental assessment and ecological risk assessment. If you have any questions concerning this case, please contact Betsy Grim, 305-7634.

CC:\ (with SACS Reregistration Summary Report attached)

Anne Barton
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List A File
Lou True
Tony Maciorowski
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List A Cover Memo File
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file Linuron.2

C. Environmental Assessment

1. Environmental Fate

At this time, two data requirements in the environmental fate guidelines are not fulfilled for linuron: leaching/adsorption/desorption (163-1) and terrestrial field dissipation (164-1). The environmental data base for only the parent linuron is essentially complete. Information on the persistence, mobility, and dissipation pathways of several primary degradates of linuron is not currently available; therefore, the environmental fate assessment must be considered incomplete and tentative.

a. Environmental Chemistry, Fate and Transport

(1) Hydrolysis (161-1)

Phenyl-labeled [^{14}C] linuron did not degrade via hydrolysis in sterile buffer solutions at Ph 5, 7, or 9 and incubated in the dark at 25 $\pm$ 1 °C for 30 days. The registrant calculated half-lives for linuron in the buffer solutions averaged 945 days. (MRID 40916201)

(2) Photodegradation in water (161-2)

Phenyl-labeled [^{14}C] linuron degraded slowly with a half-life of greater than 30 days (registrant-calculated half-life of 49 days) in sterile aqueous Ph 5 buffer solution irradiated with natural sunlight at 25° C. At 30 days posttreatment (total light intensity = 196,006 Watt-hours/m^2), linuron comprised 61.6 percent of the applied radioactivity; volatiles totaled 10.2 percent of the applied and unidentified degradates (at least 8 separate peaks) each accounted for up to 5.1 percent of the applied. In the dark control after 30 days, 92.1 percent of the recovered was undegraded parent linuron, suggesting the observed degradation was primarily photolytic rather than hydrolytic. The ultraviolet-visible light absorption spectrum for linuron at 18 ppm displayed absorption maxima at 210, 245, and 280 nm with some overlap at greater than 290 nm, further supporting direct photolysis of the parent linuron. (MRID 40103601)

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(3) Photodegradation in soil (161-3)

Phenyl-labeled [^{14}C] linuron degraded with a half-life greater than 15 days on silt loam soil irradiated continuously with a Pyrex glass-filtered xenon arc light at 25° C. After 15 days of irradiation, the soil contained 78.8 percent of the recovered radioactivity as parent linuron. Minor degradates identified were norlinuron, desmethyl linuron, and 3,4-dichloroaniline (each less than 8.4 percent of the recovered). Unidentified polar compounds comprised less than 4 percent of the recovered, unextractable compounds were less than 2.5 percent of the recovered, and volatiles were less than 0.1 percent of the recovered at all sampling intervals. In the dark controls, parent linuron accounted for 96.5 percent of the recovered radioactivity after 15 days, suggesting that degradation was primarily photolytic and not biologically-mediated. (MRID 40171711)

(4) Photodegradation in air (161-4)

No studies were reviewed. The data requirement was waived because the reported vapor pressure for linuron was 1.5×10^{-5} mm Hg at 24° C; therefore, volatilization and subsequent photodegradation in air are not considered probable routes of dissipation.

(5) Aerobic soil metabolism (162-1)

Phenyl-labeled [^{14}C] linuron (radiochemical purity >98 percent), at 7.5 lbs a.i./A (1.63 mg/plate), degraded with a half-life >15 days on silt loam soil irradiated continuously with a Pyrex glass-filtered xenon arc light at 25° C. After 15 days of irradiation, the soil contained 78.8 percent of the recovered radioactivity as parent linuron. Minor degradates identified were norlinuron, desmethyl linuron, and 3,4-dichloroaniline (each less than 8.4 percent of the recovered). Unidentified polar compounds comprised less than 4 percent of the recovered, unextractable compounds were less than 2.5 percent of the recovered, and volatiles were less than 0.1 percent of the recovered at all sampling intervals. In the dark controls, parent linuron accounted for 96.5 percent of the recovered radioactivity after 15 days, suggesting that degradation was primarily photolytic and not biologically-mediated. Material balance for all samples ranged from 95 to 123 percent of the applied and averaged 110 percent of the applied. (MRID 41625401)

(6) Anaerobic soil metabolism (162-2)

No studies were reviewed. The anaerobic aquatic metabolism study was used to fulfill this data requirement. (MRID 40142501)

(7) Anaerobic aquatic metabolism (162-3)

Phenyl-labeled [^{14}C] linuron degraded with a half-life of less than 3 weeks in nonsterile anaerobic silt loam and sand soil: water (1:1) systems incubated in the dark at 24° C. Primary degradates were desmethoxy linuron, desmethoxy monolinuron, and norlinuron. Minor degradates were desmethyl linuron and dichloroaniline. (MRID 40142501)

(8) Aerobic aquatic metabolism (162-4)

No studies were required because there are no aquatic uses of linuron.

(9) Leaching and adsorption/desorption (163-1)

Based on the results of two studies reviewed and supplemental information from three peer-reviewed journal publications on linuron mobility, linuron appears to be slightly mobile in coarse-textured soils (K_{ads} = 2.7-5.0 for sandy loams) and relatively immobile in fine-textured soils (K_{ads} = 7.2-7.7 for silt loams). Adsorption of linuron is probably related to the organic matter content with increased adsorption reported for soils with higher organic matter content ($K_{ads,om}$ less than 200 for two soils with greater than 4 percent OM). The Leaching/Adsorption/Desorption (163-1) studies are partially acceptable because information on the K_ds for the primary linuron degradates formed under anaerobic conditions (desmethoxy linuron, desmethoxy monolinuron, norlinuron) is not currently available. Adsorption coefficients (K_ds) may be determined using batch equilibrium test methodology. (MRID 00148443; Accession # 255830)

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(10) Volatility (163-2)

No studies were reviewed. The data requirement was waived because the reported vapor pressure of linuron is 1.5×10^{-5} mm Hg at 24°C; therefore, volatilization is not considered a probable route of dissipation.

