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Sethoxydim [Poast]- Human Health and Ecological Risk Assessment Final Report

Prepared for:

USDA, Forest Service

Forest Health Protection

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ACRONYMS, ABBREVIATIONS, AND SYMBOLS

a.e.	acid equivalents
a.i.	active ingredient
AEL	adverse-effect level
APHIS	Animal and Plant Health Inspection Service
ARS	Agricultural Research Station
ATSDR	Agency for Toxic Substances and Disease Registry
BCF	bioconcentration factor
bw	body weight
cm	centimeter
DG	dispersible granules
EC_{50}	concentration causing 50% inhibition of a process
EC_{100}	concentration causing complete inhibition of a process
EIS	environmental impact statement
F	female
F_1	first filial generation
FH	Forest Health
FQPA	Food Quality Protection Act
FS	Forest Service
g	gram
GC	gas chromatography
GRAS	generally recognized as safe
HQ	hazard quotient
IARC	International Agency for Research on Cancer
IRIS	Integrated Risk Information System
i.p.	intraperitoneal
kg	kilogram
$K_{o/c}$	organic carbon partition coefficient
K_{ow}	octanol-water partition coefficient
K_p	skin permeability coefficient
L	liter
lb	pound
LC_{50}	lethal concentration, 50% mortality
LD_{50}	lethal dose, 50% mortality
LD_{95}	lethal dose, 95% mortality
LOAEL	lowest-observed-adverse-effect level
m	meter
M	male
mg	milligram
mg/kg/day	milligrams of agent per kilogram of body weight per day
mL	milliliter
MSDS	material safety data sheet
MW	molecular weight
NCI	National Cancer Institute
NOAEL	no-observed-adverse-effect level

ACRONYMS, ABBREVIATIONS, AND SYMBOLS (*continued*)

NOEC	no-observed-effect concentration
NOEL	no-observed-effect level
NRC	National Research Council
OPP	Office of Pesticide Programs
ORD	Office of Research and Development
OTS	Office of Toxic Substances
ppm	parts per million
RBC	red blood cells
RfD	reference dose
UF	uncertainty factor
U.S.	United States
U.S. EPA	U.S. Environmental Protection Agency
USDA	United States Department of Agriculture
$>$	greater than
$\geq$	greater than or equal to
$<$	less than
$\leq$	less than or equal to
$=$	equal to
$\simeq$	approximately equal to

COMMON UNIT CONVERSIONS AND ABBREVIATIONS

To convert ...	Into ...	Multiply by ...
acres	hectares (ha)	0.4047
acres	square meters (m^2)	4,047
atmospheres	millimeters of mercury	760
centigrade	Fahrenheit	1.8C°+32
centimeters	inches	0.3937
cubic meters (m^3)	liters (L)	1,000
Fahrenheit	centigrade	0.556F°-17.8
feet per second (ft/sec)	miles/hour (mi/hr)	0.6818
gallons (gal)	liters (L)	3.785
gallons per acre (gal/acre)	liters per hectare (L/ha)	9.34
grams (g)	ounces, (oz)	0.03527
grams (g)	pounds, (oz)	0.002205
hectares (ha)	acres	2.471
hectares (ha)	square meters	10,000
inches (in)	centimeters (cm)	2.540
kilograms (kg)	ounces, (oz)	35.274
kilograms (kg)	pounds, (lb)	2.2046
kilograms per hectare (hg/ha)	pounds per acre (lb/acre)	0.892
kilometers (km)	miles (mi)	0.6214
liters (L)	cubic centimeters (cm^3)	1,000
liters (L)	gallons (gal)	0.2642
liters (L)	ounces, fluid (oz)	33.814
miles (mi)	kilometers (km)	1.609
miles per hour (mi/hr)	cm/sec	44.70
milligrams (mg)	ounces (oz)	0.000035
meters (m)	feet	3.281
ounces (oz)	grams (g)	28.3495
ounces per acre (oz/acre)	grams per hectare (g/ha)	70.1
ounces per acre (oz/acre)	kilograms per hectare (kg/ha)	0.0701
ounces fluid	cubic centimeters (cm^3)	29.5735
pounds (lb)	grams (g)	453.6
pounds (lb)	kilograms (kg)	0.4536
pounds per acre (lb/acre)	kilograms per hectare (kg/ha)	1.121
pounds per acre (lb/acre)	mg/square meter (mg/m^2)	112.1
pounds per acre (lb/acre)	μg/square centimeter ($\mu g/cm^2$)	11.21
pounds per gallon (lb/gal)	grams per liter (g/L)	119.8
square centimeters (cm^2)	square inches (in^2)	0.155
square centimeters (cm^2)	square meters (m^2)	0.0001
square meters (m^2)	square centimeters (cm^2)	10,000
yards	meters	0.9144

Note: All references to pounds and ounces refer to avoirdupois weights unless otherwise specified.

CONVERSION OF SCIENTIFIC NOTATION

Scientific Notation	Decimal Equivalent	Verbal Expression
$1 \cdot 10^{-10}$	0.0000000001	One in ten billion
$1 \cdot 10^{-9}$	0.000000001	One in one billion
$1 \cdot 10^{-8}$	0.00000001	One in one hundred million
$1 \cdot 10^{-7}$	0.0000001	One in ten million
$1 \cdot 10^{-6}$	0.000001	One in one million
$1 \cdot 10^{-5}$	0.00001	One in one hundred thousand
$1 \cdot 10^{-4}$	0.0001	One in ten thousand
$1 \cdot 10^{-3}$	0.001	One in one thousand
$1 \cdot 10^{-2}$	0.01	One in one hundred
$1 \cdot 10^{-1}$	0.1	One in ten
$1 \cdot 10^{0}$	1	One
$1 \cdot 10^{1}$	10	Ten
$1 \cdot 10^{2}$	100	One hundred
$1 \cdot 10^{3}$	1,000	One thousand
$1 \cdot 10^{4}$	10,000	Ten thousand
$1 \cdot 10^{5}$	100,000	One hundred thousand
$1 \cdot 10^{6}$	1,000,000	One million
$1 \cdot 10^{7}$	10,000,000	Ten million
$1 \cdot 10^{8}$	100,000,000	One hundred million
$1 \cdot 10^{9}$	1,000,000,000	One billion
$1 \cdot 10^{10}$	10,000,000,000	Ten billion

EXECUTIVE SUMMARY

INTRODUCTION

This document provides risk assessments for human health effects and ecological effects to support an assessment of the environmental consequences of using sethoxydim in Forest Service programs. The USDA Forest Service uses the herbicide, sethoxydim, in its vegetation management programs. The USDA Forest Service plans on using only one commercial formulation, Poast.

This document has four chapters: the introduction, program description, risk assessment for human health effects, and risk assessment for ecological effects or effects on wildlife species. Each of the two risk assessment chapters has four major sections, including an identification of the hazards associated with sethoxydim, an assessment of potential exposure to this compound, an assessment of the dose-response relationships, and a characterization of the risks associated with plausible levels of exposure.

Almost no risk estimate presented in this document is given as a single number. Instead, risk is expressed as a central estimate and a range, which is sometimes very large. Because of the need to encompass many different types of exposure as well as the need to express the uncertainties in the assessment, this risk assessment involves numerous calculations. Most of the calculations are relatively simple, and the very simple calculations are included in the body of the document. Some of the calculations, however, are cumbersome. For those calculations, a set of worksheets is included as an attachment to the risk assessment. The worksheets provide the detail for the estimates cited in the body of the document. two versions of the worksheets are available: one in a word processing format and one in a spreadsheet format. The worksheets that are in the spreadsheet format are used only as a check of the worksheets that are in the word processing format. Both sets of worksheets are provided with the hard-text copy of this risk assessment as well as with the electronic version of the risk assessment. Documentation for the use of these worksheets is provided in a separate document that also accompanies this risk assessment.

PROGRAM DESCRIPTION

Poast is a commercial formulation of sethoxydim, available from BASF, that is used by the USDA Forest Service. Sethoxydim is recommended as selective postemergence herbicides for the control of annual or perennial grass weeds. Poast is labeled for application to a number of different crops. Poast Plus is labeled for application to alfalfa, citrus, clover, corn, cotton, peanuts, and soybeans as well as for deciduous trees, non-food crop areas, and fallow lands. The Forest Service will used Poast only in non-crop areas and the only use contemplated by the Forest Service and considered in this risk assessment involves the control of unwanted vegetation in nurseries.

The most common method of application for sethoxydim in Forest Service programs will involve broadcast foliar applications. Although Poast is registered for aerial applications, this application method will not be used in Forest Service programs. The labeled application rates for Poast range from 0.09375 lb sethoxydim/acre to 0.375 lb sethoxydim/acre. For simplicity, all application rates cited in this risk assessment are referenced simply as lb/acre rather than lb a.i./acre or lb a.e./acre. Unless otherwise specified, all such designations refer to lb a.i./acre or lb sethoxydim/acre. For this risk assessment, the lower and upper limits of the application rate are taken as 0.09375 lb/acre to 0.375 lb/acre, respectively, based on the lower and upper limits of the labeled rates. Based on the most recent use statistics from the Forest Service, the central estimate of the application rate is taken as 0.3 lbs/acre.

Poast as well as many of the other commercial formulations of sethoxydim are used extensively in agriculture. Based on the most recent use statistics encountered in the literature, over 1,000,000 lbs of sethoxydim are applied to crops annually, primarily to soybeans and cotton in the mid-west. By comparison, the uses of sethoxydim by the Forest Service are trivial - i.e., a total of 3.8 lbs in 1999.

HUMAN HEALTH RISK ASSESSMENT

Hazard Identification – Reported gavage LD_{50} values for sethoxydim range from about 3000 to 6000 mg/kg in rats and 5600 to 6500 mg/kg in mice. The oral LD_{50} in dogs is 2500-5000 mg/kg but the method of administration involved capsules rather gavage exposures and thus the results cannot be directly compared to those in rats and mice. The acute oral LD_{50} of the formulated product, Poast, is comparable to that of sethoxydim – i.e., 4390 to 5000 mg Poast/kg. For both sethoxydim and Poast, the primary signs of acute poisoning in mice, rats, and dogs are consistent with neurological effects: lacrimation, salivation, incontinence, ataxia, tremors, and convulsions.

The available data on sethoxydim are sufficient to define NOAELs for systemic toxic effects from both acute and chronic exposures. Sethoxydim has been tested for and does not appear to cause carcinogenicity, birth defects, or other reproductive effects.

Poast contains a substantial amount of petroleum solvent (74%) that includes naphthalene (7% of the solvent). The primary effect of naphthalene and petroleum solvents involves CNS depression and other signs of neurotoxicity that are similar to the effects seen in animals exposed to Poast as well as sethoxydim. While sethoxydim is rapidly degraded in the environment, some of the degradation products are much more persistent and this pattern is quantitatively considered in the risk assessment.

Based on standard studies required for pesticide registration, Poast may cause skin and eye irritation. Concentrations of sethoxydim in the air that would be much higher than any plausible concentrations in human exposure scenarios have been associated with lung congestion in rats. The potential inhalation toxicity of sethoxydim is not of substantial concern to this risk assessment because of the implausibility of inhalation exposure involving high concentrations of this compound.

Exposure Assessment – There are no occupational exposure studies in the available literature that are associated with the application of sethoxydim. Consequently, worker exposure rates are estimated from an empirical relationship between absorbed dose per kilogram of body weight and the amount of chemical handled in worker exposure studies on nine different pesticides. Separate exposure assessments are given for broadcast ground spray (low boom spray) and backpack applications.

For both types of applications, central estimates of worker exposure are similar: about 0.007 mg/kg/day for broadcast ground spray and 0.004 mg/kg/day for backpack applications. The upper limits of the exposure estimates are about 0.06 mg/kg/day for broadcast ground spray and 0.03 mg/kg/day for backpack applications.

Except in the case of accidental exposures, the levels of sethoxydim to which the general public might be exposed should be far less than the levels for workers. Longer-term exposure scenarios for the general public lead to central estimates of daily doses in the range of about 0.0000002 to 0.0002 mg/kg/day with upper limits of exposure in the range of 0.000007 to 0.003 mg/kg/day. While these exposure scenarios are intended to be conservative, they are nonetheless plausible. Accidental exposure scenarios result in central estimates of exposure of up to 0.2 mg/kg/day and upper ranges of exposure up to 0.77 mg/kg/day. All of the accidental exposure scenarios involve relatively brief periods of exposure, and most should be regarded as extreme.

Dose-Response Assessment – The Office of Pesticide Programs of the U.S. EPA has derived both an acute and chronic RfD for sethoxydim. The chronic RfD of 0.09 mg/kg/day based on a NOAEL of 9 mg/kg/day for a 1-year feed study in dogs and an uncertainty factor of 100. This uncertainty factor includes 10 for extrapolating from animals to humans and 10 for extrapolating to sensitive individuals within the human population. The acute RfD is 0.6 mg/kg/day based on a NOAEL in rabbits of 180 mg/kg/day and an uncertainty factor of 300. The uncertainty factor for the acute RfD includes the same two components as the uncertainty factor for the chronic RfD as well as an FQPA (Food Quality Protection Act) uncertainty factor of 3 for the possible increased sensitivity of children to sethoxydim.

Risk Characterization – None of the exposure scenarios for workers result in levels that exceed the RfD. For members of the general public, none of the longer term exposure scenarios exceed the chronic RfD and the only acute exposure scenario that exceeds the acute RfD involves an accidental spill into a small pond.

Based on central estimates of longer term exposure for workers and the general public, the levels of exposure will be below the RfD by factors of about 25 (backpack workers) to about 50,000 (contaminated fish for members of the general public). Even for accidental exposures, the upper limits of the exposure estimates are below the RfD by factors of about 10 to over 100 except for the consumption of contaminated water by a child after an accidental spill. As detailed in the exposure assessment, the accidental spill scenario should be regarded as extreme. Nonetheless, this assessment does suggest that measures should be taken to limit exposure in the event of a large spill. Such measures would be routinely taken by the Forest Service after any spill into ambient water.

Thus, sethoxydim does not seem likely to pose any substantial risk to human health. This conclusion is consistent with the recent evaluation of sethoxydim by the U.S. EPA/OPP (1998a) in which margins of exposure were calculated to be over 100 for acute exposure and over 1000 for chronic exposure.

The only reservation associated with this assessment of sethoxydim is the same reservation associated with any risk assessment in which no plausible hazards can be identified: ***Absolute safety cannot be proven and the absence of risk can never be demonstrated***. No chemical, including sethoxydim, is studied for all possible effects. Furthermore, using data from laboratory animals to estimate hazard or the lack of hazard to humans is an uncertain process. Prudence dictates that normal and reasonable care should be taken in the handling of this or any other chemical. Notwithstanding these reservations, the use of sethoxydim in Forest Service programs does not pose any identifiable hazard to workers or members of the general public.

Although the U.S. EPA does not classify sethoxydim as an irritant to the skin and eyes, other reports not addressed by U.S. EPA suggest that skin and eye irritation can result from exposure to relatively high levels of Poast. From a practical perspective, eye or skin irritation is likely to be the only overt effect as a consequence of mishandling sethoxydim. These effects can be minimized or avoided by prudent industrial hygiene practices during the handling of the compound.

ECOLOGICAL RISK ASSESSMENT

Hazard Identification – Data used in the human health risk assessment to identify the toxicity of sethoxydim and Poast to humans can also be used to identify potential toxic effects in wildlife mammalian species. In mammals, the major effects of sethoxydim as well as Poast appear to be related to neurologic effects and the major signs of toxicity in mammals include lacrimation, salivation, incontinence, ataxia, tremors, and convulsions. Based on studies in mice, rats, and dogs, larger mammals appear to be more sensitive than smaller mammals. Because relatively few studies are available to support this apparent relationship, quantitative estimates of inter-species differences in sensitivity are not developed. Instead, the assumption is made that wildlife species may be as sensitive to sethoxydim as the most sensitive species on which data are available - i.e., the dog. Based on acute toxicity studies, sethoxydim and Poast appear to be about equally toxic to mammals.

The U.S. EPA/OPP (1998a) classified sethoxydim as practically non-toxic to birds and this assessment is supported by standard toxicity studies on sethoxydim in ducks and quail. No acute toxicity studies on the formulated product – i.e., Poast – are available and the U.S. EPA has indicated that such studies will need to be conducted.

