TFW-WQ1-91-001

PROPOSED SURFACE WATER STANDARDS FOR SELECTED PESTICIDES USED IN FORESTRY IN OREGON AND WASHINGTON

By

Logan A. Norris and Frank Dost

TIMBER/FISH
&WILDLIFE

MAY 28, 1991

Proposed
Surface Water Standards
for
Selected Pesticides Used in Forestry In Oregon and Washington

Logan A. Norris[1] and Frank Dost[2]
May 28, 1991

Surface water standards for pesticides used in forestry are needed to (1) permit evaluation of the effect of pesticide use on aquatic organisms and on humans and animals which consume water from forest areas, (2) determine the effectiveness of strategies used to protect water quality, and (3) provide a basis for evaluating adherence to regulatory rules which govern the use of pesticides in forestry in Washington and Oregon, and thus a basis for their enforcement.

Water quality standards are established for administrative and regulatory purposes to achieve specific objectives. They are often expressed as a concentration below which the objective will be achieved. Water quality standards for forest pesticides are usually developed to assure protection of human health and prevent adverse toxic effects on aquatic organisms, or terrestrial animals which may reside in or consume the water. This report identifies specific pesticide concentrations in surface water which will achieve these goals. These in turn can provide a basis for establishment of water quality standards.

This report is in three major sections. Section 1 deals with concentrations to protect human health. Section 2 focuses on protection of freshwater aquatic organisms. Section 3 combines information from Sections 1 and 2 to identify potential water quality standards which we feel will protect humans, aquatic organisms, and other animals.

[1] Professor and Department Head, Department of Forest Science, Oregon State University, Corvallis, Oregon 97331

[2] Professor and Extension Toxicologist, Department of Agricultural Chemistry, Oregon State University, Corvallis, Oregon 97331

Section 1. Protecting Human Health

For protection of humans, any water quality standard must take into account potential consumption of water from the affected source, and the expected potential impact on each individual who may use the source. The generally accepted approach in protecting human health is to (1) establish a water quality standard based on an intake level or dose of the chemical that can be expected (with a high degree of confidence) to produce no effect over the period of possible exposure, and (2) assure through regulation and management, that such a dose is not exceeded.

The dose (step 1) is derived from experimental toxicological data (usually the most sensitive experiments demonstrating a no-observed-effect level [NOEL]). Depending on the quality and uncertainties of the data, a margin of safety is usually included so the intake level (or dose) allowed by the standard is 100- to 1000-fold lower than the NOEL.

In this section of the report we identify levels of specific forestry pesticides in water that should not cause adverse human health effects. In some cases these levels are recommended in EPA Health Advisories as acceptable over a 10-day period of intake. The EPA Health Advisories are produced by the EPA Office of Drinking Water, and include many pesticides used in forestry. The EPA Health Advisories are not regulatory positions, but represent a best judgement of EPA of a level that should trigger a decision process and will occur prior to any health impact. Where no Health Advisory has been defined, we have either derived a health-based level from the NOEL, using criteria similar to those used by EPA or have used Lifetime Allowable Daily Intakes (ADI) recommended by EPA or the World Health Organization

Chemicals used in nursery operations should be considered differently. The same criteria for judging acceptable water concentrations may be appropriate, however, the intensity and frequency of chemical use may be quite different from woodland operation. Thus, the potential for offsite movement may be greater and may possibly exceed degradation capacity of intervening space that would be more than adequate to block movement of a single application. There is also a greater potential for sustained exposure, and in these cases lifetime exposure limits are recommended.

Methods of application in the nursery, however, should be easily controllable, and monitoring should also be easier. Thus, verifying adherence to standards is easier to determine.

The approach used by EPA in developing Health Advisories is to estimate one-day, ten-day, longer term and life time exposure levels, below which no adverse effect is expected. In most cases, EPA did not set a one-day exposure level, and defaulted to the more conservative ten-day estimate as a substitute for the short term estimate. A similar approach is taken here for pesticides used in forestry (non-nursery) applications. This is appropriate for these standards, because surface water contamination resulting from forestry operations are of short duration, normally much shorter than 10 days.

This report does not determine risks of carcinogenic response. Of the forestry pesticides included in this report, few are equivocally carcinogenic, and those are of very low potency. Our assumption is exceedance of water quality standards as a result of a non-nursery forestry application of a pesticide will almost certainly be of very short duration, at levels that would provide a minuscule dose in terms of carcinogenic effect. Others have gone through this exercise and it is quite clear that such risk cannot be practically differentiated from zero (Shipp, et al. 1986). If necessary, carcinogenic risk estimates can be developed but we judge this is unnecessary for forestry operations.