(11) Terrestrial Field Dissipation (164-1)

Additional data are required for the terrestrial field dissipation studies to assess the rates and pathways of dissipation of parent linuron and its primary degradates. Two studies were reviewed; (MRID# 41734201, 41734202) which provided partially acceptable or supplemental information on the field dissipation of linuron in California and Delaware. The data requirement is not fulfilled because the patterns of formation and decline of total linuron residues could not be assessed, and field test procedures and analytical methodology were not completely described. The California study may be upgradable if additional information on study methods and early soil sample results can be provided; however, the Delaware study can not be upgraded because the consistent presence of linuron in the control plot confounds accurate assessment of the pattern of formation and decline of total linuron residues. A new study is needed to satisfy the data requirement. (MRIDs 41734201, 41734202)

(12) Confined and Field Rotational Crop (165-1;165-2)

No studies were reviewed. These data requirements were transferred to Health Effects Division 2/22/93.

(13) Bioaccumulation in Fish (165-4)

Linuron residues accumulated in bluegill sunfish during 28 days of exposure to water treated at 0.1 and 1.0 ppm [^{14}C] linuron. Maximum bioconcentration factors were 49x for whole fish, 240x for viscera, 34x for muscle and 39x for carcass tissues. After 28 days of exposure, linuron residues in the viscera were identified as desmethyl linuron, norlinuron, and glucuronide conjugates. The edible tissues were not analyzed for linuron residues. Residues rapidly declined to approximately 10 percent of maximum levels after the 14-day depuration period. (Accession # 258300)

(14) Droplet Size Spectrum (201-1)

No studies were reviewed. The registrant is a participating member of the Spray Drift Task Force. Information regarding spray drift of linuron should be provided upon completion of the Spray Drift Task Force data base. This study may be required by EFED when toxicological considerations are indicated by either the Ecological Effects Branch and/or the Health Effects Division.

(15) Drift Field Evaluation (202-1)

No studies were reviewed. The registrant is a participating member of the Spray Drift Task Force. Information regarding spray drift of linuron should be provided upon completion of the Spray Drift Task Force data base. This study may be required by EFED when toxicological considerations are indicated by either the Ecological Effects Branch and/or the Health Effects Division.

b. Environmental Fate Assessment

The review of acceptable, partially acceptable and supplemental information in the environmental fate data base, indicates that linuron appears to be moderately persistent and relatively immobile. Increased mobility of linuron may occur under specific environmental conditions such as coarse textured soils and soils with low organic matter levels.

Linuron dissipates principally by biotic processes such as microbial degradation. Degradation of linuron by abiotic processes (hydrolysis, photolysis, volatilization) does not appear to be a significant route of dissipation.

Partially acceptable and supplemental information on leaching and adsorption/desorption suggests that linuron is primarily adsorbed to soil organic matter with limited adsorption to the inorganic, mineral phase of soil. Linuron would tend to be more mobile in surface soils with low organic matter levels, subsoils or subsoils exposed on the land surface because of erosion. Decreased adsorption in low organic matter soil horizons may result in enhanced mobility and increased leaching potential of parent linuron. For surface soils with adequate organic matter levels, the combined processes of adsorption and microbial degradation would limit the potential for linuron to migrate to ground water.

Transport of linuron dissolved in surface runoff and/or in suspended sediment through runoff to surface water bodies (lakes, streams, etc.) could result; however, based on degradation rates and by-products from anaerobic aquatic metabolism studies, fairly rapid degradation of parent linuron to three primary metabolites (desmethoxy linuron, desmethoxy monolinuron, norlinuron) would occur. Information on the mobility and persistence of these primary degradates is not currently available from the studies submitted for the environmental fate data base.

Information reported in the "Pesticides in Ground Water Database" (Hoheisel et al., 1992) shows detections of linuron in 111 of the 1,666 wells sampled. Linuron concentrations in ground water ranged from 0.042-5.00 μg/L with four states reporting detectable levels. Georgia reported linuron concentrations ranging from 1-5 μg/L for 67 of 70 wells sampled; Missouri showed levels of 0.2-1.9 μg/L for 38 of 269 wells sampled; Virginia listed linuron detections in 5 of 12 wells sampled with concentrations ranging from 0.04-3.8 μg/L; and Wisconsin had 1 detection of 3.0 μg/L in 26 sampled wells.

Ground Water. Linuron has been detected in ground water in four states including Georgia, Missouri, Virginia, and Wisconsin at levels ranging up to 5.00 μg/L (Hoheisel et al., 1992). A review of the studies in which the ground water detections were reported gave the following results:

1. Georgia

Detections in ground water were solely from STORET which did not allow a detailed review. Concentrations of linuron ranged from 1 to 5 μg/L (ppb).

2. Missouri

Rural private wells in agricultural areas of Missouri were monitored for pesticide residues. Linuron was detected at concentrations ranging from 0.5 to 1.9 μg/L (Sievers and Fulhage, 1989a and 1991). In another study conducted in Missouri (Sievers and Fulhage, 1989b), linuron was also detected in ground water in rural agricultural wells at levels ranging from 0.48 to 0.9 μg/L. The study examined ground-water quality in eight major agricultural areas in the state, without regard to the vulnerability of the soils to leaching, nor to areas of high linuron use.