Relatively little information is available of the toxicity of sethoxydim to terrestrial invertebrates. A standard acute toxicity study in bees indicates that direct applications of 10 μg sethoxydim/bee are not toxic and this value is used quantitatively in the risk assessment as a NOAEL. There is a published study on effects in beetle larvae that suggests that Poast is relatively non-toxic at application rates higher than those planned by the Forest Service.

Standard pre-emergence and post-emergence toxicity studies have been conducted on a number of terrestrial plant species and these studies are adequate for assessing the potential damage to non-target plant species posed by runoff or drift.

Unlike the case with mammals, Poast is much more toxic to aquatic species than sethoxydim. Poast contains 74% petroleum solvent and only 18 % sethoxydim. While somewhat speculative, it appears that the acute toxicity of Poast to aquatic species may be attributable almost exclusively to the solvent rather than to sethoxydim.

Exposure Assessment – Terrestrial animals might be exposed to any applied herbicide from direct spray, the ingestion of contaminated media (vegetation, prey species, or water), grooming activities, or indirect contact with contaminated vegetation. In acute exposure scenarios and under the assumption of 100% dermal absorption, the highest exposures for small terrestrial vertebrates will occur after a direct spray and could reach up to about 7 mg/kg under typical exposure conditions and up to about 9 mg/kg under more extreme conditions. Other routes of exposure, like the consumption of contaminated water or contaminated vegetation, generally will lead to much lower levels of exposure. In chronic exposure scenarios, the maximum estimated daily doses for a small vertebrate is 0.006 mg/kg/day. Based on general relationships of body size to body volume, larger vertebrates will be exposed to lower doses and smaller animals, like insects, will be exposed to much higher doses under comparable exposure conditions. Because of the apparent low toxicity of sethoxydim to animals, the rather substantial variations in the exposure assessments have little impact on the assessment of risk to terrestrial animals.

The primary hazards to non-target terrestrial plants are associated with unintended direct deposition or spray drift. Unintended direct spray will result in an exposure level equivalent to the application rate. At least some plants that are sprayed directly with sethoxydim at or near the recommended range of application rates will be damaged. Based on the AgDRIFT model, no more than 0.0058 of the application rate would be expected to drift 100 m offsite after low boom ground applications. The AgDrift model is discussed further in Section 4.2.3.2.

In order to encompass a wide range of field conditions, GLEAMS simulations were conducted for clay, loam, and sand at annual rainfall rates from 5 to 250 inches. Under arid conditions (i.e., annual rainfall of about 10 inches or less), there is no or very little runoff. Under these conditions, degradation, not dispersion, accounts for the decrease of sethoxydim concentrations in soil. At higher rainfall rates, plausible offsite movement of sethoxydim results in runoff losses that range from about negligible up to about 0.5 of the application rate, depending primarily on the amount of rainfall rather than differences in soil type.

Exposures to aquatic species are impacted by the same factors that influence terrestrial plants except the directions of the impact are reversed. In other words, in very arid environments substantial contamination of water is unlikely. In areas with increasing levels of rainfall, exposures to aquatic organisms are more likely to occur. The anticipated concentrations in ambient water encompass a very broad range, 0.000094 to 0.003 mg/L, depending primarily on differences in rainfall rates.

Dose-Response Assessment – A summary of all toxicity values used in this risk assessment is given in Table 4-2. For terrestrial mammals, the dose-response assessment is based on the same data as the human health risk assessment (i.e., an estimated chronic NOAEL of 9 mg/kg/day and an acute NOAEL of 180 mg/kg/day. For birds, a chronic NOAEL of 10 mg/kg bw/day is used from a subchronic feeding study that assayed for both signs of systemic toxicity as well as reproductive capacity. The potential effects of acute exposures of birds are characterized using an acute NOAEL of 500 mg/kg/day. For terrestrial invertebrates, the dose-response assessment is based on a study in honey bees in which a dose of 107 mg/kg bw caused no apparent adverse effects.

Sethoxydim is a herbicide that causes adverse effects in a variety of target and non-target plant species. In general, grasses are much more sensitive to sethoxydim than broad-leaved plants. For exposures associated with direct sprays or drift, NOAELs for sensitive and tolerant species are 0.006 lbs/acre and 0.03 lbs/acre, respectively. With respect to soil contamination, the NOAEL for sensitive species is 0.059 lbs/acre and the NOAEL for tolerant species is 0.235 lbs/acre.

Sethoxydim has a low order of acute toxicity to fish and aquatic invertebrates, with LC_{50} values of 1.2 and 2.6 mg/L, respectively. Aquatic macrophytes are much more sensitive to sethoxydim than fish or invertebrates. For aquatic plants, a NOAEL of 0.25 mg/L is used to assess the consequences of sethoxydim exposure.

Risk Characterization – None of the hazard quotients for mammals or birds approach a level of concern, even at the upper limit of exposure. For sethoxydim, further refinement of the exposure assessment would have little impact on the risk characterization because the hazard quotients are below a level of concern by factors of at least 10 for acute exposure scenarios (a large mammal consuming vegetation) and about 7 for chronic exposure scenarios (a large bird consuming vegetation at the application site). The more plausible scenarios involving off-site exposures have hazard quotients below a level of concern by factors of about 385 (large bird) to 50,000 (small mammal). The simple verbal interpretation of this quantitative risk characterization for terrestrial animals is similar to that of the human health risk assessment: the weight of evidence suggests that no adverse effects in terrestrial animals are plausible using typical or even very conservative worst case exposure assumptions.

For terrestrial plants, runoff may present a risk to some sensitive species. The extent to which this effect might be observed in the field is likely to depend on a number of site specific conditions, particularly how the runoff is distributed in areas adjacent to the application site. For sensitive species in areas with high rates of rainfall, the hazard quotients are slightly above unity - e.g., the highest hazard quotient is about 3. In arid environments - i.e., annual rainfall rates of about 15 inches per year or less - very little runoff of sethoxydim would occur and risks to any nontarget plant species would be minimal and below the level of concern. Drift, including dispersion of contaminated soil by wind, does not appear to present a major hazard to nontarget plant species. Hazard quotients for offsite drift indicate that sethoxydim is not likely to result in damage at distances as close as 25 feet from the application site. For sensitive species, the hazard quotient exceeds unity at 25 feet but not at 50 feet.

There is no indication that fish, aquatic invertebrates, or aquatic plants are likely to be exposed to concentrations of sethoxydim that will result in toxic effects, although the upper range of the hazard quotient for aquatic plants – i.e., 0.75) approaches a level of concern. A major limitation of this risk characterization for aquatic animals is the lack of any chronic toxicity studies on fish or aquatic invertebrates.

1. INTRODUCTION

This document provides risk assessments for human health effects and ecological effects to support an assessment of the environmental consequences of using sethoxydim in Forest Service programs. The USDA Forest Service uses the herbicide, sethoxydim, in its vegetation management programs. The USDA Forest Service plans on using only one commercial formulation, Poast.

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This is a technical support document and it addresses some specialized technical areas. Nevertheless an effort was made to ensure that the document can be understood by individuals who do not have specialized training in the chemical and biological sciences. Certain technical concepts, methods, and terms common to all parts of the risk assessment are described in plain language in a separate document (SERA 2000). Some of the more complicated terms and concepts are defined, as necessary, in the text.

In the preparation of this risk assessment, literature searches of Poast and sethoxydim were conducted in the open literature using AGRICOLA and TOXLINE as well as the U.S. EPA CBI files. In addition to these standard literature searches, additional sources of information were used including U.S. EPA/OPP (1998a) pesticide tolerances for sethoxydim, the U.S. EPA ecological risk assessment on sethoxydim (Bryceland et al. 1997), the IRIS entry for this compound (U.S. EPA/IRIS 1989), as well as the EXTOXNET review of this compound (Extoxnet 2000). The Forest Service funded a review of this compound - i.e., a chemical background statement - in 1989 (Sczerzenie et al. 1989) and this review was also consulted.

The search of U.S. EPA's FIFRA/CBI files indicated that there is a complete set of standard studies conducted for this compound - i.e., a total of 184 submissions. While many of these studies were conducted to support the initial registration of sethoxydim, a substantial number of studies were conducted and submitted to EPA after 1989, the date of the last Forest Service review of sethoxydim. Full text copies of the most relevant CBI studies [n=93] were kindly provided by the U.S. EPA Office of Pesticide Programs. The studies were reviewed, and synopses of the most relevant studies are included in the appendices to this document. In several areas of concern, the U.S. EPA review by Bryceland et al. (1997) discusses studies that were apparently submitted to U.S. EPA but studies that did not appear in the searches of the CBI files. When the data described by Bryceland et al. (1997) results in more conservative dose-response assessments, the summaries from Bryceland et al. (1997) are used. In most cases, this did not have a substantial impact on the risk assessment. Specific examples are discussed in various sections of this risk assessment as appropriate.

The human health and ecological risk assessments presented in this document are not, and are not intended to be, comprehensive summaries of all of the available information. The information presented in the appendices and the discussions in chapters 2, 3, and 4 of the risk assessment are intended to be detailed enough to support a review of the risk analyses; however, they are not intended to be as detailed as the information generally presented in Chemical Background documents or other comprehensive reviews.

For the most part, the risk assessment methods used in this document are similar to those used in risk assessments previously conducted for the Forest Service as well as risk assessments conducted by other government agencies. Details regarding the specific methods used to prepare the human health risk assessment are provided in SERA (2000).

Risk assessments are usually expressed with numbers; however, the numbers are far from exact. *Variability* and *uncertainty* may be dominant factors in any risk assessment, and these factors should be expressed. Within the context of a risk assessment, the terms *variability* and *uncertainty* signify different conditions.

Variability reflects the knowledge of how things may change. Variability may take several forms. For this risk assessment, three types of variability are distinguished: *statistical*, *situational*, and *arbitrary*. *Statistical variability* reflects, at least, apparently random patterns in data. For example, various types of estimates used in this risk assessment involve relationships of certain physical properties to certain biological properties. In such cases, best or maximum likelihood estimates can be calculated as well as upper and lower confidence intervals that reflect the statistical variability in the relationships. *Situational variability* describes variations depending on known circumstances. For example, the application rate or the applied concentration of a herbicide will vary according to local conditions and goals. As discussed in the following section, the limits on this variability are known and there is some information to indicate what the variations are. In other words, *situational variability* is not random. *Arbitrary variability*, as the name implies, represents an attempt to describe changes that cannot be characterized statistically or by a given set of conditions that cannot be well defined. This type of variability dominates some spill scenarios involving either a spill of a chemical on to the surface of the skin or a spill of a chemical into water. In either case, exposure depends on the amount of chemical spilled and the area of skin or volume of water that is contaminated.

Variability reflects a knowledge or at least an explicit assumption about how things may change, while *uncertainty* reflects a lack of knowledge. For example, the focus of the human health dose-response assessment is an estimation of an “acceptable” or “no adverse effect” dose that will not be associated with adverse human health effects. For sethoxydim and for most other chemicals, however, this estimation regarding human health must be based on data from experimental animal studies, which cover only a limited number of effects. Generally, judgment is the basis for the methods used to make the assessment. Although the judgments may reflect a consensus (i.e., be used by many groups in a reasonably consistent manner), the resulting estimations of risk cannot be proven analytically. In other words, the estimates regarding risk involve uncertainty. The primary functional distinction between variability and uncertainty is that variability is expressed quantitatively, while uncertainty is generally expressed qualitatively.

In considering different forms of variability, almost no risk estimate presented in this document is given as a single number. Usually, risk is expressed as a central estimate and a range, which is sometimes very large. Because of the need to encompass many different types of exposure as well as the need to express the uncertainties in the assessment, this risk assessment involves numerous calculations.

Most of the calculations are relatively simple, and the very simple calculations are included in the body of the document. Some of the calculations, however, are cumbersome. For those calculations, a set of worksheets is included as an attachment to the risk assessment. The worksheets provide the detail for the estimates cited in the body of the document. The worksheets are divided into the following sections: general data and assumptions, chemical specific data and assumptions, exposure assessments for workers, exposure assessments for the general public, and exposure assessments for effects on nontarget organisms. The worksheets are included at the end of this risk assessment and further documentation for these worksheets are included as Attachment 1. As detailed in Attachment 1, two versions of the worksheets are available: one in a word processing format and one in a spreadsheet format. The worksheets that are in the spreadsheet format are used only as a check of the worksheets that are in the word processing format. Both sets of worksheets are provided with the hard-text copy of this risk assessment as well as with the electronic version of the risk assessment. Documentation for the use of these worksheets is provided in a separate document that also accompanies this risk assessment (SERA 2001).

2. PROGRAM DESCRIPTION

2.1. OVERVIEW

Poast is a commercial formulation of sethoxydim, available from BASF, that is used by the USDA Forest Service. Sethoxydim is recommended as selective postemergence herbicides for the control of annual or perennial grass weeds. Poast is labeled for application to a number of different crops. Poast Plus is labeled for application to alfalfa, citrus, clover, corn, cotton, peanuts, and soybeans as well as for deciduous trees, non-food crop areas, and fallow lands. The Forest Service will used Poast only in non-crop areas and the only use contemplated by the Forest Service and considered in this risk assessment involves the control of unwanted vegetation in nurseries.

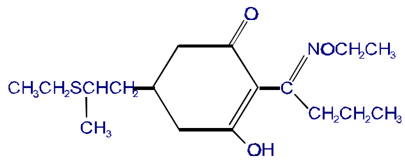
Poast contains a petroleum solvent (74%) that includes naphthalene (7% of the solvent). The potential impact of these inert components on this risk assessment is discussed further in Sections 3.1.9 (human health) and 4.1.3 (ecological effects).

The most common method of application for sethoxydim in Forest Service programs will involve broadcast foliar applications. Although Poast is registered for aerial applications, this application method will not be used in Forest Service programs. The labeled application rates for Poast range from 0.09375 lb sethoxydim/acre to 0.375 lb sethoxydim/acre. For simplicity, all application rates cited in this risk assessment are referenced simply as lb/acre rather than lb a.i./acre or lb a.e./acre. Unless otherwise specified, all such designations refer to lb a.i./acre or lb sethoxydim/acre. For this risk assessment, the lower and upper limits of the application rate are taken as 0.09375 lb/acre to 0.375 lb/acre, respectively, based on the lower and upper limits of the labeled rates. Based on the most recent use statistics from the Forest Service, the central estimate of the application rate is taken as 0.3 lbs/acre.

Poast as well as many of the other commercial formulations of sethoxydim are used extensively in agriculture. Based on the most recent use statistics encountered in the literature, over 1,000,000 lbs of sethoxydim are applied to crops annually, primarily to soybeans and cotton in the mid-west. By comparison, the uses of sethoxydim by the Forest Service are trivial - i.e., a total of 3.8 lbs in 1999.

2.2. CHEMICAL DESCRIPTION AND COMMERCIAL FORMULATIONS

Sethoxydim is the common name for 2-(1-(ethoxyimino)butyl)-5-(2-(ethylthio)propyl)-3-hydroxy-2-cyclohexen-1-one. The chemical structure of sethoxydim (Cambridge Software 2001) is:



Selected chemical and physical properties of sethoxydim are summarized in Table 2-1. Additional information is presented in worksheet B03.

Several commercial formulations of sethoxydim are available (Table 2-2). Only one commercial formulation of sethoxydim, Poast, is used in Forest Service programs. This formulation is produced by BASF and contains sethoxydim as the only active ingredient. Poast is a liquid formulation containing sethoxydim (18%) at a concentration of 1.5 lbs per gallon and inerts (82%). Poast is recommended as a selective postemergence herbicide for the control of annual or perennial grass weeds. Poast is labeled for application to a number of different crops. A very similar formulation used in agriculture, Poast Plus, is labeled for application to alfalfa, citrus, clover, corn, cotton, peanuts, and soybeans as well as for deciduous trees, non-food crop areas, and fallow lands (BASF 2000). The Forest Service will use Poast only in non-crop areas and the only use contemplated by the Forest Service and considered in this risk assessment involves the control of unwanted vegetation in nurseries.

The identity of the inerts has been disclosed to the U.S. EPA as part of the registration process. Inerts are classified by the U.S. EPA as ranging from inerts of toxicologic concern (List 1) to inerts of minimal concern (List 4) (U.S. EPA/OPP 1998b). Some inerts - i.e., those listed under SARA Title III, Section 313 - are specified on the product material safety data sheets (BASF 2000) and can be publicly disclosed.