For this analysis, the route of exposure is by ingestion of contaminated water. We assume that adults weigh 70 kg (154 pounds) and consume two liters (about two quarts) of water daily, and that children weigh 10 kg (22 pounds) and consume one liter of water daily. Further, we assume water consumption is only from the affected surface water body over a ten-day exposure period. The standards we identify are for a 10 kg child. Those for adults will be higher. These are health-conservative estimates.

Health risks for forest mammals are adequately accounted for by the human health estimates. In many cases the standard as determined for humans is higher than that identified for aquatic species. The reason is that exposure of fish is vastly greater per unit body weight because contact is continuous. In addition, fish are sometimes intrinsically more sensitive than mammals.

2,4-D, 2,4-DP and triclopyr esters and amines are not differentiated in the recommendations on human standards because the various forms hydrolyze quickly to the parent acid in the body fluids, and the toxicological pattern is similar within each group.

Table 1 identifies EPA 10-day Health Advisory concentrations or our recommendations of human health trigger concentrations which we derived in a similar manner in the absence of values from EPA. The text following the table provides more detail about these values for specific chemicals. Finding one of the pesticides identified in this report at the advisory level suggested in this report should not be interpreted as representing a health threat. All incorporate safety factors and uncertainty estimates to indicate a daily intake that should not be exceeded but can be expected with high confidence to produce no harm. Findings which exceed these levels should trigger careful evaluation of procedures which produced them to avoid reoccurrence.

Table 1. Surface Water Quality Advisory Standards Which Will Provide Protection of Human Health in Forestry Operations.

Pesticide	EPA 10-day Health Advisory Standard (mg/liter)	NOEL derived Standard[1]
Acephate	---	0.005
Amitrole	---	0.05
Asulam	---	1.0
Atrazine	1.0	
Bifenthrin		0.5
BT	No useful data available	
Carbaryl	1.0	
Chlorothalonil	0.15	
Dalapon	2.7	
Dicamba	0.3	
2,4-D (All form.)[2]	0.3	
Dienachlor	Data not available	
Endosulfan[3]	---	0.08
Fosamine	2.0	
Glyphosate	17.5	
Hexazinone	2.5 (90 day)	
Imazapyr	---	10.0
Mancozeb	---	0.03
Picloram	20.0	
Propargite	---	0.08
Simazine	0.5	
Sulfmeturonmethyl	---	0.1
Triclopyr[4]	---	0.5

[1] EPA has not identified a 10-day water quality Health Advisory level for chemicals with values listed in this column. Some values are derived from EPA or WHO ADI recommendations. See following section.

[2] Includes ester and amine forms, and 2,4-DP.

[3] Endosulfan and metabolites.

[4] Includes amine and ester forms.

RATIONALE FOR ESTIMATES OF HUMAN HEALTH STANDARDS WHERE AN EPA 10-DAY HEALTH ADVISORY STANDARD HAS NOT BEEN DEFINED.

Imazapyr

Data in our hands for Imazapyr (Arsenal formulation) is incomplete. Imazapyr is neither carcinogenic or mutagenic. The NOEL for teratogenic effect in rats is 1000 mg/kg/day, with modest maternal toxicity. The teratogenic NOEL for rabbits is 400 mg/kg/day. Excretion half time is about one day. On the basis of the rabbit NOEL of 400 mg/kg/day and with 30 and 90 day general toxicity studies not presently available to us, a standard based on a tentative reference dose of one mg/kg/day is recommended. This dose rate is based on a standard 100 fold safety factor, with a multiplier of 4X to accommodate unavailable data. For a 10 kg child, the total dose would be 10 mg/day, or 10 ppm in water.

Asulam

Asulam has limited mammalian toxicity. Asulam appears to have no genetic or carcinogenic effects, although the latest data available to us indicates that one carcinogenicity study is not acceptable because the test substance was not properly identified. For this standard, the rabbit teratogenicity NOEL of 40 mg/kg/day will be used as a basis. It was the highest dose tested, and is the lowest NOEL for asulam. A 100 fold safety factor plus a four-fold multiplier for some uncertainty of data suggests an acceptable standard of 0.1 mg/kg/day. For a 10 kg child consuming one liter per day, this represents a water standard of 1.0 ppm.