Although there is indication that there were some interference problems with the mass spectrometer detector due to sulfur and organic matter for linuron detections below 1 μg/L, results for detections reported above 1 μg/L appear valid. No information was provided about the wells, depth to ground water, or detection limits.

3. Virginia

Eight monitoring wells and four household wells were sampled for a suite of pesticides including linuron (Mostaghimi, 1992). There were no indications of point-source contamination or problems with the wells during the study. Linuron was detected in 50 percent of the monitoring wells (4 of 8 wells) at levels ranging from 0.35 to 1.31 μg/L. The extensive QA/QC plan for the sampling program and GC analysis provided a high degree of confidence for these detections.

4. Wisconsin

In a Wisconsin study (Postle and Brey, 1991), monitoring wells were located in areas that were highly vulnerable to ground-water contamination. All detections were from areas with normal field use conditions. Linuron was detected at one site at concentrations that ranged from 1.3 to 2.7 μg/L.

Linuron exhibits some of the properties and characteristics associated with chemicals that have been detected in ground water. Linuron is a persistent chemical with an aerobic soil metabolism half-life that ranges from 84 to 91 days (12 to 13 weeks). In addition, its field dissipation half-life has been reported to range from a minimum of 57 days to a maximum of 100 days (≈8 to ≈14 weeks, respectively). Based on its persistence, linuron use may have a significant impact on ground-water quality.

Because linuron is persistent and may be mobile under certain environmental conditions, it has the potential to significantly impact ground-water quality at levels that may affect human health. To date, linuron residues have been detected in ground water at levels up to 80 percent of the estimated lifetime Health Advisory level.

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EFED estimated the lifetime Health Advisory using the following calculations:

$$\text{lifetime HA} = \frac{(\text{RfD})(70\text{kg})}{(2\text{ L/d})} = \frac{(0.008)(70)(0.2^{*})}{(2)}$$

$$\text{lifetime HA} = \frac{0.056\text{ mg/L}}{10^{**}} = 6\ \mu\text{g/L}$$

(Reference Dose from a one-year dog feeding study)

(* Assumption that 20 percent of the linuron consumed by an adult is from drinking water)

(** 10-fold safety factor for Group C carcinogen)

Linuron has been placed in Cancer Group C (unquantified) indicating that it is a possible human carcinogen.

Surface Water. Linuron can be applied by ground spray and therefore could contaminate surface waters by spray drift. Substantial quantities of linuron could be available for runoff to surface waters for several weeks post-application (photodegradation on soil half-life = approximately one month; aerobic soil half-life =49 days; terrestrial field dissipation half-lives = 57 and 100 days). The moderately low to intermediate soil/water partitioning of linuron (K_d = 2.7, 5.0, 7.7, and 7.2; K_{oc} from SCS database = 370) indicates that substantial fractions of linuron runoff could occur as both dissolution in runoff water and adsorption to eroding soil.

Resistance to abiotic hydrolysis coupled with only moderate susceptibility to direct photolysis in water (half-life = 1-2 months) and aerobic biodegradation indicates that linuron has the potential to be somewhat persistent in surface waters, particularly those with low microbiological activities and long hydrological residence times. Its reported half-life in an anaerobic aquatic metabolism study (less than 21 days) indicates that it may be less persistent in water and sediment under anaerobic conditions than under aerobic conditions. Based upon its relatively low to intermediate soil and sediment to water partitioning, significant fractions of any linuron in water could exist both dissolved in the water column and adsorbed to suspended and bottom sediment. The reported BCFs for linuron (ranging from 40X to 240X) indicate that the bioconcentration potential for linuron is relatively low.

The available data on the major degradates of linuron are insufficient to assess their runoff potential or persistence in surface water.

Baker (1988) sampled 8 tributaries of Lake Erie from April 15 to August 15 of 1983 through 1985. He reported April 15-August 15 time weighted mean concentrations of linuron ranging from below the detection limit of 0.001 ug/L to 0.860 ug/L and an average April 15-August time weighted mean of 0.21 ug/L. He reported maximum concentrations ranging from below the detection limit to 10.9, 14.2 and 160 ug/L and an average maximum of 8.8 ug/L. The USGS sampled 8 widely spread locations within the Mississippi Basin at frequent intervals from April 1991 to April 1992. Linuron was detected at a concentration of approximately 0.1 ug/L in one of the 46 samples collected from the White River. Linuron was not detected above a detection limit of 0.01 ug/L in any of the samples collected from the other 7 locations.

EFED has used the computer model PRZM to compare the relative leaching potential of linuron and 12 other corn herbicides to that of atrazine. Based upon that analysis, EFED predicted that under the conditions modeled, the percent of applied linuron removed by runoff could be comparable to somewhat greater than atrazine.

Linuron is not currently regulated under the Safe Drinking Water Act (SDWA). Therefore, no MCL has been established for it and water supply systems are not required to sample and analyze for it. In addition, no drinking water health advisories have been established for linuron. However, based upon the Reference Dose, EFED has (for screening purposes only) a low lifetime health advisory for linuron of 6.0 ug/L. Although the available data suggests that the average annual linuron concentration will generally be well below 6 ug/L, the available data do not necessarily include those from watersheds that drain high linuron use areas. In addition, the relatively low to intermediate soil to water partitioning of linuron indicates that the primary treatment processes employed by most water supply systems to remove suspended sediment may not always be completely effective in removing linuron. Consequently, EFED does have some moderate concerns for potential risks of linuron to surface water source supply systems.