Poast contains a petroleum solvent (74%) that includes naphthalene (7% of the solvent). Based on the CAS Number given on the MSDS [64742-94-5], the specific petroleum solvent is specified by the U.S. EPA as “solvent naphtha (petroleum) heavy aromatic” and is classified by the U.S. EPA as List II: Potentially Toxic with a high priority for testing (U.S. EPA/OPP 1998b). Poast also contains a non-ionic emulsifier [CAS No. 9016-45-9], polyoxyethylene nonylphenol, that is classified by the U.S. EPA as List 4B, Inerts of Minimal Concern. The potential impact of these inert components on this risk assessment is discussed further in the human health (Section 3.1.9.) and ecological (Section 4.1.3.) risk assessments.

2.3. APPLICATION METHODS

Sethoxydim may be applied by directed foliar, broadcast foliar, or aerial methods. The most common method of application for sethoxydim in Forest Service programs will involve broadcast foliar applications. Broadcast foliar ground applications will most often involve the use of a two to six nozzle boom mounted on a tractor or other heavy duty vehicle. With this equipment, workers will typically treat 11 to 21 acres per hour, with the low end of this range representative of a four-wheel drive vehicle in tall grass and the upper end of the range representative of a large bulldozer (USDA 1989b p 2-9 to 2-10).

In selective foliar applications, the herbicide sprayer or container is carried by backpack and the herbicide is applied to selected target vegetation. Application crews may treat up to shoulder high brush, which means that chemical contact with the arms, hands, or face is plausible. To reduce the likelihood of significant exposure, application crews are directed not to walk through treated vegetation. Usually, a worker treats approximately 0.5 acre/hour with a plausible range of 0.25-1.0 acre/hour.

Poast is registered for aerial applications (BASF 2000). In Forest Service programs, this application method will not be used and is not further considered in this risk assessment.

2.4. MIXING AND APPLICATION RATES

The labeled application rates for Poast range from 0.09375 lb sethoxydim/acre to 0.375 lb sethoxydim/acre (Table 2-3). For simplicity, all application rates cited in this risk assessment are referenced simply as lb/acre rather than lb a.i./acre or lb a.e./acre. Unless otherwise specified, all such designations refer to lb a.i./acre or lb sethoxydim/acre.

While multiple applications of Poast may be made to various food crops, the product label for Poast does not include multiple applications to deciduous trees, non-food crops, and fallow land - i.e., the areas that would be treated in Forest Service programs.

For this risk assessment, the lower and upper limits of the application rate are 0.09375 lb/acre to 0.375 lb/acre, respectively, based on the lower and upper limits of the labeled rates. In 1999, the most recent year for which statistics are available, the Forest Service used a total of 3.8 lbs of sethoxydim on 13 acres for an average application rate of about 0.3 lbs/acre (USDA/FS/FH 2000). This will be taken as the typical application rate for this risk assessment.

Mixing volumes for sethoxydim vary only modestly depending on the type of vegetation to be treated as well as the application method. For ground applications of Poast, 5 to 20 gallons of water per acre are recommended but not less than 10 gallons per acre in the western and southwestern United States (BASF 2000).

For this risk assessment, the extent to which a formulation of sethoxydim is diluted prior to application primarily influences dermal and direct spray scenarios, both of which are dependent on ‘field dilution’(i.e., the concentration of sethoxydim in the applied spray). In all cases, the higher the concentration of sethoxydim - equivalent to the lower dilution of sethoxydim - the greater the risk. For this risk assessment, the lowest dilution is taken as 5 gallons/acre, the minimum recommended for ground applications. The highest dilution is based on 20 gallons of water per acre, the highest application volume specifically recommended for ground applications. A typical dilution rate is taken as 10 gallons/acre, the minimum volume recommended in the west and southwest regions of the United States. Details regarding the calculation of field dilution rates are given in worksheet B01.

In addition to dilution rates, the area that the Forest Service might treat has a major impact on the estimates of concentrations of sethoxydim that could occur in ambient water. Given the projected and limited use of Poast by the Forest Service, this risk assessment models a 10 acre square plot rather than a right-of-way.

2.5. USE STATISTICS

Poast as well as many of the other commercial formulations of sethoxydim are used extensively in agriculture. A summary of the agricultural use of sethoxydim is presented in Figure 2-1 (USGS 1992). As indicated in this table, over 1,000,000 lbs of sethoxydim are applied to crops annually, primarily to soybeans and cotton in the mid-west. By comparison, the uses of sethoxydim by the Forest Service are trivial - i.e., a total of 3.8 lbs in 1999 (USDA/FS/FHP 2000).

Table 2-1. Selected physical and chemical properties of sethoxydim

Synonyms and trade names	Aljaden, Alloxol S, BAS 9052H, BAS 9052 06H, BAS 562 05H, Checkmate, Expand, Fervinal, Grasidim, Nabu, NP-55, Poast, Tritex-Extra, and Vantage (BASF 2000, Extoxnet 2000)
U.S. EPA Reg. No.	7969-58
CAS number	74051-80-2 (BASF 2000)
Molecular weight	327.50 (BASF 2000)
Specific Gravity	0.935 g/mL (BASF 2000); 1.043 @ 25°C (technical) (WSSA 1989)
Appearance, ambient	amber-colored, oily, odorless liquid (Kidd and James 1991)
Odor	aromatic (BASF 2000)
Vapor pressure	<0.1 mPa @ 20°C (EXTOXNET 2000); 2 mmHg @ 20° (BASF 2000); 1.67×10^{-7} mm Hg @ 25°C (USDA/SCS 1990; WSSA 1989); 4.55×10^{-10} mm Hg @ 25°C (estimated) (SRC 2001). 0.02 mPa (USDA/ARS 1995).
pKa	5.0 (Brudenell et al. 1995)
Water solubility (mg/L)	25 mg/L @ pH 4 and 20°C (experimental) (SRC 2001); 4700 mg/L @ pH 7 and 20°C (Extoxnet 2000); forms an emulsion (BASF 2000), 4700 mg/L @ pH 7 and 25°C, 4390 mg/L @ pH 7 and 20°C (USDA/ARS 1995); 4390 mg/L (Knisel et al. 1992)
log K_{ow}	1.65 [reported as K_{ow} = 45.1] (Bryceland et al. 1997) 4.38 (experimental) (SRC 2001) (probably at low pH) 3.99 (estimated) (SRC 2001) (undissociated) 1.32-1.43 [reported as K_{ow} = 21-27] (Sczerzenie et al. 1989)
Henry's law constant	1.47×10^{-11} atm-m^3/mol (Bryceland et al. 1997) 1.39×10^{-6} Pa-m^3/mol (USDA/ARS 1995)
Soil sorption, K_{oc}	50 (BCPC 1983) 100 (Knisel et al. 1992)
Soil mobility, K_{ads} (mL/g)	0.03-0.94 (Bryceland et al. 1997) 0.02-0.84 (Soeda and Shiotani 1988d)
Field dissipation half-time (days)	1 to 10 (USDA/ARS 1995)
Foliar half-time (days)	3 (Knisel et al. 1992)
Soil half-time (days)	1-3 (aerobic) (USDA/ARS 1995) 5 (Knisel et al. 1992) biphasic and highly variable in field (Koskinen et al. 1994, see Section 3.2.3). <1 (aerobic) (Bryceland et al. 1997) >60 (anaerobic) (Bryceland et al. 1997) 0.7 to 0.9 (aerobic, sandy loam and sandy clay loam)(Shiotani 1989)
Anaerobic sediment (aqueous) half-time (days)	1-3 (USDA/ARS 1995) 0.7-1 (Shiotani 1990a) 39.9 (Bryceland et al. 1997) 25-40 (Soeda and Shiotani 1989)
Water half-time (hydrolysis) (days)	2.8 (25°C, pH 3) (USDA/ARS 1995) 46.2 (25°C, pH 6) (USDA/ARS 1995) 439 (25°C, pH 9) (USDA/ARS 1995) 0.7-1 (Bryceland et al. 1997) 8.8 (25°C, pH 5) (Soeda and Shiotani 1988a) 155.2 (25°C, pH 7) (Soeda and Shiotani 1988a) 283.7 (25°C, pH 8.6) (Soeda and Shiotani 1988a)
Photolysis halftime (days)	43.3 (aqueous) (USDA/ARS 1995) 5.23 (aqueous) (Bryceland et al. 1997) 5.53 (aqueous) (25°C, pH 8.7) (Soeda and Shiotani 1988b) 0.16 (soil) (3.8 hrs, 25°C) (Soeda and Shiotani 1988c)

Table 2-2: Commercial liquid formulations of sethoxydim[a] (C&P Press 1999)

Commercial Name	Supplier	Active Ingredients	Inerts
Conclude G	BASF Corporation	sethoxydim (1.5 lbs/gal)	petroleum solvent (57%) with naphthalene (7%); other inerts (25%)
Conclude Xact	BASF Corporation	bentzon, sodium salt (2.67 lbs/gal); acifluorfen, sodium salt (1.33 lbs/gal); sethoxydim (2.0 lbs/gal)	inerts (65.1%)
Manifest G	BASF Corporation	sethoxydim (1.5 lbs/gal)	petroleum solvent (74%) with napthalene (7%); non-ionic emulsifier (7%); impurities (1%)
Poast	BASF Corporation	sethoxydim (1.5 lbs/gal)	petroleum solvent (74%) with napthalene (7%); non-ionic emulsifier (7%); other inerts (1%)
Poast Plus	BASF Corporation	sethoxydim (1.0 lbs/gal)	napthalene (1.3%); other inerts (85.7%)
Rezult G	BASF Corporation	sethoxydim (1.0 lbs/gal)	napthalene (1.3%); other inerts (85.7%)
Torpedo	BASF Corporation	sethoxydim (1.0 lbs/gal)	napthalene (1.3%); other inerts (85.7%)
Vantage	TopPro	sethoxydim (1.0 lbs/gal)	napthalene (1.3%); other inerts (85.7%)

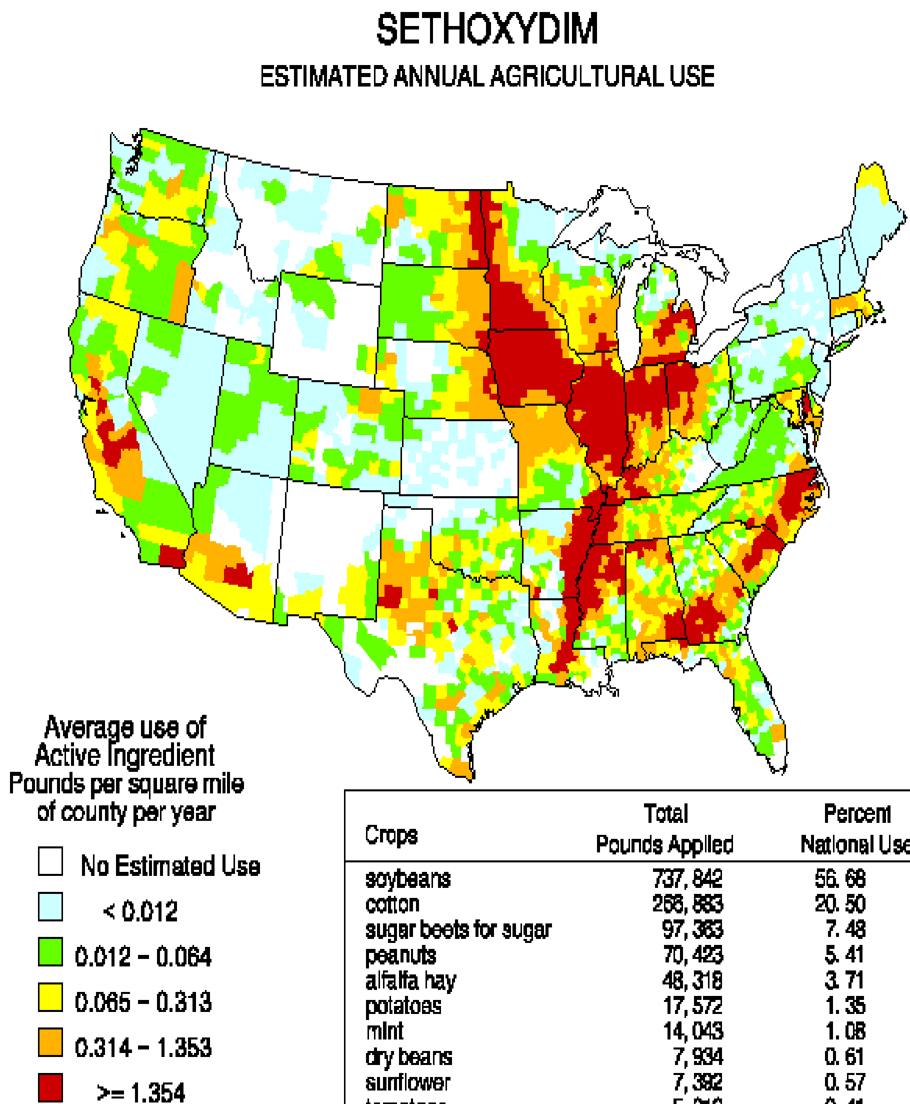
Table 2-3: Labeled Application Rates for Poast.

Poast 1.5 lbs a.i./gallon

	Pints Poast /acre[1]	Gallons Poast/acre	lbs a.i./acre
Typical	1	0.125	0.1875
Minimum	0.5	0.0625	0.09375
Maximum	2	0.25	0.375

Conversions:
8 pints/gallon

[1] Values from BASF (2000)



Crops	Total Pounds Applied	Percent National Use
soybeans	737,842	56.68
cotton	266,883	20.50
sugar beets for sugar	97,363	7.48
peanuts	70,423	5.41
alfalfa hay	48,318	3.71
potatoes	17,572	1.35
mint	14,043	1.08
dry beans	7,934	0.61
sunflower	7,392	0.57
tomatoes	5,313	0.41

Figure 2-1: Statistics on the agricultural uses of sethoxydim (USGS 1992).

3. HUMAN HEALTH RISK ASSESSMENT

3.1. HAZARD IDENTIFICATION

3.1.1. Overview. Reported gavage LD_{50} values for sethoxydim range from about 3000 to 6000 mg/kg in rats and 5600 to 6500 mg/kg in mice. The oral LD_{50} in dogs is 2500-5000 mg/kg but the method of administration involved capsules rather gavage exposures and thus the results cannot be directly compared to those in rats and mice. The acute oral LD_{50} of the formulated product, Poast, is comparable to that of sethoxydim – i.e., 4390 to 5000 mg Poast/kg. For both sethoxydim and Poast, the primary signs of acute poisoning in mice, rats, and dogs are consistent with neurological effects: lacrimation, salivation, incontinence, ataxia, tremors, and convulsions.

The available data on sethoxydim are sufficient to define NOAELs for systemic toxic effects from both acute and chronic exposures. Sethoxydim has been tested for and does not appear to cause carcinogenicity, birth defects, or other reproductive effects.

Poast contains a substantial amount of petroleum solvent (74%) that includes naphthalene (7% of the solvent). The primary effect of naphthalene and petroleum solvents involves CNS depression and other signs of neurotoxicity that are similar to the effects seen in animals exposed to Poast as well as sethoxydim. While sethoxydim is rapidly degraded in the environment, some of the degradation products are much more persistent and this pattern is quantitatively considered in the risk assessment.

Based on standard studies required for pesticide registration, Poast may cause skin and eye irritation. Concentrations of sethoxydim in the air that would be much higher than any plausible concentrations in human exposure scenarios have been associated with lung congestion in rats. The potential inhalation toxicity of sethoxydim is not of substantial concern to this risk assessment because of the implausibility of inhalation exposure involving high concentrations of this compound.

3.1.2. Acute Toxicity. Acute toxicity studies on sethoxydim have been conducted as part of the FIFRA pesticide registration process (BASF 1982; Kirsch and Hildebrand 1983; Nishibe et al. 1980,1981,1984). In addition, several unpublished studies have been submitted to the U.S. EPA under requirements of the Toxic Substances Control Act (BASF 1980; Bio-Medical Research Laboratories Co. Ltd. 1979,1980; Nisso Inst. 1980a,b). Both groups of studies are summarized in Appendix 1.

The most common measure of acute oral (gavage) toxicity is the LD_{50}, the estimate of a dose that is most likely to cause 50% mortality in the test species after a single oral dose. As summarized in Appendix 1, the acute oral LD_{50} values for sethoxydim in rats range from 2676 mg/kg (Bio-Medical Research Laboratories Co. Ltd. 1980) to 5573 mg/kg (Nishibe et al. 1980). Mice may be somewhat less sensitive than rats, with acute LD_{50} values in the range of 5600 to 6500 mg/kg (BASF 1982; Bio-Medical Research Laboratories Co. Ltd. 1980).