Bifenthrin

There is very little specific data available on bifenthrin. Data available indicates it is not genotoxic, and the class of chemicals which incudes bifenthrin shows little evidence of carcinogenicity. Bifenthrin is not teratogenic and is eliminated rapidly by mammals. Based on acute toxicity (LD_{50} 54.5 mg/kg) and the apparent absence of cumulative activity, we believe a provisional water quality standard that provides a 1000-fold lower dose (0.05 mg/kg) will be fully protective. The concentration in water which will not exceed this dosage level for a 10-kg child is 0.5 mg/liter.

Triclopyr

Data on triclopyr is extensive. General toxicity studies up to 90 days indicate NOELs of from 20 to 30 mg/kg/day. A long term study in the rat indicated minor changes in the rat kidney at lower doses, with a NOEL of 5 mg/kg/day, which will be used as the basis for this standard. Studies in the dog show a somewhat lower NOEL, but the dog is unique among mammals in having poor capacity for excretion of organic acids such as triclopyr; the dog is an inappropriate test subject for triclopyr but the data for the dog is used here as a health conservation strategy. At 5 mg/kg/day, with a safety factor of 100, the reference dose may be set at 0.05 mg/kg/day, or 0.5 mg total for a 10 kg child. At one liter per day, the expected water standard will be 0.5 ppm.

Sulfmeturonmethyl (Oust)

Mammalian toxicity data for this chemical is not presently in our hands. It is stated to be not teratogenic. A one year dog study has provided a NOEL of 3.75 mg a.i./kg/day. Other NOELs are much higher. A single dose of 0.01 mg/kg or 0.1 mg total dose for a 10 kg child consuming one liter of water provides a safety factor of 375; a water standard of 0.1 ppm meets those criteria.

Amitrole

The most important toxic effect of amitrole is decreased thyroid function and consequent hyperplasia of the thyroid. A NOEL of 25 mg/kg day for 119 days has been noted, but a lower NOEL for amitrole in water of 0.5 mg/kg/day is used as the basis for this standard. We recommend a 500 fold safety factor because of the degree of variability in the data, providing a reference dose of 0.001 mg/kg day, or a total dose for a 10 kg child of 0.01 mg/day. This translates to a water standard of 0.01 ppm. (In our opinion, amitrole use should be confined to very special cases, with applicators particularly well informed about the characteristics of this chemical.)

2,4-DP

Data for 2,4-D is generally assumed to represent 2,4-DP, and the same standards are recommended.

Chlorothalonil (Bravo, Daconil)

Half times in loamy soils are up to a month at temperatures somewhat higher than those of the northwest, and the principal metabolite is slower to degrade. Movement in soil is slow and the chemical should not be expected to move through soil to water courses.

Absorption across body surfaces is limited, tissue residues are low after high doses, and excretion is complete in a few days. The most important effect for applicators is contact dermatitis and sensitization and reversible eye irritation. Chlorothalonil is probably carcinogenic, causing some renal tubular adenomas and carcinomas in rats at high doses and non-dose related forestomach tumors in mice. The systemic NOEL for most chronic assays is between 1.5 and 3 mg/kg/day, with various relatively non-specific findings. EPA uses a Health Advisory of 0.2 ppm, rounded up from 0.15 ppm. The NOEL of 1.5 mg/kg/day represents a total dose of 15 mg for a 10 kg child. A safety factor of 100 is justified by the extensive data base, which provides an allowable dose maximum of 0.15 mg/kg/day. At a consumption of one liter of water per day, that dose would be met at a concentration of 0.15 ppm.

Endosulfan (Thiodan)

Endosulfan has been reviewed by WHO-FAO, and a temporary lifetime ADI of 0.008 mg/kg/day is recommended. It is a chlorinated cyclodiene hydrocarbon, but is rapidly excreted. The toxicological data base is extensive, and the compound is interesting in that almost all NOELs are somewhat below one mg/kg/day, in a variety of species, study durations and effects. The NOEL used is 0.75

mg/kg/day, which with 100 fold safety factor leads to the allowable daily intake of 0.008 mg/kg/day. For a 10 kg child the total dose NOEL is 0.08 mg/day, which is represented by consumption of one liter of water per day at a concentration 0.08 ppm.

Acephate (Orthene)

Acephate has been reviewed by the World Health Organization, by FDA, and by the OSU Extension Toxicology Program in connection with the effort to eradicate a Gypsy Moth infestation in Lane County, Oregon. It is an acetylcholine esterase (AChase) inhibitor, and in lifetime studies produces such inhibition at doses that do not cause other forms of toxicity. Because AChase inhibition does not reverse quickly, intake at rates greater than the recovery rate could cause cumulative effects.