2. Ecological Effects

a. Ecological Effects Data

(1) Terrestrial Animal Data

Avian Acute Toxicity

Avian Acute Oral Toxicity Findings			
Species	**% Test Material (TGAI)**	**LD_{50}**	**Conclusion**
Mallard duck	92.8	940 mg/kg	slightly toxic

These results show that linuron is slightly toxic to birds on an acute basis. The guideline requirement for the avian acute oral LD_{50} study is fulfilled. (MRID 00150170)

Avian Subacute Dietary Toxicity

No acceptable avian dietary toxicity studies on technical linuron have been submitted for review. However, the following data from the USFWS (United States Fish and Wildlife Service) using a 50 percent formulation were considered. Tests with the technical material are still required.

Avian Subacute Dietary Toxicity Findings			
Species	**% Test Material**	**LC_{50}**	**Conclusions**
Mallard Duck	50	3083 ppm	slightly toxic
Japanese Quail	50	>5,000 ppm	practically nontoxic
Ring-necked Pheasant	50	3438 ppm	slightly toxic

The USFWS extrapolation suggests that 100 precent active ingredient material would be considered "slightly toxic" to the mallard and ring-necked pheasant and "practically nontoxic" to the Japanese quail. (MRIDs 00034769; 00034769; 0034769).

Avian Reproductive Toxicity

Avian reproduction studies are required when birds may be exposed repeatedly or continuously through persistence, bioaccumulation, or multiple applications, or if mammalian reproduction tests indicate reproductive hazard. Because linuron is persistent can be applied more than one time during a season these studies are required.

Avian Reproductive Toxicity		
Species	**% Test Material**	**Results**
Mallard Duck	98.4	NOEL = 100 ppm LOEL = 300ppm(1)
Bobwhite Quail	98.4	NOEL = 100 ppm LOEL = 300 ppm(2)

(1) Treatment-related effects in adult body weight, feed consumption, egg production, and eggshell thickness.

(2) Treatment-related effects in egg production, hatchability, and offspring survival.

The No Observable Effects Level for the mallard duck is 100 ppm and the Lowest Observable Effects Level is 300 ppm. (MRID 42541802)

The No Observable Effects Level for the bobwhite quail is 100 ppm and the Lowest Observable Effects Level is 300 ppm. (MRID 42541801)

Toxicity to Mammals

Mammalian Acute Oral Toxicity Findings		
Species	**LD_{50}(mg/kg)**	**Conclusion**
Rat	2100	practically nontoxic

The available data indicate that at a lowest acute oral LD50 of 2100 mg/kg, linuron is practically nontoxic to the rat.

Toxicity to Insects

The minimum data required to establish the acute toxicity to honey bees is an acute contact LD_{50} study with the technical material.

Acute Toxicity to Insects			
Species	**% Test Material**	**LD_{50}**	**Conclusion**
Apis mellifera	not reported	120.86 ug/bee	practically nontoxic

There is sufficient information to characterize linuron as practically non-toxic to bees. (MRID 00018842).

(2) Aquatic Animal Data

Freshwater Fish Toxicity

(i) Acute testing with the TGAI

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. 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 Oral Toxicity			
Species	**% Test Material (TGAI)**	**LC_{50}**	**Conclusions**
Rainbow trout	96.2	3 ppm	moderately toxic
Bluegill sunfish	96.2	9.3 ppm	moderately toxic

The results of the 96-hour acute toxicity studies indicate that linuron can be characterized as being moderately toxic to both cold and warm water fish. (MRIDs 40445501, 40354201).

(ii) Acute testing with the formulated product

Formulated product testing is specified if there is direct application to an aquatic environment or if EECs are greater than or equal to the LC50. Linuron is registered for use on Right-of-ways (ROWs) which can result in a direct application to aquatic environments.

Freshwater Fish Acute Testing with the Formulated Product			
Species	**% A.I.**	**Result LC50**	**Conclusions**
Rainbow trout	Lorox 50 (WP)	16.4 ppm	slightly toxic
Bluegill sunfish	Lorox 50 (WP)	16.2 ppm	slightly toxic
Bluegill sunfish	Lorox 54 (DF)	9.2 ppm	moderately toxic

The results of the 96-hour EC50 studies indicate that Lorox 50 WP (wettable powder) is slightly toxic to rain bow trout and bluegill sunfish. Lorox 50 DF (dry flowable) is considered moderately toxic to bluegill sunfish. (MRIDs 00018165, 00018165, 00018198).

(iii) Chronic Test-Early Life Stage

The fish early life stage is required to support reregistration of a chemical if exposure is expected to be continuous, recurrent or persistent, and multiple applications of the chemical may occur. The minimum data required to establish chronic toxicity of linuron to fish is the early life stage toxicity test based on survival of fish embryos and post-hatch larvae.

Chronic Test-Early Life Cycle		
Species	**% A.I.**	**NOEC**
Rainbow trout	98.4	< 0.042 ppm

The Maximum Allowable Toxicant Concentration (MATC) could not be determined for linuron since effects on fish length were seen at the lowest test level. Additional testing is required. (MRID 42061804).

Freshwater Invertebrate Toxicity

(i) Acute testing with the TGAI

The minimum testing required to assess the hazard of a pesticide is a freshwater aquatic invertebrate toxicity test, preferably using first instar *Daphnia magna* or early instar amphipods, stoneflies, mayflies, or midges.

Freshwater Invertebrate Toxicity Findings			
Species	**% Test Material (TGAI)**	**EC_{50}**	**Conclusion**
Daphnia magna	94.4	0.12 ppm	highly toxic

There is sufficient information to characterize linuron as highly toxic to aquatic invertebrates. (MRID 00142932).