While the differences between the sensitivities of mice and rats to sethoxydim are not substantial, they are consistent with the general observation that larger mammals are more sensitive to many toxic agents than are smaller mammals. This observation is incorporated into the dose-response assessment for sethoxydim by the use of an uncertainty factor in extrapolating results from experimental mammals to humans (Section 3.3). Based on the administration of sethoxydim in gelatin capsules rather than gavage, the oral LD_{50} in dogs is 2500-5000 mg/kg (Nisso Inst. 1980a). Because of the difference in the dosing method (gavage vs. capsules), these results in dogs cannot be directly compared to those in rodents to further assess patterns in species differences in sensitivity to sethoxydim.

One study in rats (Bio-Medical Research Laboratories Co Ltd. 1979) involved the formulated product (Poast) rather than the active ingredient alone (sethoxydim) and this study reports LD_{50} values that are in the higher region of the range of sethoxydim LD_{50} values for rats – i.e., 4390 to 5000 mg Poast/kg. The LD_{50} values expressed as sethoxydim equivalents are 790 to 900 mg sethoxydim/kg bw, below the LD_{50} values for technical grade sethoxydim.

The primary signs of acute poisoning in mice, rats, and dogs are consistent with neurological effects: lacrimation, salivation, incontinence, ataxia, tremors, and convulsions (Appendix 1). Other than inferences that might be made from these gross signs of toxicity, the mechanism of the acute toxicity of sethoxydim is unclear. One mechanistic study (Yamano and Morita 1995) reports that sethoxydim uncouples mitochondrial oxidative phosphorylation, at least *in vitro*. Oxidative phosphorylation is an important biochemical process in mammals and the uncoupling of oxidative phosphorylation can lead to increased body temperature and weight loss (Gregus and Klaassen 1996). *In vivo*, sethoxydim has been shown to cause a decrease rather than increase in body temperature (Nishibe et al. 1980).

3.1.3. Subchronic or Chronic Systemic Toxic Effects. No studies have been published on the subchronic or chronic toxicity of sethoxydim to humans or mammals. As summarized in Appendix 1, standard chronic (2-year) toxicity studies have been conducted in rats (Burdock et al. 1981) and mice (Nisso Inst. 1980b; Takaori et al. 1981). All of these studies are unpublished and were submitted to the U.S. EPA in support of the registration of sethoxydim. In the rat study (Burdock et al. 1981), dietary concentrations up to 360 ppm resulted in no observed effects. Two additional chronic toxicity studies have been summarized in U.S. EPA/OPP (1998a). In one study, dietary concentrations of 0, 360, and 1,080 ppm (equivalent to 18.2/23.0, and 55.9/71.8 mg/kg/day in males/females) failed to induce any signs of toxicity. In the other study, a dietary concentration of 3,000 ppm led to changes in food consumption and body weight as well as liver pathology (U.S. EPA/OPP 1998a).

Mice appear to be somewhat more sensitive to chronic exposure to sethoxydim than rats. In the chronic mouse feeding study (Nisso Inst. 1980b; Takaori et al. 1981 summarized in Appendix 1), a dietary concentration of 1080 ppm resulted in decreased growth rate in both sexes accompanied by a slight increase in food consumption in both sexes, as well as toxic effects to the liver. At both 360 and 1080 ppm, histopathologic signs of liver toxicity were also observed - i.e., fatty degeneration and swelling of the liver.

A one-year feeding study in dogs has also been conducted in which doses were administered as rates of 0, 8.86/9.41, 17.5/19.9, and 110/129 mg/kg/day to males/females (IRDC 1984). At 8.86/9.41 mg/kg/day no adverse effects were observed. At a dose of 17.5 mg/kg/day, mild anemia was observed in male dogs and this dose level was classified by the U.S. EPA as a LOAEL. The NOAEL of 8.86/9.41 mg/kg/day was selected by the U.S. EPA as the basis for the Agency RfD (U.S. EPA/IRIS 1989).

No standard 90-day subchronic toxicity studies have been encountered. The only other repeated dose studies involve assays for reproductive or teratogenic effects (Section 3.1.4) and a dermal toxicity study (Section 3.1.7).

3.1.4. Reproductive and Teratogenic Effects. Sethoxydim has been tested for its ability to cause birth defects (i.e., teratogenicity) as well as its ability to cause reproductive impairment. Teratogenicity studies typically entail gavage administration to pregnant rats or rabbits on specific days of gestation. Two such studies (each of which is detailed in Appendix 1) were conducted on sethoxydim: one in rats and one in rabbits. Both of these studies are reported in Nisso Inst. (1980a).

In the rat study, which involved daily gavage dosing on days 7 to 17 of gestation, the maternal NOAEL was 40 mg/kg/day with decreased body weight observed at 100 mg/kg/day. No effects on fetuses were noted at the highest dose tested, 250 mg/kg/day. In the rabbit study, which involved daily gavage dosing on days 6 to 28 of gestation, the highest dose tested (480 mg/kg/day) resulted in toxic effects to the dams (decreased weight gain) and fetuses (decreased number of viable fetuses and decreased fetal weight). Thus, the maternal and fetal NOAEL was 160 mg/kg/day with a corresponding LOAEL of 480 mg/kg/day.

Another type of reproduction study involves exposing more than one generation of the test animal to the compound in the diet. No such studies were encountered in the literature or in the initial search of the FIFRA/CBI files. U.S. EPA/OPP (1998a) summarizes the results of a two generation reproduction study in which rats were fed diets containing 0, 150, 600, and 3,000 ppm which resulted in daily doses of approximately 0, 7.5, 30, and 150 mg/kg. No effects were observed in dams or offspring.

3.1.5. Carcinogenicity and Mutagenicity. The two-year feeding studies in rats and mice, discussed in Section 3.1.3 and summarized in Appendix 1, involved complete histopathology in order to assess the potential carcinogenicity of sethoxydim. Only one of the studies, the study with the high dose group of 3,000 ppm has been accepted by the U.S. EPA based on the criteria that a cancer study should involve at least one dose level at which adverse effects are observed - i.e., some evidence that the maximum tolerated dose was encompassed by the study. In this high dose study, as well as in the other lower dose studies, no evidence for carcinogenicity was noted

(U.S. EPA/OPP 1998a). The U.S. EPA/OPP (1998a) has not classified sethoxydim for carcinogenicity and the earlier review by the U.S. EPA/OPP (U.S. EPA/IRIS 1989) indicates that this compound has not been evaluated for carcinogenicity by the agency.

Several standard assays for mutagenicity, reviewed by the U.S. EPA/OPP (1998a), have been negative. These assays included an Ames assay for gene mutation, Chinese hamster bone marrow cytogenetic assay, as well as recombinant assays and forward mutation assays in *Bacillus subtilis*, *Escherichia coli*, and *Salmonella typhimurium*. Thus, based on a review of the available information, there appears to be no basis for asserting that sethoxydim is likely to pose any cancer risk.

3.1.6. Effects on the Skin and Eyes. Sethoxydim failed to cause any evidence of primary skin irritation in a standard rabbit assay (Toxicity Category IV; no irritation). A standard assay for dermal sensitization in the guinea pig was waived by the U.S. EPA/OPP (1998a) because no sensitization was seen in guinea pigs dosed with the end-use product, Poast (18% active ingredient). The MSDS for Poast, however, states that Poast is moderately irritating to the skin of rabbits (BASF 2000). In addition, the U.S. EPA/OPP (1998a) reports that slight epidermal hyperplasia was observed in rats after a daily dermal dose of 1,000 mg/kg/day over a 21-day period.

The U.S. EPA/OPP (1998a) also states that no primary eye irritation was observed in the rabbit and classifies sethoxydim as Toxicity Category IV (no irritation). The basis for this classification is unclear. As summarized in Appendix 1, sethoxydim has been shown to cause eye irritation in rabbits in two studies that have been submitted to the U.S. EPA (Souma et al. 1981; Kirsch and Hildebrand 1983). In addition, the MSDS for Poast states that Poast is moderately irritating to the eyes of rabbits (BASF 2000), a statement that is consistent with the studies summarized in Appendix 1.

3.1.7. Systemic Toxic Effects from Dermal Exposure. Most of the occupational exposure scenarios and many of the exposure scenarios for the general public involve the dermal route of exposure. For these exposure scenarios, dermal absorption is estimated and compared to an estimated acceptable level of oral exposure based on subchronic or chronic toxicity studies. Thus, it is necessary to assess the consequences of dermal exposure relative to oral exposure and the extent to which sethoxydim is likely to be absorbed from the surface of the skin.

The available toxicity studies summarized in Appendix 1 indicate that dermal exposures to single acute doses of up to 5000 mg/kg sethoxydim were below the LD_{50} for rabbits (Bio-Medical Research Laboratories Co, Ltd. 1979, 1980). While no mortality was seen in any of the exposed rats or mice, signs of neurotoxicity (i.e., decreased motor activity, ataxia and tremors) were apparent, similar to but less severe than the effects noted after oral administration. Thus, as with many chemicals (e.g. Gaines 1969), sethoxydim can cause toxic effects after dermal exposure but, in terms of mg/kg dose, sethoxydim appears to be less potent after dermal exposure compared to oral exposure, probably because the rate of dermal absorption is less than the rate of oral absorption.

The kinetics of dermal absorption of sethoxydim are not documented in the open literature and no studies on the kinetics of dermal absorption have been submitted to U.S. EPA. Such studies are not required for pesticide registration.

Dermal exposure scenarios involving immersion or prolonged contact with chemical solutions use Fick's first law and require an estimate of the permeability coefficient, K_p, expressed in cm/hour. Using the method recommended by U.S. EPA/ORD (1992), the estimated dermal permeability coefficient for sethoxydim is 0.0002667 cm/hour with a 95% confidence interval of 0.0001686 to 0.0004217 cm/hour. The details of the U.S. EPA/ORD (1992) method for estimating K_p based on the molecular weight and octanol-water partition coefficient are given in Worksheet A07b. The application of this method to sethoxydim is detailed in Worksheet B04. The estimated K_p is used in all exposure assessments in this document that are based on Fick's first law.

For exposure scenarios like direct sprays or accidental spills, which involve deposition of the compound on the skin's surface, dermal absorption rates (proportion of the deposited dose per unit time) rather than dermal permeability rates are used in the exposure assessment. Using the methods detailed in SERA (2000), the estimated first-order dermal absorption coefficient is 0.00109 $hour^{-1}$ with 95% confidence intervals of 0.00047 to 0.0025 $hour^{-1}$. The details of the method specified in SERA (2000) for estimating the first-order dermal absorption coefficient based on the molecular weight and octanol-water partition coefficient are given in worksheet A07a. The application of this method to sethoxydim is detailed in worksheet B03.

The lack of experimental data regarding the dermal absorption of sethoxydim adds uncertainty to this risk assessment. Nonetheless, uncertainties in the rates of dermal absorption, although they are substantial, can be estimated quantitatively and are incorporated in the human health exposure assessment (Section 3.2).

3.1.8. Inhalation Exposure. As summarized in Appendix 1, there is one acute inhalation toxicity study on sethoxydim (Gamer 1991), one acute inhalation toxicity study on Poast (BASF 1980) and one subchronic inhalation study on sethoxydim (Gamer 1993).

Both acute studies follow a relatively standard protocol involving acute (4-hour) exposure of rats to relatively high concentrations in which the animals were exposed only through the head and nose - i.e., the rest of the animals body was protected from exposure to rule out dermal absorption as a significant route of exposure. No effects were observed in the acute study with sethoxydim at concentrations up to 5,600 mg/m^3 (Gamer 1991). In the study using Poast, however, neurotoxicity (ataxia) was observed at a concentration of 7,640 mg/m^3 and abnormal behavior (crouching posture) persisted for 6 days after exposure (BASF 1980a).

In the subchronic study with sethoxydim, animals were exposed (head-nose only) to 0, 40, 300, or 2,400 mg/m^3 for 6 hours/day for 1 month (21 exposures). While no effects were seen in the lowest exposure group, mild nasal irritation was observed at 300 mg/m^3 and irritation to the upper respiratory tract and oral cavity as well as signs of liver toxicity were observed at 2,400 mg/m^3 (Gamer 1993). No evidence of neurologic effects were seen in any of the exposed groups.

While somewhat speculative, the neurologic effects observed after exposure to Poast are consistent with the possible role of the petroleum solvent in Poast as a CNS depressant (Section 3.1.9.3)

3.1.9. Impurities, Metabolites, and Formulation Additives.

3.1.9.1. Impurities -- There is no published information regarding the impurities in technical grade sethoxydim or any of its commercial formulations. No information on the identity of impurities in technical grade sethoxydim or Poast was been encountered in a search of the EPA/FIFRA files. This lack of information does add uncertainty to the hazard identification. Nonetheless, all of the toxicology studies on sethoxydim involve technical sethoxydim, which is presumed to be the same as or comparable to the active ingredient in the formulation used by the Forest Service. Thus, if toxic impurities are present in technical sethoxydim in substantial and toxicologically significant amounts, they are likely to be encompassed by the available toxicity studies using technical grade sethoxydim.

3.1.9.2. Metabolites -- There are two major mammalian metabolites of sethoxydim, referred to as M1-SO and M2-SO. The toxicity of these compounds is comparable to that of technical grade sethoxydim: acute oral LD_{50} (95% confidence interval) values of 3,080 (2,953 to 3,175) mg/kg for M1-SO and 5,573 (4,942 to 7,435) mg/kg for M2-SO. In addition, the signs of toxicity for these two compounds are similar to that of sethoxydim: lacrimation, salivation, ataxia, sedation, urinary incontinence, and a decrease in body temperature. In addition, M2-SO was associated with irritation and hemorrhage of the intestinal tract (Nishibe et al. 1980; Nishibe et al. 1981). Another metabolite, 2-[1-(ethoxyimino)butyl]5-[2-(ethylsulfonyl) propyl]-3,5-dihydroxy-2-cyclohexen-1-one, has an acute oral LD_{50} of >5,000 mg/kg (Nishibe et al. 1981).

In assessing the potential hazards of exposures to both sethoxydim and metabolites of sethoxydim, the U.S. EPA/OPP (1998a) combines residues of metabolites with residues of sethoxydim in establishing pesticide tolerances for this compound. In other words, the concentrations of sethoxydim and all sethoxydim metabolites are added and the mixture is treated as if it consisted entirely of sethoxydim. Based on the comparable toxicities of the metabolites with the toxicity of sethoxydim, both in terms of acute toxic potency and signs of toxicity, this approach appears to be reasonable.

For the current risk assessment, the metabolites of sethoxydim are important in the application of environmental fate models. As detailed further in Section 3.2.3, GLEAMS is used to estimate runoff and percolation of sethoxydim from soil and these estimates are used further to estimate concentrations of sethoxydim that may be present in ambient water. The selection of parameters for the environmental fate models is substantially complicated by the number of sethoxydim metabolites that may be generated in the environment in additional to those discussed above. For example, Koskinen et al. (1994) have identified eight soil metabolites in which the cyclohexen-1-one ring remains intact. Similar complex sets of metabolites have been identified in anaerobic aquatic metabolism (Shiotani 1990a), anaerobic soil metabolism (Soeda and Shiotani 1989), hydrolysis (Soeda and Shiotani 1988a) and photolysis (Huber 1981; Soeda and Shiotani 1988b; Soeda and Shiotani 1988c).

Ideally, monitored values or modeled estimates of the concentrations of each metabolite in environmental media such as water would be used along with RfD's or similar estimates for each metabolite to assess and characterize risk. This approach cannot be taken for sethoxydim and its metabolites, however, because toxicity data are not available for many of the metabolites of sethoxydim and the available data are not adequate for estimating concentrations of each metabolite in water or other environmental media.

As an alternative, the assumption, analogous to that used by U.S. EPA, is made that the metabolites of sethoxydim have a toxicity equivalent to that of sethoxydim itself. Based on the albeit limited acute toxicity data discussed above, this appears to be a reasonable and perhaps conservative assumption. As a consequence of this assumption, parameters used in the application of the GLEAMS and related models, such as halftimes in water and soil, are based on rates of conversion from sethoxydim to carbon dioxide - i.e., complete degradation - rather than on the rate of disappearance of sethoxydim itself - i.e., the conversion of sethoxydim to metabolites of sethoxydim. These longer halftimes are used in the environmental fate models applied in Section 3.2.3.4.2.