The NOEL for rats is considered by WHO-FAO to be 0.25 mg/kg/day. WHO-FAO have published a temporary value for the lifetime acceptable daily intake of 0.0005 mg/kg/day. This figure represents a 500 fold safety factor, which is quite conservative for non-carcinogenic, short term exposure. The data base is reasonably complete, although a new multigeneration reproduction and delayed neurotoxicity tests have been requested, which probably account for the additional five fold multiplier of the usual 100 fold factor. Earlier multigeneration tests were extensive, but no definitive NOEL was established. It is also adequate for potential long term exposure, for a 10 kg child consuming one liter of water daily. The ADI of 0.0005 mg/kg/day represents a water concentration of 0.005 ppm, which in this case is suggested as the standard.

Propargite (Omite)

Propargite is extensively metabolized, with small amounts detectable in milk and fat of cattle but not in other tissues. Acute toxicity is low. Fetal toxicity and teratogenicity are limited but some skeletal anomalies were seen at 25 mg/kg/day. FAO has judged the NOEL at 15 mg/kg/day. Propargite appears not to be carcinogenic, but only one species has been evaluated. Primary data is proprietary. EPA has set an Allowable Daily Intake at 0.225 mg/kg/day and FAO uses a figure of 0.08 mg/kg/day on a temporary basis. In setting the FAO figure, a 200 fold safety factor was used. For a 10 kg child, the total one day allowable dose based on the FAO allowable lifetime dose per day would be 0.8 mg. If water consumption is one liter per day, allowable concentration is 0.08 mg/liter (ppm).

Mancozeb (Dithane, Manzate)

This fungicide is an ethylene bisdithiocarbamate, and registration of all members of this class is currently under question, particularly on food crops. They metabolize to ethylene thiourea, which is carcinogenic and thyroid active. The data base is considered inadequate. The EBDC have some leaching potential, although data are sketchy. In the nursery context, this may be a concern. Longterm systemic effects in the dog appear most sensitive, with a NOEL of 3.0 mg/kg/day. The provisional EPA ADI is 0.003 mg/kg/day, based on the two year NOEL in dogs noted above with a 1000 fold safety factor because of the significant data gaps. The allowable single day total dose for a 10 kg child is then 0.03 mg. At a water intake of one liter per day, that level represents a concentration of 0.03 mg/liter or ppm.

Section 2 Protection of Aquatic Species

For non-human life forms, protection of populations of organisms rather than the protection of each individual is the usual strategy, except when rare or endangered species are involved. Thus it would be unacceptable to kill all the individuals in a population of fish in a given portion of a stream, but may be acceptable if one or a few individuals were killed because they were unusually sensitive due to stress, or some other factor. The population of organisms would be expected to recover.

The primary difference then between protecting humans and protecting aquatic organisms is only in the degree of certainty of protection which is provided. For aquatic species, concentrations which protect the population are appropriate, even though some individuals in the population might be affected. For humans, the standards must protect the most sensitive individual. Thus the strategy in establishing standards is the same, but the level of protection to be achieved (and the certainty) is different.

An appropriate strategy is to (1) determine the highest concentration of chemical which causes no effect (commonly called the no-observable-effect-level or NOEL) in any species representative of the type to be protected by the standard, and (2) then apply a safety factor to this value in establishing the standard. The safety factor is some value (commonly 1 to perhaps as much as 1000) used in establishing the standard. A safety factor of 10 for instance means the standard is 10 time less than the NOEL. The reciprocal of the safety factor is multiplied with the NOEL to establish the water quality standard. Thus if a safety factor of 10 is used, the water quality standard would be 0.1(NOEL).

For aquatic species, the results of toxicity tests are often reported as 50%-lethal concentrations after a specified period of exposure (often 48 or 96 hours) rather than the no-observable-effect-levels. Based on a review of the literature, Norris et al. (1983) concluded 0.1(96-hour LC_{50}) was a no-effect-level. In fact, in those instances where LC_{50} and NOEL values are reported, it is not unusual to find the NOEL is 0.3(LC_{50}). For regulatory purposes, the National Academy of Sciences (1973) Water Quality Criteria recommends 0.1(LC_{50}) to estimate safe concentrations for non-persistent, non-accumulating (meaning non-bioconcentrating) chemicals in aquatic species. This is an appropriate standard for contemporary forest pesticides since they are neither persistent nor bioaccumulative.