(ii) Acute testing with the formulated product

The minimum data requirement to establish acute toxicity of the formulated product to freshwater invertebrates is a 48-hour acute study.

Acute Toxicity Findings on the End-Use Formulation			
Species	**% A.I. formulated**	**LC50**	**Conclusion**
Daphnia magna	54	1.1 ppm	moderately toxic

There is sufficient information to characterize the formulated product of linuron as moderately toxic to freshwater aquatic invertebrates. (MRID 00018199).

(iii) Chronic Test-life cycle

The Daphnia Life Cycle is required to support reregistration if the chemical's presence in water is likely to be continuous, recurrent or persistent, and multiple applications of the chemical may occur. The minimum data required to establish chronic toxicity of linuron to

invertebrates if the Daphnia life cycle test based on reproduction, growth and survival.

Chronic Test-Life Cycle		
Species	**% A.I.**	**Results**
Daphnia magna	98.4	MATC > 0.13 < 0.24 ppm

Based on the data submitted, the MATC greater than 0.13 and less than 0.24 ppm. Additional testing is required based on inconsistent results with the acute toxicity data. (MRID 42153401)

Estuarine/Marine Toxicity

(i) Acute testing with the TGAI

Acute toxicity testing with estuarine and marine organisms is required when an end-use product is intended for direct application to the marine/estuarine environment or is expected to reach this environment in significant concentrations.

The 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.

Estuarine/Marine Acute Toxicity Findings			
Species	**% Test Material (TGAI)**	**LC_{50}**	**Conclusions**
Sheepshead minnow	98.4	0.89 ppm	highly toxic
Eastern oyster	98.4	5.4 ppm	moderately toxic
Mysid shrimp	98.4	3.3 ppm	moderately toxic

There is sufficient information to characterize the TGAI of linuron as highly toxic to the sheepshead minnow and moderately toxic to the eastern oyster and mysid shrimp. (MRIDs 42061801, 42061802, 42061803).

(ii) Acute testing with the formulated product

Marine and estuarine testing using the formulated products is required due to the ROW (Rights-of-way) use. ROWs could cross virtually any habitat, including marine aquatic habitat such as salt marshes. Data are not currently available. Testing is needed with at least the most sensitive species in acute testing (sheepshead minnow) using the DF (dry flowable) formulation. A DF formulation was found to be more toxic than expected based on active ingredient testing. Additional species and/or formulation may also be needed.

(iii) Chronic effects

Chronic marine and estuarine testing are indicated based on the same criteria as freshwater species. In the case of linuron, these indications include (1) and LC50 value less than 1 mg/l, (2) and EEC $\geq$ 0.01 LC50 and (3) and aquatic half-life of less than 4 days. Sheepshead minnow and mysid shrimp should be tested.

(3) Toxicity to Terrestrial, Aquatic, and Semi-Aquatic Plants

Toxicity to Terrestrial Plants

Data requirements for determining toxicity to terrestrial plants (Tier 2) remain outstanding. These data are required because linuron because it is an herbicide registered for use on terrestrial food and nonfood sites and the vapor pressure is $\geq 1.0 \times 10^{-5}$. It also reportedly has at least some aerial application (soybeans).

Toxicity to Aquatic Plants

Only one of the five required species for testing for toxicity to aquatic plants has been submitted. Testing for *Lemna gibba*, *Skeletonema costatum*, *Anabaena flos-aquae*, and a freshwater diatom remain outstanding. These data are required for linuron as it is an herbicide registered for use on terrestrial food/nonfood sites, has a vapor pressure $\geq 1.0 \times 10^{-5}$ mm Hg, and a water solubility greater than 10 ppm. It also reportedly has at least some aerial application (soybeans).

Aquatic Plant Toxicity		
Species	**% A.I.**	**EC_{50}**
Selenastrum capricornutum	**100**	**5-day = 0.067 mg ai/L**

With a 5-day exposure of 0.067 mg active ingredient per Liter of linuron, S. capricornutum can be expected to sustain a 50% reduction in density on numbers of cells. (MRID 42086801).

b. Ecological Effects Risk Assessment

(1) Risk to Terrestrial Animals

(a) Nontarget insects

Although honeybees could be exposed to linuron, corn and cotton specifically, minimal risk is expected as linuron is considered "practically nontoxic" (LD_{50} = 120.86 ug/bee) to honey bees.

(b) Avian and mammalian species

Avian and mammalian species may be exposed to linuron through multiple routes, including dietary and dermal. The criterion for the presumption of high risk from exposure for acute avian and mammalian species is a value greater than or equal to 0.5 for the quotient of the estimated environmental concentration (EEC) divided by the lowest LD_{50} value for birds and mammals—this is known as the risk quotient (RQ).

Acute RQ = EEC/LC50 ≥ 0.5 for birds and mammals

Calculation of estimated environmental residues are based on the work by Hoerger and Kenaga (1972).

(i) Avian Acute/Subacute Risk

High Risk LOCs are not exceeded at any application rate for a single application. Restricted Use Levels of Concern (LOC) are exceeded on short grass at the 3 and 4 lbs a.i./A rates. Endangered species LOC are exceeded for all the rates evaluated. Residues on insects would not exceed LOCs (see Table 1).

Table 1. Avian Acute Risk Quotient and LOC exceedance for the maximum application rates of linuron by use site. (lowest LC50 = 3083 ppm). EEC for short grass = application rate (al ai/A) x 240 ppm/lb ai. EEC for insects = application rate x 58 ppm/lb ai. Lowest avian LC50 = 3083 ppm (mallard duck) Risk Quotient = EEC/LC50.