3.1.9.3. Inerts – As indicated in Section 2, Poast contains a substantial amount of petroleum solvent (74%) that includes naphthalene (7% of the total). This material has been classified by the U.S. EPA as "solvent naphtha (petroleum) heavy aromatic" which is listed by the U.S. EPA/OPP (1998b) as a potentially toxic agent with a high priority for testing. There is a large and complex literature on the toxicity of naphthalene and petroleum solvents in general (e.g., ATSDR 1997) and a detailed review of this literature is beyond the scope of the current document. Nonetheless, the primary effect of naphthalene and petroleum solvents involves CNS depression and other signs of neurotoxicity that are similar to the effects seen in animals exposed to Poast as well as sethoxydim.

At least for oral and dermal exposures, however, the quantitative significance of the petroleum in Poast does not appear to be substantial. As discussed in Sections 3.1.2. and 3.1.7, the toxicity of Poast and sethoxydim appear to be comparable after oral and dermal exposures. For inhalation exposures (Section 3.1.8), however, there is at least some evidence that Poast may be more toxic and cause qualitatively different toxic effects consistent with the presence of petroleum solvent. Thus, the potential effect of the petroleum solvent in Poast is considered qualitatively and quantitatively in this risk assessment for potential human health effects (see Section 3.4). As detailed in the ecological risk assessment (Section 4), there is ample evidence that Poast is much more toxic to aquatic species than sethoxydim, suggestive of the role of the petroleum solvent in Poast.

3.1.10. Toxicological Interactions. No studies have been encountered on the toxicologic interactions of sethoxydim or Poast in humans or experimental mammals. In the absence of a better understanding of the mechanisms of the toxic action of sethoxydim, there is no basis for speculating as to the nature and direction of potential toxicologic interactions with other herbicides or other compounds in general.

3.2. EXPOSURE ASSESSMENT

3.2.1. Overview. There are no occupational exposure studies in the available literature that are associated with the application of sethoxydim. Consequently, worker exposure rates are estimated from an empirical relationship between absorbed dose per kilogram of body weight and the amount of chemical handled in worker exposure studies on nine different pesticides. Separate exposure assessments are given for broadcast ground spray (low boom spray) and backpack applications.

For both types of applications, central estimates of worker exposure are similar: about 0.007 mg/kg/day for broadcast ground spray and 0.004 mg/kg/day for backpack applications. The upper limits of the exposure estimates are about 0.06 mg/kg/day for broadcast ground spray and 0.03 mg/kg/day for backpack applications.

Except in the case of accidental exposures, the levels of sethoxydim to which the general public might be exposed should be far less than the levels for workers. Longer-term exposure scenarios for the general public lead to central estimates of daily doses in the range of about 0.0000002 to 0.0002 mg/kg/day with upper limits of exposure in the range of 0.000007 to 0.003 mg/kg/day. While these exposure scenarios are intended to be conservative, they are nonetheless plausible. Accidental exposure scenarios result in central estimates of exposure of up to 0.2 mg/kg/day and upper ranges of exposure up to 0.77 mg/kg/day. All of the accidental exposure scenarios involve relatively brief periods of exposure, and most should be regarded as extreme.

3.2.2. Workers. A summary of the exposure assessments for workers is presented in Table 3-1. Two types of exposure assessments are considered: general and accidental/incidental. The term *general* exposure assessment is used to designate those exposures that involve estimates of absorbed dose based on the handling of a specified amount of a chemical during specific types of applications. The accidental/incidental exposure scenarios involve specific types of events that could occur during any type of application. Details regarding all of these exposure assessments are presented in the worksheets that accompany this risk assessment, as indicated in Table 3-1.

3.2.2.1. General Exposures – Details of the calculations used in the worker exposure assessments are given in Worksheets C01a (backpack) and C01b (boom spray). No worker exposure studies with sethoxydim were found in the literature. Worker exposure rates are expressed in units of mg of absorbed dose per kilogram of body weight per pound of chemical handled. These exposure rates are based on worker exposure studies on nine different pesticides with molecular weights ranging from 221 to 416 and log K_{ow} values at pH 7 ranging from -0.75 to 6.50. The estimated exposure rates are based on estimated absorbed doses in workers as well as the amounts of the chemical handled by the workers (SERA 2000). As summarized in Table 2-1 of this risk assessment, the molecular weight of sethoxydim is 327.5 g/mole and the log K_{ow} at pH 7 is about 1.65. Both of these values are within the range of values used in the empirical relationships for worker exposure. As described in SERA (2000), the ranges of estimated occupational exposure rates vary substantially among individuals and groups, (i.e., by a factor of 50 for backpack applicators and a factor of 100 for mechanical ground sprayers). While this adds substantial uncertainty to the exposure assessment, this variability has little practical impact on this risk assessment because even the upper limits of exposure are below levels of concern (Section 3.4.2).

For the worker exposure assessments, the number of acres treated per hour is taken from previous USDA risk assessments (USDA 1989a,b,c). The number of hours worked per day is expressed as a range, the lower end of which is based on an 8-hour work day with 1 hour at each end of the work day spent in activities that do not involve herbicide exposure. The upper end of the range, 8 hours per day, is based on an extended (10-hour) work day, allowing for 1 hour at each end of the work day to be spent in activities that do not involve herbicide exposure.

It is recognized that the use of 6 hours as the lower range of time spent per day applying herbicides is not a true lower limit. It is conceivable and perhaps common for workers to spend much less time in the actual application of a herbicide if they are engaged in other activities. Thus, using 6 hours can be regarded as conservative. In the absence of any published or otherwise documented work practice statistics to support the use of a lower limit, this conservative approach is used.

The range of acres treated per hour and hours worked per day is used to calculate a range for the number of acres treated per day. For this calculation as well as others in this section involving the multiplication of ranges, the lower end of the resulting range is the product of the lower end of one range and the lower end of the other range. Similarly, the upper end of the resulting range is the product of the upper end of one range and the upper end of the other range. This approach is taken to encompass as broadly as possible the range of potential exposures.

The central estimate of the acres treated per day is taken as the arithmetic average of the range. Because of the relatively narrow limits of the ranges for backpack and boom spray workers, the use of the arithmetic mean rather than some other measure of central tendency, like the geometric mean, has no marked effect on the risk assessment.

The range of application rates and the typical application rate are taken directly from the program description (see Section 2.4).

As detailed in worksheets C01a (directed foliar) and C01b (broadcast foliar), the central estimate of the amount handled per day is calculated as the product of the central estimates of the acres treated per day and the application rate. The ranges for the amounts handled per day are calculated as the product of the range of acres treated per day and the range of application rates. Similarly, the central estimate of the daily absorbed dose is calculated as the product of the central estimate of the exposure rate and the central estimate of the amount handled per day. The ranges of the daily absorbed dose are calculated as the range of exposure rates and the ranges for the amounts handled per day. The lower and upper limits are similarly calculated using the lower and upper ranges of the amount handled, acres treated per day, and worker exposure rate.

3.2.2.2. Accidental Exposures -- Typical occupational exposures may involve multiple routes of exposure (i.e., oral, dermal, and inhalation); nonetheless, dermal exposure is generally the predominant route for herbicide applicators (van Hemmen 1992). Typical multi-route exposures are encompassed by the methods used in Section 3.2.2.1 on general exposures. Accidental exposures, on the other hand, are most likely to involve splashing a solution of a herbicide into the eyes or to involve various dermal exposure scenarios.

Poast can cause irritant effects in the skin and eyes (see Section 3.1.6). The available literature does not include quantitative methods for characterizing exposure or responses associated with splashing a solution of a chemical into the eyes; furthermore, there appear to be no reasonable approaches to modeling this type of exposure scenario quantitatively. Consequently, accidental exposure scenarios of this type are considered qualitatively in the risk characterization (Section 3.4).

There are various methods for estimating absorbed doses associated with accidental dermal exposure (U.S. EPA/ORD 1992, SERA 2000). Two general types of exposure are modeled: those involving direct contact with a solution of the herbicide and those associated with accidental spills of the herbicide onto the surface of the skin. Any number of specific exposure scenarios could be developed for direct contact or accidental spills by varying the amount or concentration of the chemical on or in contact with the surface of the skin and by varying the surface area of the skin that is contaminated.

For this risk assessment, two exposure scenarios are developed for each of the two types of dermal exposure, and the estimated absorbed dose for each scenario is expressed in units of mg chemical/kg body weight. As specified in Table 3-1, the details of these exposure estimates are presented in the worksheets appended to this risk assessment.

Exposure scenarios involving direct contact with solutions of the chemical are characterized by immersion of the hands for 1 minute or wearing contaminated gloves for 1 hour. Generally, it is not reasonable to assume that the hands or any other part of a worker will be immersed in a solution of a herbicide for any period of time. Notwithstanding this assertion, contamination of gloves or other clothing is quite plausible. For these exposure scenarios, the key element is the assumption that wearing gloves grossly contaminated with a chemical solution is equivalent to immersing the hands in a solution. In either case, the concentration of the chemical in solution that is in contact with the surface of the skin and the resulting dermal absorption rate are essentially constant.

For both scenarios (the hand immersion and the contaminated glove), the assumption of zero-order absorption kinetics is appropriate. Following the general recommendations of U.S. EPA/ORD (1992), Fick's first law is used to estimate dermal exposure.

Exposure scenarios involving chemical spills on to the skin are characterized by a spill on to the lower legs as well as a spill on to the hands. In these scenarios, it is assumed that a solution of the chemical is spilled on to a given surface area of skin and that a certain amount of the chemical adheres to the skin. The absorbed dose is then calculated as the product of the amount of the chemical on the surface of the skin (i.e., the amount of liquid per unit surface area multiplied by the surface area of the skin over which the spill occurs and the concentration of the chemical in the liquid) the first-order absorption rate, and the duration of exposure. For both scenarios, it is assumed that the contaminated skin is effectively cleaned after 1 hour. As with the exposure assessments based on Fick's first law, this product (mg of absorbed dose) is divided by body weight (kg) to yield an estimated dose in units of mg chemical/kg body weight. The specific equation used in these exposure assessments is taken from SERA (2000).

3.2.3. General Public.

3.2.3.1. General Considerations – Under normal circumstances, members of the general public should not be exposed to substantial levels of sethoxydim as a result of Forest Service activities. Nonetheless, any number of exposure scenarios can be constructed for the general public, depending on various assumptions regarding application rates, dispersion, canopy interception, and human activity. Several highly conservative scenarios are developed for this risk assessment.

The two types of exposure scenarios developed for the general public include acute exposure and longer-term or chronic exposure. Given the limited use of sethoxydim by the Forest Service – e.g., a total of 3.8 lbs in 1999 – chronic exposures to significant amounts of sethoxydim from Forest Service programs is highly implausible. Nonetheless, as detailed below, a number of standard exposure scenarios involving substantially greater amounts of sethoxydim are covered in this risk assessment in the event that the Forest Service may consider increasing the use of this compound.

Most of the acute exposure scenarios are accidental. They assume that an individual is exposed to the compound either during or shortly after its application. Specific scenarios are developed for direct spray, dermal contact with contaminated vegetation, as well as the consumption of contaminated fruit, water, and fish. Most of these scenarios should be regarded as extreme, some to the point of limited plausibility. The longer-term or chronic exposure scenarios parallel the acute exposure scenarios for the consumption of contaminated fruit, water, and fish but are based on estimated levels of exposure for longer periods after application.

The exposure scenarios developed for the general public are summarized in Table 3-2, and the details regarding the assumptions and calculations involved in these exposure assessments are provided in worksheets D01-D09. The remainder of this section focuses on a qualitative description of the data supporting each of the assessments.

3.2.3.2. Direct Spray -- Direct sprays involving ground applications are modeled in a manner similar to accidental spills for workers (see Section 3.2.2.2.). In other words, it is assumed that the individual is sprayed with a solution containing the compound and that an amount of the compound remains on the skin and is absorbed by first-order kinetics. As with the similar worker exposure scenarios, the first-order absorption kinetics are estimated from the empirical relationship of first-order absorption rate coefficients to molecular weight and octanol-water partition coefficients, as defined in worksheet A07a.

For direct spray scenarios, it is assumed that during a ground application, a naked child is sprayed directly with sethoxydim. The scenario also assumes that the child is completely covered (that is, 100% of the surface area of the body is exposed), which makes this an extremely conservative exposure scenario that is likely to represent the upper limits of plausible exposure (Worksheet D01a). An additional set of scenarios are included involving a young woman who is accidentally sprayed over the feet and legs (Worksheet D01b). For each of these scenarios, some assumptions are made regarding the surface area of the skin and body weight. These assumptions are detailed and referenced in Worksheet A03.

Because sethoxydim is only applied by backpack or low boom spray, none of these acute exposure scenarios are plausible. They are included in the current risk assessment to accommodate the possible expansion of the use and application methods of sethoxydim in Forest Service operations.

3.2.3.3. Dermal Exposure from Contaminated Vegetation -- In this exposure scenario, it is assumed that the herbicide is sprayed at a given application rate and that an individual comes in contact with sprayed vegetation or other contaminated surfaces at some period after the spray operation.

For these exposure scenarios, some estimates of dislodgeable residue and the rate of transfer from the contaminated vegetation to the surface of the skin must be available. No such data are directly available for sethoxydim, and the estimation methods of Durkin et al. (1995) are used as defined in worksheet D02. Other estimates used in this exposure scenario involve estimates of body weight, skin surface area, and first-order dermal absorption rates. The estimates of body weight and surface area are detailed in Worksheet A03 and the estimated first-order dermal absorption rate is detailed in Worksheet B03.

As discussed in Section 3.1.7, no experimental studies are available on the dermal absorption rate of sethoxydim and estimates of both zero-order and first-order dermal absorption rates are based on empirical relationships of the molecular weight and octanol-water partition coefficient

(Worksheets B03 and B04). Poast, however, contains both a petroleum solvent and an emulsifier and these adjuvants could influence the rate of dermal absorption. These influences cannot be quantitatively considered in the exposure assessment. As discussed further in Section 3.4, however, most dermal exposure scenarios lead to estimates of risk that are very far below a level of concern and the uncertainty concerning the impact of the adjuvants on dermal absorption rate has only a minor impact on the risk characterization.

3.2.3.4. Contaminated Water -- Water can be contaminated from runoff, as a result of leaching from contaminated soil, from a direct spill, or from unintentional contamination from aerial applications. For this risk assessment, the two types of estimates made for the concentration of sethoxydim in ambient water are acute/accidental exposure from an accidental spill and longer-term exposure to sethoxydim in ambient water that could be associated with the typical application of this compound to a 10 acre block.

3.2.3.4.1. ACUTE EXPOSURE – Two exposure scenarios are presented for the acute consumption of contaminated water: an accidental spill into a small pond and the contamination of a small stream by runoff.

The accidental spill scenario assumes that a young child consumes contaminated water shortly after an accidental spill into a small pond. The specifics of this scenarios are given in Worksheet D05. Because this scenario is based on the assumption that exposure occurs shortly after the spill, no dissipation or degradation of sethoxydim is considered. This is an extremely conservative scenario dominated by arbitrary variability. The actual concentrations in the water would depend heavily on the amount of compound spilled, the size of the water body into which it is spilled, the time at which water consumption occurs relative to the time of the spill, and the amount of contaminated water that is consumed. Based on the spill scenario used in this risk assessment, the concentration of sethoxydim in a small pond is estimated to range from 0.42 mg/L to 6.8 mg/L with a central estimate of 2.7 mg/L (Worksheet D05).

As with some other scenarios used in this risk assessment, these exposures are implausibly high given the current use of sethoxydim by the Forest Service. At the upper limit, this spill scenario involves 200 gallons (257 liters) of a 9000 mg/L solution. This is equivalent to about 6.8 kg of sethoxydim [257 liters × 9000 mg/L = 6,813,000 mg ≃ 6.8 kg] or about 15 lbs. This is about 4 times more sethoxydim than the Forest Service used in all of 1999 – i.e., 3.8 lbs as discussed in Section 2. Again, this scenario is presented in this risk assessment in the event that the Forest Service considers increasing the use of this compound.

The other acute exposure scenario for the consumption of contaminated water involves runoff into a small stream. No monitoring data have been encountered on the contamination of streams with sethoxydim after ground or aerial applications of the compound over a wide area. Consequently, for this component of the exposure assessment, estimates of levels in ambient water are made based on the GLEAMS model. GLEAMS is a root zone model that can be used to examine the fate of chemicals in various types of soils under different meteorological and hydrogeological conditions (Knisel et al. 1992). As with many environmental fate and transport models, the input and output files for GLEAMS can be complex. The general application of the GLEAMS model to estimating concentrations in ambient water are given in Attachment 2.