Based on this information it would seem relatively easy to select a safety factor, and based on established toxicity data, establish water quality standards. The problem is the nature of the exposure is greatly different in the field than it is in toxicity tests with aquatics.

In the field, if a pesticide enters a stream the concentration typically reaches a peak and then decreases quickly as fresh, uncontaminated water flows in from upstream. Thus the organism is exposed to a highly variable concentration of pesticide. In toxicity tests, the concentration of pesticide is relatively uniform by comparison because the water is usually not exchanged, or if it is, fresh pesticide is added to maintain the concentration. Thus, in toxicity tests, organisms are exposed to fixed concentrations for prolonged periods compared to exposure in the field (Norris et al., 1983).

Because of the lack of specifically defined NOEL values for most aquatics, the standard of $0.1(LC_{50})$ is an appropriate standard for instantaneous concentrations, that is maximum permitted concentration at any time and $0.01(LC_{50})$ for 24-hour average values. These are the values arrived at by Norris et al. (1983) in their evaluation of the potential effects of forest pesticides on aquatic species in the Pacific Northwest.

In the water quality standards which follow, the peak and 24-hour concentration standard is specified for cold, fresh-water fish and for cold, fresh-water aquatic invertebrates based on the lowest reported LC_{50} value for species which represent these types of organisms. The water quality standard for the peak concentration is $0.1(LC_{50})$ and the standard for the 24-hour average concentration is $0.01(LC_{50})$.

Table 2. Surface water quality advisory standards which will provide protection for aquatic organisms in forestry operations.

Pesticide	Aquatic Organism			
	Invertebrates		Fish	
	Instantaneous maximum	24-hour average	Instantaneous maximum	24-hour average
	--------mg/liter--------		--------mg/liter--------	
Acephate	0.64	0.064	5.0	0.5
Amitrole	1.8	0.18	7.0	0.7
Asulam	Data not yet located			
Atrazine	0.07	0.007	0.49	0.049
Bifenthrin	0.0002	0.00002	0.00001	0.000001
BT	Data not yet located			
Carbaryl	0.0006	0.00006	0.43	0.043
Chlorothalonil[1]	Data not yet located			
Dalapon	0.1	0.01	34	3.4
Dicamba	0.39	0.039	3.5	0.35
2,4-D amine	0.4	0.04	10	1
2,4-D ester	0.12	0.012	0.1	0.01
2,4-DP ester[2]	0.12	0.012	0.1	0.01
Dienachlor[1]	Data not yet located			
Endosulfan	0.0002	0.00002	0.0001	0.00001
Fosamine	152	15.2	53	5.3
Glyphosate	0.3	0.03	0.24	0.024
Hexazinone	5.6	0.56	32	3.2
Imazapyr	10	1.0	11	1.1
Mancozeb[1]	Data not yet located			
Picloram	0.005	0.0005	0.15	0.015
Propargite[1]	Data not yet located			
Simazine	0.1	0.01	0.28	0.028
Sulfmeturonmethyl	1.2	0.12	1.2	0.12
Triclopyr, amine	114	11.4	11.7	1.17
Triclopyr, ester	0.1[3]	0.01[3]	0.07	0.007

[1] Data not yet located

[2] Values based on 2,4-D because of lack of adequate data base for 2,4-DP, and chemical similarity between 2,4-D and 2,4-DP

[3] Values estimated, based on 200 - 1000 fold higher toxicity of triclopyr ester to fish compared to triclopyr amine

Section 3 Water Quality Standards to Assure Protection of Human Health, Aquatic Organisms and Other Animals.

In forestry operations it is desirable to set water quality standards that trigger a management response at some concentration less than considered virtually safe by regulatory bodies. With that approach, the response to exceedance of standards need not be an immediate health protective action, but rather an examination of the practices leading to the finding to learn if procedures should be changed.

The concentration of pesticides in surface water identified in Tables 1 and 2 are those which if not exceeded will assure protection of human health, aquatic organisms, and other animals. Based on current knowledge, we are confident in these values because the assumptions used in their derivation are conservative and margins of safety are incorporated to provide for uncertainty and for extrapolation of laboratory data to field settings.

In this section we identify (Table 3) the concentration of each pesticide which will protect aquatics (24-hour average exposure), and humans and other animals (10-day exposure). We believe these can be the basis for establishing water quality standards.