Use Site	Application Rate	Substrate (EEC)	Risk Quotient (EEC/LC50)	LOC
Carrots, celery, sweet corn, cottonseed, parsley, parsnips, sorghum; ornamental herbaceous plants	1.5 lbs ai	Short Grass (360)	0.12	High Risk ≥ 0.5 RU ≥ 0.2 ES ≥ 0.1
		Insects (87)	0.03	High Risk ≥ 0.5 RU ≥ 0.2 ES ≥ 0.1
Field corn	1.54 lbs ai	short grass (370)	0.12	High Risk ≥ 0.5 RU ≥ 0.2 ES ≥ 0.1
		Insects (89)	0.03	High Risk ≥ 0.5 RU ≥ 0.2 ES ≥ 0.1
Winter wheat (drill planted)	1.75 lbs ai	short grass (420)	0.14	High Risk ≥ 0.5 RU ≥ 0.2 ES ≥ 0.1
		Insects (101.5)	0.03	High Risk ≥ 0.5 RU ≥ 0.2 ES ≥ 0.1
Potatoes; poplar (forest/ shelterbelt)	2.0 lbs ai	short grass (480)	0.16	High Risk ≥ 0.5 RU ≥ 0.2 ES ≥ 0.1
		Insects (116)	0.04	High Risk ≥ 0.5 RU ≥ 0.2 ES ≥ 0.1
Soybeans; non-ag. ROW/fencerows/ hedgerows/ uncultiv. areas/ soils	3.0 lbs ai	short grass (720)	0.23	High Risk ≥ 0.5 RU ≥ 0.2 ES ≥ 0.1
		Insects (174)	0.06	High Risk ≥ 0.5 RU ≥ 0.2 ES ≥ 0.1
Asparagus	4.0 lbs ai	short grass (960)	0.31	High Risk ≥ 0.5 RU ≥ 0.2 ES ≥ 0.1
		Insects (232)	0.08	High Risk ≥ 0.5 RU ≥ 0.2 ES ≥ 0.1

RU = Restricted Use ES = Endangered Species

(ii) Avian Chronic and Reproductive Risk

The avian reproduction NOEL is considered 100 ppm, with effects seen at 300 ppm Both of these levels are below those residue levels that could occur on short grass within the treated area at even the lowest of the maximum application rates by crop, from a single application. Given this, as well as the persistence of linuron described by EFED, it appears that chronic avian risk is present for all use sites.

Table 2. Avian Chronic Risk Quotient and LOC exceedance for the maximum application rates of linuron by use site. (NOEL = 100 ppm). Table uses same EECs as Table 1. Risk Quotient = EEC/NOEL.

Use Site	Application Rate	Substrate (EEC)	Risk Quotient (EEC/NOEL)	LOC
Carrots, celery, sweet corn, cottonseed, parsley, parsnips, sorghum; ornamental herbaceous plants	1.5 lbs ai	Short Grass (360)	3.60	Chronic Risk* $\geq$ 1
		Insects (87)	0.87	Chronic Risk* $\geq$ 1
Field corn	1.54 lbs ai	short grass (370)	3.70	Chronic Risk* $\geq$ 1
		Insects (89)	0.89	Chronic Risk* $\geq$ 1
Winter wheat (drill planted)	1.75 lbs ai	short grass (420)	4.20	Chronic Risk* $\geq$ 1
		Insects (101.5)	1.02	Chronic Risk* $\geq$ 1
Potatoes; poplar (forest/ shelterbelt)	2.0 lbs ai	short grass (480)	4.80	Chronic Risk* $\geq$ 1
		Insects (116)	1.16	Chronic Risk* $\geq$ 1
Soybeans; non-ag. ROW/fencerows/ hedgerows/ uncultiv. areas/ soils	3.0 lbs ai	short grass (720)	7.20	Chronic Risk* $\geq$ 1
		Insects (174)	1.74	Chronic Risk* $\geq$ 1
Asparagus	4.0 lbs ai	short grass (960)	9.60	Chronic Risk* $\geq$ 1
		Insects (232)	2.32	Chronic Risk* $\geq$ 1

* "Chronic risk, endangered birds may be affected, restricted use recommended"

In addition to risk from direct application, there can be risk to birds feeding in areas adjacent to treated fields, due to drift, particularly with aerial application. The current EEB estimate is 5%. This added risk, based on this assumption, does not by itself exceed the LOC (see Table 3).

Table 3. Avian Chronic Risk Quotient and LOC exceedance -- off-site exposure with soybeans. Off-site drift estimate = 5% of EEC (from Table 1).

Use Site	Application Rate	Substrate	Risk Quotient (EEC/NOEL)	LOC
Soybeans	3.0 lbs ai	short grass (36)	0.36	Chronic Risk* $\geq$ 1
		Insects (8.7)	0.087	Chronic Risk* $\geq$ 1

* "Chronic risk, endangered birds may be affected, restricted use recommended"

(iii). Risk to Mammals

Tables 4 and 5 show LD50s/sq. ft. for the use sites, for two small mammals. LD50s/sq. ft. will vary with the weight of the animal, since LD50s are expressed in mg/kg body weight (i.e., for a given LD50, a smaller animal will require less toxicant to receive a lethal dose). For linuron, all LOCs are exceeded for the small, carnivorous least shrew whereas none are for the much heavier, omnivorous rat.

Table 4. Mammalian Risk Quotient and LOC exceedance for the maximum application rates of linuron by use site. (lowest LD50 = 2100 mg/kg; mammal body weight= 0.005 kg, least shrew). Mg ai/sq. ft = lb ai/A x 10.4 (conversion factor). Risk Quotient = LD 50/sq.ft. = mg ai/sq.ft./LD50 x animal weight).