For the current risk assessment, the methods detailed in Attachment 2 were used with the exception that the application site was assumed to consist of a 10 acre square area rather than a 10 acre rights-of-way or 100 acre plot. This adjustment reflects the limited use of sethoxydim by the Forest Service primarily in relatively small nursery plots. The chemical specific values used in the GLEAMS modeling are summarized in Table 3-3.

Sethoxydim is rapidly degraded in the environment to a variety of metabolites that are structurally similar to sethoxydim (Bryceland et al. 1997) and whose toxicity appears to be of the same order or less than the toxicity of sethoxydim (Section 3.1.9.2). The formation of metabolites impacts the GLEAMS modeling in that the relatively rapid degradation rates for sethoxydim itself – i.e., the transformation from sethoxydim to one of the sethoxydim metabolites – cannot be used for estimating exposure to sethoxydim and sethoxydim metabolites. As an alternative, half-times for the transformation of sethoxydim to carbon dioxide, which represent the complete mineralization of sethoxydim, are used.

For example, in an anaerobic aquatic environment, sethoxydim is rapidly degraded with a halftime of less than one day. Most of the degradation products, however, consist of M1-SO and three other structurally similar compounds. Over a one year period, only 16.6% to 36.5% of the original sethoxydim is recovered as CO_2 (Shiotani 1990a). These recovery rates correspond to 0.0049 $days^{-1}$ ($t_{½}$=141 days) and 0.0028 $days^{-1}$ ($t_{½}$=247 days), identical to the degradation rates in an aerobic environment. For the risk assessment, the average of this range, 194 days, is rounded to two significant digits (i.e., 190 days) and used in the GLEAMS modeling.

The GLEAMS modeling yielded estimates of sethoxydim runoff and percolation that were used to estimate concentrations in the stream adjacent to a treated plot, as detailed in Section 5.5 of Attachment 2. The results of the GLEAMS modeling for the small stream are summarized in Table 3-4. These estimates are expressed as the water contamination rates (WCR) - i.e., the concentration of the compound in water in units of mg/L normalized for an application rate of 1 lb/acre.

The maximum concentrations of sethoxydim in stream water ranged from 0 to about 500 µg/L (0.5 ppm) depending on rainfall rates. The typical WCR – i.e., mg/L per lb/acre applied – is taken as 200 µg/L per lb/acre. This is about the peak concentrations that could be expected at rainfall rates of about 100 inches per year from sand – i.e., 174 µg/L in Table 3-4 rounded to one significant digit. The upper limit is taken at 500 µg/L, approximately the peak concentration from loam soils at rainfall rates of 250 inches per year – i.e., 491 µg/L in Table 3-4 rounded to one significant digit. The functional lower limit is taken as 0.020 mg/L per lb/acre applied, about the peak concentration from sandy soil at an annual rainfall rate of 15 inches per year (see Table 3-4, 19.8 µg/L maximum for sandy soil at an annual rainfall of 15 inches per year). In very arid environments, the actual lower limit would approach zero. The resulting estimates of peak concentrations of sethoxydim in a small stream based on the application rates that might be used by the Forest Service are given in Worksheet B06.

3.2.3.4.2. LONGER-TERM EXPOSURE -- The scenario for chronic exposure to sethoxydim from contaminated water is detailed in worksheet D07. This scenario assumes that an adult (70 kg male) consumes contaminated ambient water for a lifetime. As with the above stream scenario, there are no monitoring studies available on sethoxydim that permit an assessment of concentrations in ambient water associated with applications of sethoxydim. Consequently, for this component of the exposure assessment, estimates of levels in a small pond are based on GLEAMS modeling as detailed in the previous section. The specific methods used to calculate the concentration of sethoxydim in a small pond based on the GLEAMS output are detailed in Section 5.4 of Attachment 2.

The results of the GLEAMS modeling for the pond is summarized in Table 3-5 and the specific estimates of concentrations of sethoxydim in ambient water that are used in this risk assessment are summarized in Worksheet B06. As with the corresponding values for a small stream, these estimates are expressed as the water contamination rates (WCR) in units of mg/L per lb/acre. The typical WCR is taken as 0.0008 mg/L. This is about the average concentration that could be expected at rainfall rates of about 100 inches per year from loam – i.e., 0.81 µg/L in Table 3-4. The upper limit is taken as 0.0012 mg/L, approximately the longer-term average concentration from loam soils at rainfall rates of 250 inches per year – i.e., 1.23 µg/L in Table 3-4. The lower limit of the WCR is taken as 0.00002 mg/L, the average concentration from loam soil at an annual rainfall rate of 10 inches per year – i.e., 0.02 µg/L in Table 3-4.

Using these water contamination rates, the expected concentrations of sethoxydim in ambient water range from about 0.0000019 to 0.00045 mg/L with a central value of 0.00024 mg/L. These values are used in all of the worksheets involving long-term exposures to contaminated water (e.g., Worksheet D07).

3.2.3.5. Oral Exposure from Contaminated Fish -- Many chemicals may be concentrated or partitioned from water into the tissues of animals or plants in the water. This process is referred to as bioconcentration. Generally, bioconcentration is measured as the ratio of the concentration in the organism to the concentration in the water. For example, if the concentration in the organism is 5 mg/kg and the concentration in the water is 1 mg/L, the bioconcentration factor (BCF) is 5 L/kg [5 mg/kg ÷ 1 mg/L]. As with most absorption processes, bioconcentration depends initially on the duration of exposure but eventually reaches steady state. Details regarding the relationship of bioconcentration factor to standard pharmacokinetic principles are provided in Calabrese and Baldwin (1993).

Several studies are available on the bioconcentration of sethoxydim (Appendix 3). In catfish, bioconcentration factors in whole fish and edible tissue have been measured at 0.75 and 0.71, respectively (BASF 1982). In other words, the concentration in the fish tissue was less than the concentration in water. Substantially higher bioconcentration factors have been measured in bluegill sunfish. In an early study (Vilkas and Kuc 1981a), bioconcentration factors of 6.98 in whole body and 2.87 in edible tissue were measured. In a more recent study (McKenna and Patel 1991), somewhat higher bioconcentration factors are reported for bluegills: 21 in whole body and 7 in edible tissue.

For this risk assessment, the higher values from McKenna and Patel (1991) are used. For the human health risk assessment, the BCF of 7 in edible tissue is used for the chronic risk assessment. For the acute risk assessment, the BCF is adjusted for the expected bioconcentration after 1 day. As summarized in Appendix 3, the elimination half-life of sethoxydim residue in fish was 3.6 days, corresponding to an elimination coefficient of 0.19 $days^{-1}$ [ln(2)÷3.6 days]. Thus, the proportion to steady-state after one day would be 0.173 [$1-e^{-0.19/day \times 1day}$] and the estimated one-day bioconcentration factor is 1.211 [0.173×7]. For the acute risk assessment, this BCF is rounded to 1.2 as summarized in Worksheet B02.

For both the acute and longer-term exposure scenarios involving the consumption of contaminated fish, the water concentrations of sethoxydim used are identical to the concentrations used in the contaminated water scenarios (see Section 3.2.3.4). Because of the available and well-documented information and substantial differences in the amount of caught fish consumed by the general public and native American subsistence populations (U.S. EPA/ORD 1996), separate exposure estimates are made for these two groups (Worksheets D08a and D08b). The chronic exposure scenarios (Worksheet D09a and D09b) are constructed in a similar way, except that estimates of sethoxydim concentrations in ambient water are based on GLEAMS modeling as discussed in Section 3.2.3.4.

For the acute scenarios, the consumption of contaminated fish is based on the maximum amount of fish that an individual might consume in a single day. For the chronic scenarios, the consumption of contaminated fish is based on the average amount of fish that an individual might consume in a single day. These values and the documentation for these values are given in Worksheet A03.

3.2.3.6. Oral Exposure from Contaminated Vegetation -- Under normal circumstances and in most types of applications, it is extremely unlikely that humans will consume vegetation contaminated with sethoxydim. Any number of accidental scenarios could be developed involving either spraying of crops, gardens, or edible wild vegetation. Again, in most instances and particularly for longer-term scenarios, treated vegetation would probably show signs of damage from exposure to sethoxydim (Section 4.3.2.4), thereby reducing the likelihood of consumption that would lead to significant levels of human exposure.

Notwithstanding that assertion, it is conceivable that individuals could consume contaminated vegetation that is accidentally sprayed. One of the more plausible scenarios involves the consumption of contaminated berries after the accidental spray of an area in which wild berries grow. The two accidental exposure scenarios developed for this exposure assessment include one scenario for acute exposure, as defined in Worksheet D03 and one scenario for longer-term exposure, as defined in Worksheet D04. In both scenarios, the concentration of sethoxydim on contaminated vegetation is estimated using the empirical relationships between application rate and concentration on vegetation developed by Fletcher et al. (1994) which is in turn based on a re-analysis of data from Hoerger and Kenaga (1972). These relationships are defined in worksheet A04. For the acute exposure scenario, the estimated residue level is taken as the product of the application rate and the residue rate (Worksheet D03).

For the longer-term exposure scenario (D04), a duration of 90 days is used and the dissipation on the vegetation is estimated using a foliar half-time. Although the duration of exposure of 90 days is somewhat arbitrarily chosen, this duration is intended to represent the consumption of contaminated fruit that might be available over one season. Longer durations could be used for certain kinds of vegetation but would lower the estimated dose (i.e., would result in a less conservative exposure assessment).

For the longer-term exposure scenarios, the time-weighted average concentration on fruit is calculated from the equation for first-order dissipation. Assuming a first-order decrease in concentrations in contaminated vegetation, the concentration in the vegetation at time t after spray, $\mathbf{C_t}$, can be calculated based on the initial concentration, C_0, as:

$$\mathbf{C_t = C_0 \times e^{-kt}}$$

where k is the first-order decay coefficient [$k=\ln(2)\div t_{50}$]. Time-weighted average concentration ($\mathbf{C_{TWA}}$) over time t can be calculated as the integral of C_t (De Sapio 1976, p. p. 97 ff) divided by the duration (t):

$$\mathbf{C_{TWA} = C_0 \, (1 - e^{-k\,t}) \div (k\,t)}.$$

For the acute exposure scenario, it is assumed that a woman consumes 1 lb (0.4536 kg) of contaminated fruit. Based on statistics summarized in U.S. EPA/ORD (1996) and presented in worksheet D04, this consumption rate is approximately the mid-range between the mean and upper 95% confidence interval for the total daily vegetable intake for a 64 kg woman. The range of exposures presented in Table 3-2 is based on the range of concentrations on fruit and the range of application rates for sethoxydim. The longer-term exposure scenario is constructed in a similar way, except that the estimated exposures include the range of fruit consumption (Worksheet A03) as well as the range of concentrations on fruit and the range of application rates for sethoxydim.

When applied to nursery plots, there will typically be a 300 foot buffer between the application site and any vegetation that might be consumed by the general public – i.e., farm crops, home gardens or bushes containing edible berries that the general public might access. Based on the AGDRIFT model using low boom ground applications, the proportion of drift estimated at 300 feet off-site is 0.0024 (Worksheet A06). In other words, at the highest application rate that would be used by the Forest Service, 0.375 lb/acre, the "functional application rate" at 300 feet offsite would be 0.0009 lbs/acre [0.375 lb/acre × 0.0024 = 0.0009 lb/acre]. For this risk assessment, the effects of the buffer is not considered quantitatively and the assumption is made that the vegetation is accidentally sprayed at the nominal application rate (Worksheet D03). As detailed further in Section 3.4, this approach is adopted for sethoxydim because the direct spray scenario leads to estimates of risk that are far below a level of concern. Thus, considering spray drift and a buffer zone quantitatively would have no impact on the characterization of risk.

3.3. DOSE-RESPONSE ASSESSMENT

3.3.1. Overview.

The Office of Pesticide Programs of the U.S. EPA has derived both an acute and chronic RfD for sethoxydim. The chronic RfD of 0.09 mg/kg/day based on a NOAEL of 9 mg/kg/day for a 1-year feed study in dogs and an uncertainty factor of 100. This uncertainty factor includes 10 for extrapolating from animals to humans and 10 for extrapolating to sensitive individuals within the human population. The acute RfD is 0.6 mg/kg/day based on a NOAEL in rabbits of 180 mg/kg/day and an uncertainty factor of 300. The uncertainty factor for the acute RfD includes the same two components as the uncertainty factor for the chronic RfD as well as an FQPA (Food Quality Protection Act) uncertainty factor of 3 for the possible increased sensitivity of children to sethoxydim.

3.3.2. Existing Guidelines. U.S. EPA's Office of Pesticide Programs (U.S. EPA/OPP 1998a) has derived a chronic RfD of 0.09 mg/kg/day for sethoxydim. This RfD is based on a 1-year dietary exposure study using dogs (IRDC 1984, detailed in Appendix 1). In this study, the dogs were given sethoxydim in the diet at concentrations of 0 (control), 300, 600, and 3600 ppm for1 year. Based on measured food consumption in male/female dogs, these dietary concentrations corresponded to average daily doses of 0, 8.86/9.41, 17.5/19.9, and 110/129 mg/kg/day. Signs of toxicity in dogs were noted in the liver (increased weights and slight hepatocellular cytoplasmic changes) and blood (decreased erythrocyte counts, hemoglobin and hematocrit) at 600, and 3600 ppm but not at 300 ppm. Thus, the U.S. EPA identified the NOAEL, rounded to one significant digit, as 9 mg/kg/day. In deriving the chronic RfD, the U.S. EPA/OPP (1998a) used an uncertainty factor of 100, consisting of two components: a factor of 10 for extrapolating from animals to humans and a factor of 10 for extrapolating to sensitive individuals within the human population. This is identical to the chronic RfD on IRIS (U.S. EPA/IRIS 1989).

3.3.3. Dose-Severity-Duration Relationships. For acute dietary exposure, the U.S. EPA/OPP (1998a) uses a short-term NOAEL of 180 mg/kg/day from a reproductive toxicity study in rabbits. This NOAEL was not found in the studies identified in the CBI search on sethoxydim but is very similar to the 160 mg/kg/day NOAEL in the rabbit reproduction study by IRDC (1980a) that is also discussed in IRIS (U.S. EPA/IRIS 1989). As with the chronic RfD, the EPA used uncertainty factors of 10 for extrapolating from animals to humans and an additional factor of 10 for extrapolating to sensitive individuals within the human population. In addition, the U.S. EPA/OPP (1998a) used an FQPA (Food Quality Protection Act) uncertainty factor of 3 for the possible increased sensitivity of children. Thus, the acute RfD is (180 mg/kg/day ÷ (10×10×3) = 0.6 mg/kg/day). This acute RfD is a factor of about 7 above the chronic RfD and will be used in the current risk assessment for short-term exposures to children and adults. For adults, the applicability of the FQPA uncertainty factor is questionable but, as discussed further in Section 3.4, the use of this factor has no impact on the risk characterization.

The LOAEL used to define the NOAEL for the chronic RfD involved only slight decreases in hematologic parameters in dogs. These are characterized by U.S. EPA as *equivocal anemia* (U.S. EPA/OPP 1998a) or mild anemia (U.S. EPA/IRIS 1989). While there were enzymatic changes indicative of liver damage (Appendix 1), no liver pathology was noted and the dogs evidenced no overt signs of toxicity. Thus, excursions above the chronic RfD would not be expected to result in frank adverse effects and modest excursions would probably not result in clinically significant effects.

3.4. RISK CHARACTERIZATION

3.4.1. Overview. None of the exposure scenarios for workers result in levels that exceed the RfD. For members of the general public, none of the longer term exposure scenarios exceed the chronic RfD and the only acute exposure scenario that exceeds the acute RfD involves an accidental spill into a small pond.

Based on central estimates of longer term exposure for workers and the general public, the levels of exposure will be below the RfD by factors of about 25 (backpack workers) to about 50,000 (contaminated fish for members of the general public). Even for accidental exposures, the upper limits of the exposure estimates are below the RfD by factors of about 10 to over 100 except for the consumption of contaminated water by a child after an accidental spill. As detailed in the exposure assessment, the accidental spill scenario should be regarded as extreme. Nonetheless, this assessment does suggest that measures should be taken to limit exposure in the event of a large spill. Such measures would be routinely taken by the Forest Service after any spill into ambient water.