As a general philosophy, we believe it is prudent to minimize exposure of aquatic organisms, humans, and other animals. However, there are legitimate and compelling reasons to use pesticides to achieve the objective for which any property is managed. Then we ascribe to minimizing surface water contamination while achieving those management goals.

Table 3. Recommended regulatory and management permissible concentration of selected pesticides in surface water due to forest operations.

Pesticides	Concentration which protects both aquatics and humans[1] (except as noted)	most sensitive group of organisms	Recommended maximum permissible concentration
	---mg/liter---		---mg/liter---
Acephate[3]	0.005	human	0.005
Amitrole	0.05	human	0.05
Asulam[2]	1.0	human	1.0
Atrazine	0.007	aquatic	0.07
Bifenthrin[3]	0.00001	aquatic	0.00001
Carbaryl[3]	0.00006	aquatic	0.00006
Chlorothalonil[2,3]	0.1	human	0.1
Dalapon	0.01	aquatic	0.01
Dicamba	0.04	aquatic	0.04
2,4-D amine	0.04	aquatic	0.04
2,4-D ester	0.01	aquatic	0.01
2,4-DP ester	0.01	aquatic	0.01
Endosulfan[3]	0.00001	aquatic	.00001
Fosamine	2.0	human	2.0
Glyphosate	0.02	aquatic	0.02
Hexazinone	0.56	aquatic	0.56
Imazapyr	1.0	aquatic	1.0
Mancozeb[2,3]	0.07	human	0.07
Picloram	0.0005	aquatic	0.0005
Propargite[2,3]	0.08	human	0.08
Simazine	0.01	aquatic	0.01
Sulfmeturonmethyl	0.1	human	0.1
Triclopyr, amine	0.5	human	0.5
Triclopyr, ester	0.007	aquatic	0.007

[1] Protection for aquatics is based on 24-hour average exposure level and humans on a 10-day exposure except for those noted[3], which are based on a lifetime exposure level.

[2] Data lacking on aquatic organisms.

[3] Human toxicity value based on lifetime exposure to reflect use in forest nurseries.

References

Bureau of Foods. 1981. The FDA Surveillance index for pesticides. U.S. Food and Drug Administration, Washington, D.C. 525 p.

EPA. 1989. Drinking water health advisories - Pesticides. U.S. Environmental Protection Agency. Lewis Publishers, Inc. Chelsea, Michigan. 819 p.

FAO, various dates. Pesticide residues in food: toxicology. A series of reports on specific pesticides. Food and Agriculture Organization, United Nations. Rome.

Mayer, F.L. Jr. and N.R. Ellersieck. 1986. Manual of acute toxicity: Interpretation and data base for 410 chemicals and 66 species of freshwater animals. USDI, Fish and Wildlife Service, Resource Publication 160. Washington, D.C. 579 p.

Norris, L.A., H.W. Lorz and S.V. Gregory. 1983. Forest Chemicals. USDA Forest Service General Technical Report PNW 149. Pacific Northwest Forest and Range Experiment Station, Portland Oregon. 95 p.

National Academy of Sciences. 1973. Water Quality Criteria. 1972. USEPA Ecol. Res. Series EPA-R3-73-033. Washington, D.C. 594 p.

Shipp, A.M., M.L. Hogg, K.S. Crump, and R.L. Kodell. 1986. Worst case analysis study on forest plantation herbicide use. K.S. Crump and Co., Inc., Ruston, LA. Prepared for Forest Land Management Division, Department of Natural Resources, State of Washington. 266 p.

USDA Forest Service. 1984. Pesticide Background Statements. Vol 1. Herbicides. Agriculture Handbook 633. U. S. Dept. Agric., Washington, D. C. 1071 p.

USDA Forest Service. 1986. Pesticide Background Statements. Vol. II. Fungicides and fumigants. Agriculture Handbook 661. U.S. Dept. Agric., Washington, D.C.

USDA Forest Service. 1987. Pesticide Background Statements. Vol. III. Nursery pesticides. Agriculture Handbook 670. U.S. Dept. Agric., Washington, D.C.

USDA Forest Service. 1989. Pesticide Background Statements. Vol. IV. Insecticides. Agriculture Handbook 685. U.S. Dept. Agric., Washington, D.C.

Weeks, J.A. et al. 1988. Risk Assessment for the use of herbicides in the southern region, USDA Forest Service. USDA Forest Service Management Bulletin R8-MB-23. Final Environmental Impact Statement, Volume II.

WHO. 1984. Endosulfan. Environmental Health Criteria 40. World Health Organization. Geneva.