Use Site	Application Rate	mg ai/sq. ft.	LD50/sq. ft.	LOC
Carrots, celery, sweet corn, cottonseed, parsley, parsnips, sorghum; ornamental herbaceous plants	1.5 lbs ai	15.6	1.49	High Risk $\geq$ 0.5 RU $\geq$ 0.2 ES $\geq$ 0.1
Field corn	1.54 lbs ai	16.0	1.52	High Risk $\geq$ 0.5 RU $\geq$ 0.2 ES $\geq$ 0.1
Winter wheat (drill planted)	1.75 lbs ai	18.2	1.7	High Risk $\geq$ 0.5 RU $\geq$ 0.2 ES $\geq$ 0.1
Potatoes; poplar (forest/ shelterbelt)	2.0 lbs ai	20.8	2.0	High Risk $\geq$ 0.5 RU $\geq$ 0.2 ES $\geq$ 0.1

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Soybeans; non-ag. ROW/fencerows/ hedgerows/ uncultiv. areas/ soils	3.0 lbs ai	31.2	3.0	High Risk ≥ 0.5 RU ≥ 0.2 ES ≥ 0.1
Asparagus	4.0 lbs ai	41.6	4.0	High Risk ≥ 0.5 RU ≥ 0.2 ES ≥ 0.1

RU = Restricted Use ES = Endangered Species

Table 5. Mammalian Risk Quotient and LOC exceedance for the maximum application rates of linuron by use site. (lowest LD50 = 2100 mg/kg; mammal body weight= 0.3 kg, rat).

Use Site	Application Rate	mg ai/sq. ft.	LD50/sq. ft.	LOC
Carrots, celery, sweet corn, cottonseed, parsley, parsnips, sorghum; ornamental herbaceous plants	1.5 lbs ai	15.6	0.02	High Risk ≥ 0.5 RU ≥ 0.2 ES ≥ 0.1
Field corn	1.54 lbs ai	16.0	0.03	High Risk ≥ 0.5 RU ≥ 0.2 ES ≥ 0.1
Winter wheat (drill planted)	1.75 lbs ai	18.2	0.03	High Risk ≥ 0.5 RU ≥ 0.2 ES ≥ 0.1
Potatoes; poplar (forest/ shelterbelt)	2.0 lbs ai	20.8	0.03	High Risk ≥ 0.5 RU ≥ 0.2 ES ≥ 0.1
Soybeans; non-ag. ROW/fencerows/ hedgerows/ uncultiv. areas/ soils	3.0 lbs ai	31.2	0.05	High Risk ≥ 0.5 RU ≥ 0.2 ES ≥ 0.1
Asparagus	4.0 lbs ai	41.6	0.07	High Risk ≥ 0.5 RU ≥ 0.2 ES ≥ 0.1

RU = Restricted Use ES = Endangered Species

(iv) Mammalian Chronic Risk

The lowest NOEL dietary concentration reported in submitted data is 25 ppm, seen in a 1-year dog feeding study and in a 3-generation reproduction study in rats. Oncogenic effects were reported in both mice and rat studies. For mice, "hepatocellular adenomas were significantly increased in the high dose group [1500 ppm] and reached borderline significance in the low dose group [50 ppm]". For rats, "testicular interstitial cell adenomas increased in 125 and 625 ppm males" (submitted data). Given the persistence of linuron in the field and the effects seen in the lab at concentrations well below those expected after initial application, it appears that chronic effects in wild mammals are likely.

(2) Aquatic Risk

Aquatic - Acute Risk

Acute risk to aquatic organisms has been estimated by comparing EECs to the lowest available linuron technical LC50 or EC50 for fish and aquatic invertebrates. EECs used were derived from two models, one involving runoff to a 6' pond (A) and the second involving runoff to a 6" water body or wetland (B). The latter is to be used for linuron only for the ROW use. Table 6 shows that fish restricted use LOCs are exceeded under model B (ROWs). Fish endangered species LOCs are exceeded under model B (ROWs) and also under model A for the 4 lb ai/A rate.

Table 7 shows that the aquatic invertebrate high risk LOC is exceeded with model B (ROWs). Aquatic invertebrate restricted use and endangered species LOCs are exceeded for all sites with both models.

Direct application to aquatic habitat could also potentially occur with a ROW use. Direct application to 6" of water would result in 2202 ppb at a 3 lb ai/A rate. This would produce a risk quotient of 2,474 for fish and 18,350 for aquatic invertebrates, vastly exceeding all LOCs.

Table 6. Fish Risk Quotient and LOC exceedance for the maximum application rates of linuron by use site. (lowest LC50 = 0.89 ppm). EEC for model A (runoff to 6' pond) = [application rate (lb ai/A) x % runoff x 10 acre drainage basin] x 61 ppb/lb ai. where % runoff = 2% (based on linuron water solubility of 81 ppm).
Risk Quotient = EEC/EC50 where fish LC 50 = 0.89 ppm (sheepshead minnow).