Thus, sethoxydim does not seem likely to pose any substantial risk to human health. This conclusion is consistent with the recent evaluation of sethoxydim by the U.S. EPA/OPP (1998a) in which margins of exposure were calculated to be over 100 for acute exposure and over 1000 for chronic exposure.

The only reservation associated with this assessment of sethoxydim is the same reservation associated with any risk assessment in which no plausible hazards can be identified: ***Absolute safety cannot be proven and the absence of risk can never be demonstrated***. No chemical, including sethoxydim, is studied for all possible effects. Furthermore, using data from laboratory animals to estimate hazard or the lack of hazard to humans is an uncertain process. Prudence dictates that normal and reasonable care should be taken in the handling of this or any other chemical. Notwithstanding these reservations, the use of sethoxydim in Forest Service programs does not pose any identifiable hazard to workers or members of the general public.

Although the U.S. EPA does not classify sethoxydim as an irritant to the skin and eyes, other reports not addressed by U.S. EPA suggest that skin and eye irritation can result from exposure to relatively high levels of Poast. From a practical perspective, eye or skin irritation is likely to be the only overt effect as a consequence of mishandling sethoxydim. These effects can be minimized or avoided by prudent industrial hygiene practices during the handling of the compound.

3.4.2. Workers. A quantitative summary of the risk characterization for workers is presented in Table 3-6. The quantitative risk characterization is expressed as the hazard quotient. For general exposures, the hazard index is calculated as the estimated doses from Table 3-1 divided by the chronic RfD of 0.09 mg/kg/day. For accidental exposure scenarios, the estimated doses are divided by the acute RfD of 0.6 mg/kg. Documentation for both of these RfD's is provided in Section 3.3.2.

Given the very low hazard quotients for accidental exposure, the risk characterization is reasonably unambiguous. None of the accidental exposure scenarios approach a level of concern. While the accidental exposure scenarios are not the most severe one might imagine (e.g., complete immersion of the worker or contamination of the entire body surface for a prolonged period of time) they are representative of reasonable accidental exposures. Given that the highest hazard quotient for any accidental exposure scenario - i.e., 0.08 as the upper range of the hazard quotient for wearing contaminated gloves for one hour - is a factor of 12.5 lower than the level of concern, substantially more severe and less plausible scenarios would be required to suggest a potential for systemic toxic effects. As discussed in Section 3.2, confidence in this assessment is diminished by the lack of information regarding the dermal absorption kinetics of sethoxydim in humans as well as the lack of information on the effects of additives in Poast on the dermal absorption of sethoxydim. Nonetheless, the statistical uncertainties in the estimated dermal absorption rates, both zero-order and first-order, are incorporated into the exposure assessment and risk characterization. Again, these estimates would have to be in error by a factor of greater than 12.5 in order for the basic characterization of risk to change.

Similarly, the hazard quotients for backpack and low boom broadcast applications are below a level of concern by a factor of 3 or more for upper limits and factors of over 10 for central estimates. As with the accidental exposures, there are uncertainties in these exposure assessments; however, given the low hazard quotients, these uncertainties do not impact substantially the characterization of risk.

As discussed in Section 3.1.6, sethoxydim can cause mild irritation to the skin and eyes. Quantitative risk assessments for irritation are not derived; however, from a practical perspective, eye or skin irritation is likely to be the only overt effect as a consequence of mishandling sethoxydim. These effects can be minimized or avoided by prudent industrial hygiene practices during the handling of the compound.

3.4.3. General Public. The quantitative hazard characterization for the general public is summarized in Table 3-7. Like the quantitative risk characterization for workers, the quantitative risk characterization for the general public is expressed as the hazard quotient using the U.S. EPA chronic RfD of 0.09 mg/kg/day for longer-term exposures and the U.S. EPA acute RfD of 0.6 mg/kg for acute exposures.

None of the longer-term exposure scenarios exceed a level of concern. Although there are several uncertainties in the longer-term exposure assessments for the general public, as discussed in Section 3.2, the upper limits for hazard indices are below a level of concern by factors of 25 (longer term consumption of contaminated fruit) to 2000 (longer-term consumption of fish by the general population). The risk characterization is thus relatively unambiguous: based on the available information and under the foreseeable conditions of application, there is no route of exposure or exposure scenario suggesting that the general public will be at risk from longer-term exposure to sethoxydim.

The exposure scenario for drinking water following an accidental spill results in a modest excursion about the RfD at the upper limit of exposure – i.e, a hazard quotient of 1.3. As detailed in Section 3.2.3.4.1, this exposure scenario is extreme to the point of limited plausibility. This sort of scenario is routinely used in Forest Service risk assessments as an index of the measures that should be taken to limit exposure in the event of a relatively large spill into a relatively small body of water. For sethoxydim, this standard exposure scenario may have only very limited applicability because the amount spilled, about 15 lbs, is about 4 times more sethoxydim than the Forest Service used in all of 1999. The acute drinking water scenario for water contamination of a small stream after a rainfall is much more plausible (although still highly conservative) and leads to very low hazard quotients – i.e., 0.008 to 0.04.

3.4.4. Sensitive Subgroups. There is no information to assess whether or not specific groups or individuals may be especially sensitive to the systemic effects of sethoxydim. As indicated in Section 3.1.3, the mechanism of the acute and chronic toxicity of sethoxydim is unclear but may be related to the ability of sethoxydim to uncouple oxidative phosphorylation. Other effects noted in experimental mammals include decreases in food consumption as well as decreased body weight and the occurrence of liver pathology.

3.4.5. Connected Actions. No data are available on the combined toxicity of sethoxydim with other pesticides. As noted in Section 2, Poast does contain a petroleum solvent as well as a polyoxyethylene nonylphenol emulsifier. While these agents have a substantial impact on the ecological risk assessment (Section 4), there is no information suggesting that these agents have a substantial impact on the toxicity of sethoxydim to humans or experimental mammals.

3.4.6. Cumulative Effects. This risk assessment specifically considers the effect of both acute as well as chronic exposures to sethoxydim. Consequently, the risk characterizations presented in this risk assessment encompass the potential impact of long-term exposure and cumulative effects.

Table 3-1: Summary of Worker Exposure Scenarios

Scenario	Dose (mg a.i./kg/day or event)			Exposure Assessment Worksheet
	Central	Lower	Upper	
General Exposures (dose in mg/kg/day)				
Directed ground spray (Backpack)	3.94e-03	4.22e-05	3.00e-02	C01a
Broadcast ground spray (Boom spray)	6.72e-03	6.19e-05	5.67e-02	C01b
Aerial applications		N/A		C01c
Accidental/Incidental Exposures (dose in mg a.i./kg/event)				
Immersion of Hands, 1 minute	1.94e-04	1.90e-05	7.56e-04	C02a
Contaminated Gloves, 1 hour	1.17e-02	1.14e-03	4.54e-02	C02b
Spill on hands, 1 hour	3.80e-04	2.53e-05	2.16e-03	C03a
Spill on lower legs, 1 hour	9.36e-04	6.23e-05	5.32e-03	C03b

Table 3-2: Summary of Exposure Scenarios for the General Public

Scenario	Target	Dose (mg a.i./kg/day)			Worksheet
		Central	Lower	Upper	
Acute/Accidental Exposures					
Direct spray, entire body	Child	1.44e-02	9.54e-04	8.15e-02	D01a
Direct spray, lower legs	Woman	1.44e-03	9.59e-05	8.19e-03	D01b
Dermal, contaminated vegetation	Woman	7.38e-04	8.94e-05	2.10e-03	D02
Contaminated fruit	Woman	3.53e-03	1.10e-03	7.00e-02	D03
Contaminated water, spill	Child	2.05e-01	1.94e-02	7.68e-01	D05
Contaminated water, stream	Child	4.51e-03	8.60e-05	2.11e-02	D06
Consumption of fish, general public	Man	7.38e-03	1.15e-03	1.85e-02	D08a
Consumption of fish, subsistence populations	Man	3.60e-02	5.60e-03	8.99e-02	D08b
Chronic/Longer Term Exposures					
Contaminated fruit	Woman	1.70e-04	5.30e-05	3.37e-03	D04
Consumption of water	Man	6.86e-06	3.75e-08	1.54e-05	D07
Consumption of fish, general public	Man	2.40e-07	1.88e-09	4.50e-07	D09a
Consumption of fish, subsistence populations	Man	1.94e-06	1.52e-08	3.65e-06	D09b

Table 3-3: Pesticide specific parameters used in GLEAMS modeling and estimation of concentrations in ambient water

Parameter	Clay	Loam	Sand	Comment/ Reference
Halftimes (days)				
Aquatic Sediment	190	190	190	Note 1
Foliar	3	3	3	(Knisel et al. 1992)
Soil	22	22	22	Note 2
Water	155.2	155.2	155.2	Note 3
Ko/c	100	100	100	Knisel et al. 1992
K_d	0.03	0.84	0.06	Soeda and Shiotani 1988d. See Note 4.
Water Solubility, mg/L	4700	4700	4700	pH 7 and 25°C. USDA/ARS 1995

Note 1 The mean of halftimes of 141 and 247 days for the generation of $C0_2$ from sethoxydim in an anaerobic aquatic environment (Shiotani 1990b). See Section 3.1.9.2.

Note 2 15% trapped as CO_2 over a 61 day incubation period (Shiotani. 1989). Corresponds to a k (degradation rate in soil) of 0.031 day^{-1} and a halftime of 22.2 days.

Note 3 Hydrolysis at 25°C, pH 7 from Soeda and Shiotani (1988a)

Note 4 Value of 0.84 is for sandy clay loam. Value of 0.03 is for clay loam.

Table 3-4: Estimated concentrations of sethoxydim in a small stream based on GLEAMS modeling with different soil types and annual rainfall rates and using a normalized application rate of 1 lb/acre.

Annual Rainfall	Concentrations in Ambient Water (μg/L per lb/acre) [1]					
	Clay		Loam		Sand	
	Average	Maximum	Average	Maximum	Average	Maximum
5	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00029	0.02	3.99	0.03	7.81
15	0.03	4.62	0.08	14.7	0.07	19.8
20	0.06	10.1	0.14	28.7	0.11	32.0
25	0.09	16.7	0.19	44.2	0.15	43.9
50	0.24	54.9	0.45	128	0.30	95.7
100	0.51	141	0.81	306	0.49	174
150	0.72	229	1.01	406	0.63	226
200	0.89	320	1.14	455	0.74	269
250	1.03	411	1.23	491	0.83	304

[1] The maximum concentration is the highest concentration modeled. This occurs on the day after the first rainfall. The average is calculated as the average value over a four year period assuming one application per year.

Table 3-5: Estimated concentrations of sethoxydim in a small pond based on GLEAMS modeling with different soil types and annual rainfall rates and using a normalized application rate of 1 lb/acre.

Annual Rainfall	Concentrations in Ambient Water (µg/L per lb/acre) [1]					
	Clay		Loam		Sand	
	Average	Maximum	Average	Maximum	Average	Maximum
5	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.000040	0.16	0.75	0.26	1.24
15	0.15	0.83	0.50	2.57	0.59	2.92
20	0.30	1.73	0.89	4.70	0.91	4.50
25	0.48	2.78	1.28	7.01	1.21	5.93
50	1.31	8.40	2.94	17.9	2.38	12.2
100	2.72	19.3	5.31	38.4	3.93	22.1
150	3.81	28.3	6.61	50.9	5.00	28.8
200	4.69	39.5	7.39	57.0	5.84	34.2
250	5.41	50.7	7.95	61.5	6.52	38.7

[1] The maximum concentration is the highest concentration modeled. This occurs on the day after the first rainfall. The average is calculated as the average value over a four year period assuming one application per year.

Table 3-6: Summary of risk characterization for workers[1]

Acute RfD	0.6	mg/kg/day	Sect. 3.3.3.	
Chronic RfD	0.09	mg/kg/day	Sect. 3.3.3.	

Scenario	Hazard Quotient Based on Chronic RfD			Exposure Assessment Worksheet
	Central	Lower	Upper	
General Exposures [using Chronic RfD]				
Directed ground spray (Backpack)	4e-02	5e-04	3e-01	C01a
Broadcast ground spray (Boom spray)	7e-02	7e-04	6e-01	C01b
Aerial applications	N/A			
Accidental/Incidental Exposures [using Acute RfD]				
Scenario	Hazard Quotient Based on Acute RfD			Exposure Assessment Worksheet
	Typical	Lower	Upper	
Immersion of Hands, 1 minute	3e-04	3e-05	1e-03	C02a
Contaminated Gloves, 1 hour	2e-02	2e-03	8e-02	C02b
Spill on hands, 1 hour	6e-04	4e-05	4e-03	C03a
Spill on lower legs, 1 hour	2e-03	1e-04	9e-03	C03b

[1] Hazard quotient is the level of exposure divided by the provisional RfD then rounded to one significant decimal place or digit. See Table 3-1 for summary of exposure assessment.

Table 3-7: Summary of risk characterization for the general public [1] .

Scenario	Target	Hazard Quotient			Worksheet
Chronic RfD		0.09	mg/kg/day	Sect. 3.3.3.	
Acute RfD		0.6	mg/kg/day	Sect. 3.3.3.	
		Central	Lower	Upper	
Acute/Accidental Exposures					
Direct spray, entire body	Child	2e-02	2e-03	1e-01	D01a
Direct spray, lower legs	Woman	2e-03	2e-04	1e-02	D01b
Dermal, contaminated vegetation	Woman	1e-03	1e-04	4e-03	D02
Contaminated fruit	Woman	6e-03	2e-03	1e-01	D03
Contaminated water, spill	Child	3e-01	3e-02	1.3	D05
Contaminated water, stream	Child	8e-03	1e-04	4e-02	D06
Consumption of fish, general public	Man	1e-02	2e-03	3e-02	D08a
Consumption of fish, subsistence populations	Man	6e-02	9e-03	1e-01	D08b
Chronic/Longer Term Exposures					
Contaminated fruit	Woman	2e-03	6e-04	4e-02	D04
Consumption of water	Man	8e-05	4e-07	2e-04	D07
Consumption of fish, general public	Man	3e-06	2e-08	5e-06	D09a
Consumption of fish, subsistence populations	Man	2e-05	2e-07	4e-05	D09b

[1] Hazard quotient is the level of exposure divided by the provisional RfD then rounded to one or two significant decimal places or digits. See Worksheet E01 for summary of exposure assessments. Hazard quotients >0.5 and <1.5 are shown to two significant digits. All others are rounded to one significant decimal place or integer.

4. ECOLOGICAL RISK ASSESSMENT

4.1. HAZARD IDENTIFICATION

4.1.1. Overview. Data used in the human health risk assessment to identify the toxicity of sethoxydim and Poast to humans can also be used to identify potential toxic effects in wildlife mammalian species. In mammals, the major effects of sethoxydim as well as Poast appear to be related to neurologic effects and the major signs of toxicity in mammals include lacrimation, salivation, incontinence, ataxia, tremors, and convulsions. Based on studies in mice, rats, and dogs, larger mammals appear to be more sensitive than smaller mammals. Because relatively few studies are available to support this apparent relationship, quantitative estimates of inter-species differences in sensitivity are not developed. Instead, the assumption is made that wildlife species may be as sensitive to sethoxydim as the most sensitive species on which data are available - i.e., the dog. Based on acute toxicity studies, sethoxydim and Poast appear to be about equally toxic to mammals.

The U.S. EPA/OPP (1998a) classified sethoxydim as practically non-toxic to birds and this assessment is supported by standard toxicity studies on sethoxydim in ducks and quail. No acute toxicity studies on the formulated product – i.e., Poast – are available and the U.S. EPA has indicated that such studies will need to be conducted.

Relatively little information is available of the toxicity of sethoxydim to terrestrial invertebrates. A standard acute toxicity study in bees indicates that direct applications of 10 µg sethoxydim/bee are not toxic and this value is used quantitatively in the risk assessment as a NOAEL. There is a published study on effects in beetle larvae that suggests that Poast is relatively non-toxic at application rates higher than those planned by the Forest Service.

Standard pre-emergence and post-emergence toxicity studies have been conducted on a number of terrestrial plant species and these studies are adequate for assessing the potential damage to non-target plant species posed by runoff or drift.

Unlike the case with mammals, Poast is much more toxic to aquatic species than sethoxydim. Poast contains 74% petroleum solvent and only 18 % sethoxydim. While somewhat speculative, it appears that the acute toxicity of Poast to aquatic species may be attributable almost exclusively to the solvent rather than to sethoxydim.