Use Site	Application Rate	RQ (EEC/EC50) (model[1])	LOC
Carrots, celery, sweet corn, cottonseed, parsley, parsnips, sorghum; ornamental herbaceous plants	1.5 lbs ai	0.021 (A)	High Risk ≥ 0.5 RU ≥ 0.1 ES ≥ 0.05
Field corn	1.54 lbs ai	0.021 (A)	High Risk ≥ 0.5 RU ≥ 0.1 ES ≥ 0.05
Winter wheat (drill planted)	1.75 lbs ai	0.024 (A)	High Risk ≥ 0.5 RU ≥ 0.1 ES ≥ 0.05
Potatoes; poplar (forest/ shelterbelt)	2.0 lbs ai	0.027 (A)	High Risk ≥ 0.5 RU ≥ 0.1 ES ≥ 0.05
Soybeans; non-ag. ROW/fencerows/ hedgerows/ uncultiv. areas/ soils	3.0 lbs ai	0.041 (A) 0.49 (B) (ROW)	High Risk ≥ 0.5 RU ≥ 0.1 (B) ES ≥ 0.05 (B)
Asparagus	4.0 lbs ai	0.055(A)	High Risk ≥ 0.5 RU ≥ 0.1 ES ≥ 0.05 (A)

RU = Restricted Use ES = Endangered Species

1. model: A =runoff to 6' pond; B = runoff to 6" wetland

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Table 7. Aquatic Invertebrate Risk Quotient and LOC exceedance for the maximum application rates of linuron by use site. (lowest EC50 = 0.12 ppm). EEC for model B (runoff to 6" wetland) = [application rate (lb ai/A x % runoff x 10 acre drainage basin] x 734 ppb/lb ai. with 2% runoff. Risk Quotient = EEC/LC50 where lowest aquatic invertebrate = 0.12 ppm (*D. Magna*)

Use Site	Application Rate	RQ (EEC/EC50) (model[1])	LOC
Carrots, celery, sweet corn, cottonseed, parsley, parsnips, sorghum; ornamental herbaceous plants	1.5 lbs ai	0.15 (A)	High Risk ≥ 0.5 RU ≥ 0.1 (A) ES ≥ 0.05 (A)
Field corn	1.54 lbs ai	0.157 (A)	High Risk ≥ 0.5 RU ≥ 0.1 (A) ES ≥ 0.05 (A)
Winter wheat (drill planted)	1.75 lbs ai	0.178 (A)	High Risk ≥ 0.5 RU ≥ 0.1 (A) ES ≥ 0.05 (A)
Potatoes; poplar (forest/ shelterbelt)	2.0 lbs ai	0.203 (A)	High Risk ≥ 0.5 RU ≥ 0.1 (A) ES ≥ 0.05 (A)
Soybeans; non-ag. ROW/fencerows/ hedgerows/ uncultiv. areas/ soils	3.0 lbs ai	0.305 (A) 3.67 (B) (ROW)	High Risk ≥ 0.5 (B) RU ≥ 0.1 (A,B) ES ≥ 0.05 (A,B)
Asparagus	4.0 lbs ai	0.4 (A)	High Risk ≥ 0.5 RU ≥ 0.1 (A,B) ES ≥ 0.05 (A,B)

RU = Restricted Use ES = Endangered Species

1. model: A = runoff to 6' pond; B = runoff to 6" wetland

Aquatic - Chronic Risk

Chronic aquatic effects cannot be fully assessed at this time. Effects (on fish length) were seen at the lowest concentration (0.042 ppm) with rainbow trout in an early life stage test. The "rough-cut" EECs used for the above tables under model A exceed this effect level at the 4 lb ai/A rate and under model B at the 3 lb ai rate (ROWs). Since the NOEL for this study was some untested level below 0.042 ppm, there would likely be further exceedances of the NOEL and thus the chronic LOC (EEC/NOEL $\geq$ 1).

Although the above comparisons are with "rough-cut" EECs, available environmental fate information from EFED (see above) indicates potential persistence in water. There is little or no effect of hydrolysis or photolysis (both half-lives greater than 30 days). Microbial degradation is described by EFED; the anaerobic aquatic half-life is reported as less than 21 days. Three degradates of unknown toxicity have been identified by EFED. Thus, the toxicity of the combined degradates plus remaining parent linuron is also not known.

The chronic effect level for *D. magna* is reportedly 2X the LC50 seen in a previous acute study, a major inconsistency. Also, invertebrates were more sensitive than fish in acute tests, but appear considerably less sensitive in the chronic test. Further testing appears necessary to resolve this problem. All available information that would address this inconsistency needs to be provided so that the Agency can determine whether further acute testing, chronic testing, or both are required.

(3) Plants

Valid data on the toxicity of linuron to nontarget plants is available for only one of five aquatic plants, and not available at all for the ten required terrestrial species. Exposure of nontarget terrestrial and aquatic plants to linuron is expected primarily due to runoff from ground applications (all use sites) and from runoff and drift for aerial applications (certain soybean labels, as per HED Use Table).

No terrestrial plant risk assessment can be done due to the lack of adequate data. High risk is likely, based on the herbicidal properties of linuron.

Only a preliminary aquatic plant risk assessment can be done since adequate data are available for just one of five species. High risk and endangered plant LOCs are exceeded for aquatic plants if the EEC/EC50 $\geq$ 1. Based on the EECs previously calculated to evaluate risk to aquatic animals, and the one available EC50 (0.067 ppm), these LOCs are exceeded under the runoff to wetland model (6") for ROWs, but not the runoff to 6' pond model for all other uses.

(4) Endangered Species

As described in the above risk assessment sections, endangered species LOCs are exceeded in some instances for acute effects to birds, wild mammals, aquatic organisms and nontarget plants. Endangered species LOCs are exceeded for chronic effects to birds, wild mammals, and aquatic organisms.

The Endangered Species Protection Program is expected to become final in 1994. Limitations on the use of linuron will be required to protect endangered and threatened species, but these limitations have not yet been defined (and may be formulation specific). OPP anticipates that 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 any required label modifications are necessary. Such modifications would most likely consist of the generic label statement referring pesticide users to use limitations contained in county Bulletins.