4.1.2. Toxicity to Terrestrial Organisms.

4.1.2.1. Mammals– As summarized in the human health risk assessment (Section 3.1), there are several standard toxicity studies in experimental mammals that were conducted as part of the registration process. Just as these studies are used in the human health risk assessment to identify the potential toxic hazards associated with exposures to sethoxydim or Poast to humans, they can also be used to identify potential toxic effects in wildlife mammalian species.

The major effects of sethoxydim as well as Poast appear to be related to neurologic effects and the major signs of toxicity in mammals include lacrimation, salivation, incontinence, ataxia, tremors, and convulsions (Section 3 and Appendix 1). The mechanism of action of sethoxydim in mammals, however, is unclear. One published study (Yamano and Morita 1995) has reported that sethoxydim uncouples mitochondrial oxidative phosphorylation *in vitro* at concentrations of 10^{-3} M.

Because toxicity data in mammals are available in only three species of experimental mammals (mice, rats, and dogs), the use of these data to assess the potential hazards to large number of diverse mammalian wildlife species is an uncertain process. One approach to this process involves identifying patterns of toxicity in mammals of various sizes (i.e., allometric relationships as discussed in SERA 2000, Section 3.2.). The acute oral LD_{50} values for sethoxydim in mice, rats, and dogs range from about 2,500 mg/kg to 6,000 mg/kg (Section 3.1.2). While this is not a particularly wide range, a comparison of gavage oral LD_{50} values in mice and rats suggests that rats are somewhat more sensitive to sethoxydim than are mice. The only acute LD_{50} data in dogs involve dosing by gelatin capsule rather than gavage and the oral LD_{50} is in the range 2500-5000 mg/kg, encompassing the values for mice and rats. The use of a different method of administration in dogs from that used in mice and rats complicates the interpretation of any allometric relationship in species sensitivity. In chronic studies, however, dogs do appear to be the most sensitive species, with the lowest observed adverse effect level (LOAEL) in the range of 17.5 to 19.9 mg/kg/day in a one-year feeding study. In contrast, the LOAEL in mice from a two-year feeding study is about 44 mg/kg/day (Takaori et al. 1981, Appendix 1). While a chronic LOAEL has not been identified in rats, the highest 2-year dietary NOAEL is 18 mg/kg/day (Burdock et al. 1981, Appendix 1), again indicating that dogs are more sensitive than either mice or rats.

Thus, the limited available data appear to suggest that larger mammals, such as dogs, are more sensitive to sethoxydim than smaller mammals such as mice and rats. Because relatively few studies are available to support this apparent relationship, quantitative estimates of inter-species differences in sensitivity are not developed. Instead, the assumption is made that wildlife species may be as sensitive to sethoxydim as the most sensitive species on which data are available - i.e., the dog.

4.1.2.2. Birds– Both acute and subchronic reproductive toxicity studies have been conducted on mallard ducks and bobwhite (Appendix 2). These studies are required by the U.S. EPA for pesticide registration and were submitted to the U.S. EPA during the registration process. Consistent with the gavage studies in rats (Section 3.1 and Appendix 1), the acute toxicity of sethoxydim to birds appears to be low, with no mortality observed after single gavage doses as high as 2000 mg/kg and no effects on reproductive performance at dietary concentrations of up to 1000 ppm (approximately 100 to150 mg/kg assuming food consumption of 10% to15% of body weight per day). The U.S. EPA/OPP (1998a) classified sethoxydim as practically non-toxic to birds. However, based on the higher acute toxicity of Poast to mammals when expressed as sethoxydim equivalents (Section 3.1.2), the U.S. EPA/OPP (1998a) indicated that an acute toxicity study of Poast in birds is required. Studies on the toxicity of Poast to birds were not encountered in the studies submitted to the U.S. EPA as of January, 2001, the time that the search of U.S. EPA's CBI files was conducted in the preparation of this risk assessment.

Bryceland et al. (1997) summarize an avian reproduction study by Beavers (1996) in which a decrease in the number of hatchlings was observed at dietary sethoxydim concentrations of 100 ppm and 500 ppm in mallard ducks. This study is summarized in the U.S. EPA/OPP ecological risk assessment of sethoxydim (Bryceland et al. 1997) but was not encountered in a search of the U.S. EPA CBI files. This is the lowest effect level for birds. Another study in bobwhite quail (Munk 1996) reports no effects on reproductive parameters at a dietary concentration of 1000 ppm. This study is also summarized in Bryceland et al. (1997).

4.1.2.3. Terrestrial Invertebrates– Two studies are available on the toxicity of sethoxydim to bees: a direct contact study and a spray study, both presented in BASF (1982). The direct contact study is a standard study required by the U.S. EPA for the registration of pesticides. In this study, the compound is dissolved in acetone or some other appropriate vehicle and applied to the thorax of groups of bees (typically 1 to 7 day old animals at 50 animals per dose). The study on sethoxydim, however, is not described in detail in BASF (1982). The only information reported is that the direct application of 10 µg sethoxydim/bee (BAS 9052) was not toxic.

Similarly, the spray study summarized in BASF (1982) is not described in detail. The summary simply indicates that a solution of sethoxydim was sprayed on the bees at a concentration simulating exposure to "the maximum recommended use rate", 2000 ppm (mg/L). The field concentrations that may be used in Forest Service programs are estimated to range from 0.56 to 9 mg/mL with a typical value of 3.59 mg/mL. These correspond to concentrations of 560 to 9000 ppm (mg/L) with a typical value of 3,590 ppm.

The only other available information on the toxicity of sethoxydim to terrestrial invertebrates comes from the publication by Agnello et al. (1986). In this study, Poast was applied at a rate of 31-38 L/ha to soybean and lima bean plants. This application is equivalent to about 8.2-10 gallons/ha [0.2642 L/gallon] or 3.3-4 gallons/acre [2.471 acres/ha] which is in turn equivalent to 5-6 lbs/acre [see Table 2-3, 0.25 gallons/acre = 0.375 lb/acre, 1 gallon/acre = 1.5 lbs/acre]. Mexican bean beetle larvae (*Epilachna varivestis*, Coleoptera:Coccinellidae) were then reared on the treated plants. The only potentially adverse effects noted were a slight increase in days to pupation (19.1 days in treated animals compared to 17.7 days in control animals). In addition, there were significant increases in both the number of egg masses as well as total number of eggs produced by beetles feeding on sethoxydim treated plants relative to beetles feeding on untreated plants. While a delay in pupation would be regarded generally as an adverse effect, the increases in the number of eggs and egg masses would not necessarily be regarded as adverse.

4.1.2.4. Terrestrial Plants (Macrophytes) – Two types of toxicity studies on terrestrial plants are typically required by the U.S. EPA for the registration of herbicides: Tier I and Tier II. Tier I studies are seedling emergence studies and typically involve exposure of seeds in a petri dish and the measurement of the proportion of seeds that emerge after treatment with the herbicide at various application rates (mg compound/cm^2 surface area). Tier II studies involve both seedling emergence assays and assays referred to as *vegetative vigor*. In the seedling emergence assay for Tier II, exposure is through contaminated soil - i.e., the compound is incorporated into the soil and the response of seedlings planted in the contaminated soil is observed. The *vegetative vigor* assay involves direct foliar spray of the growing plant with subsequent measurements of plant growth and survival.

Both sets of studies have been conducted on sethoxydim. An early study (Ludwig 1980) was identified in the EPA/FIFRA files and a full text copy of this study has been reviewed. In the U.S. EPA's RED chapter on the ecological effects of sethoxydim (Bryceland et al. 1997), additional and more recent Tier I and Tier II studies are described.

Ludwig (1980) conducted a Tier II study on Poast. The study specifically states that Poast and not just sethoxydim was assayed. The emergence assays consisted of the incorporation of Poast into soil at initial concentrations that mimic application rates of 0.2, 0.4, 0.8, 1.5, and 3.0 lb/acre. The species tested in this assay included tomatoes, lettuce, cabbage, carrots, onions, cucumbers, corn, soybeans, oats, and perennial ryegrass. The plants were observed for up to 120 days after application. Oats and ryegrass were severely damaged over the full course of the study at all dose rates - i.e., a NOAEL was not determined. Corn was damaged at day 20 by all doses but recovered by day 29 at the dose rates of 0.2 and 0.4 lb/acre.

In the postemergence application, Poast was sprayed on to the growing plants, again at application rates of 0.2, 0.4, 0.8, 1.5, and 3.0 lb/acre. No effects were seen on tomatoes, carrots, lettuce, and onions. Severe adverse effects were observed at all dose levels for ryegrass, oats, and corn. The toxicity of Poast to cabbage, soybeans, and cucumbers was between these most and least sensitive plant groups (Ludwig 1980).

The more recent Tier II study summarized in Bryceland et al. (1997) is consistent with the earlier study by Ludwig (1980) but used lower application rates that defined a NOAEL. The most sensitive species in the pre-emergence assay was ryegrass (NOAEL of 0.059 lb/acre and an EC_{25} of 0.065 lb/acre) followed by oats (NOAEL of 0.059 lb/acre and an EC_{25} of 0.197 lb/acre). The least sensitive species was corn (NOAEL of 0.235 lb/acre and an EC_{25} of 0.418 lb/acre). In the vegetative vigor (postemergence) assay, corn was most sensitive in terms of the NOAEL (NOAEL of 0.0074 lb/acre and an EC_{25} of 0.021 lb/acre) and ryegrass was most sensitive in terms of the EC_{25} (NOAEL of 0.025 lb/acre and an EC_{25} of 0.019 lb/acre).

4.1.2.5. Terrestrial Microorganisms– The effect of sethoxydim on mixed bacterial populations in sandy loam have been assayed by Roslycky (1987). At soil concentrations of 50 ppm (µg/g), no remarkable effects were noted. At 1000 ppm, however, substantial but transient increases were noted in the population of actinomycete and various bacteria and slight decreases were noted in the population of various fungi. In a separate series of pure culture studies in artificial media, a slight inhibition of oxygen consumption was observed at concentrations as low as 1 ppm (µg/mL)

(Roslycky 1987, Table 1, p. 415). Various species and strains of *Azotobacter* were much less sensitive to sethoxydim, with inhibition of growth and nitrogen fixation in liquid shake cultures at concentrations of 5,000 ppm (Roslycky (1991).

Reichad et al. (1997) assayed the effects of various herbicides on a plant pathogen, *Sclerotinia trifoliorum*, which caused stem rot in alfalfa and other legumes. The pathogen was cultured in dextrose agar. At a concentration of 10 µg/mL (10 ppm), sethoxydim inhibited mycelial growth. At 1000 µg/mL (1000 ppm), sclerotium weight was reduced.

4.1.3. Aquatic Organisms.

4.1.3.1. Fish– Standard toxicity bioassays to assess the effects of sethoxydim on fish are summarized in Appendix 3. The acute static LC_{50} values for technical grade sethoxydim range from 170 to 265 ppm (mg/L) in bluegill sunfish and rainbow trout, respectively (BASF 1982). The formulated product, Poast, however, is much more toxic with LC_{50} values of 2.6 ppm in bluegill sunfish and 1.2 ppm in rainbow trout (Bowman and Howell 1991a,b).

The higher toxicity (lower LC_{50} values) of Poast compared to sethoxydim is probably attributable to the presence of naphtha solvent in Poast. As summarized in Section 2, Poast contains 74% petroleum solvent (approximately 740,000 mg/L) but only 18 % sethoxydim (1.5 lbs per gallon or 680.5 g/3.785 L or 179,789 mg/L). Information on the aquatic toxicity of the specific solvent used in Poast has not been encountered in the literature. A related solvent (Stoddard Solvent) has LC_{50} values of 0.5 to 5.0 ppm (mg/L) (Anon. 1996).

As detailed by Finney (1971, p. 233), the toxicity of a mixture under the assumption of concentration addition may be calculated as:

$$\zeta_M = \zeta_1 / (\pi_1 + \pi_2 (\zeta_1/\zeta_2))$$

where ζ is some measure of uniform toxicity, such as the LC_{50} and π_i is the proportion of the i^{th} agent in the mixture. Taking 200 ppm as the approximate LC_{50} for sethoxydim (ζ_2) and 0.5 to 5.0 ppm range for the plausible LC_{50} values for the petroleum solvent (ζ_1) in Poast and using the proportions of 0.74 for the solvent (π_1) and 0.18 for sethoxydim (π_2)), the estimated LC_{50} value for Poast would range from about 0.67 ppm to 6.8 ppm using the above equation, with sethoxydim itself making virtually no contribution to the toxicity of the mixture - i.e., the term $\pi_1(\zeta_1/\zeta_2)$ ranges from 0.0025 to 0.025. Thus, the acute toxicity of Poast to fish may be attributable almost exclusively to the solvent rather than to sethoxydim. Further, because the toxic components in the solvent are volatilized and/or sorbed to sediments, the apparent acute toxic potency of the solvent and thus of Poast may overestimate the potential effects in the environment (Anon. 1996). This is considered quantitatively in the exposure and dose response assessments (Sections 4.2 and 4.3) as well as the risk characterization (Section 4.4).

4.1.3.2. Amphibians– Neither the published literature nor the U.S. EPA files include data regarding the toxicity of sethoxydim to amphibian species.

4.1.3.3. Aquatic Invertebrates– Standard toxicity bioassays have been conducted to assess the effects of sethoxydim and Poast on an aquatic invertebrate, *Daphnia magna*. As with fish, the acute toxicity of sethoxydim (LC_{50} = 78.1 ppm) is less than that of Poast (LC_{50} = 2.6 ppm) by a factor of about 30. Sethoxydim is less toxic to daphnids than fish by a factor of about two to three [170 to 265 ppm ÷ 78.1 ppm ≈ 2.2 to 3.4]. The LC_{50} values of Poast to daphnids and fish are virtually identical (1.2 ppm to 2.6 ppm).

The U.S. EPA has asked for a life cycle study in daphnids for both sethoxydim and Poast (Bryceland et al. 1997). These studies were not encountered in the search of the EPA files conducted as part of this risk assessment (in January 2001).

4.1.3.4. Aquatic Plants– Standard toxicity bioassays to assess the effects of sethoxydim on aquatic plants were submitted to the U.S. EPA in support of the registration of sethoxydim and are summarized in Appendix 3. The most sensitive species on which data are available is the aquatic macrophyte, *Lemna gibba* (duckweed), with an NOEC of < 0.56 ppm (Hughes 1980a). Since the reported effect consisted of an increase rather than a decrease in growth, however, it is not clear that the study in *Lemna gibba* constitutes an adverse effect. Unicellular algae are less sensitive with LC_{50} values greater than 5.6 ppm (Hughes 1980a,b).

In a general screening study involving a variety of different herbicides, Schrader et al. (1998) have reported that sethoxydim has no inhibitory effect on *Oscillatoria chalybea*, a cyanobacterium that produces an unpleasant odor in water, at concentrations of up to 1 mM (327.5 ppm).

4.1.3.5. Other Aquatic Microorganisms– U.S. EPA files do not include data regarding the toxicity of sethoxydim to other aquatic microorganisms and no studies on this group have been encountered in the open literature.

4.2. EXPOSURE ASSESSMENT

4.2.1. Overview. Terrestrial animals might be exposed to any applied herbicide from direct spray, the ingestion of contaminated media (vegetation, prey species, or water), grooming activities, or indirect contact with contaminated vegetation. In acute exposure scenarios and under the assumption of 100% dermal absorption, the highest exposures for small terrestrial vertebrates will occur after a direct spray and could reach up to about 7 mg/kg under typical exposure conditions and up to about 9 mg/kg under more extreme conditions. Other routes of exposure, like the consumption of contaminated water or contaminated vegetation, generally will lead to much lower levels of exposure. In chronic exposure scenarios, the maximum estimated daily doses for a small vertebrate is 0.006 mg/kg/day. Based on general relationships of body size to body volume, larger vertebrates will be exposed to lower doses and smaller animals, like insects, will be exposed to much higher doses under comparable exposure conditions. Because of the apparent low toxicity of sethoxydim to animals, the rather substantial variations in the exposure assessments have little impact on the assessment of risk to terrestrial animals.

The primary hazards to non-target terrestrial plants are associated with unintended direct deposition or spray drift. Unintended direct spray will result in an exposure level equivalent to the application rate. At least some plants that are sprayed directly with sethoxydim at or near the recommended range of application rates will be damaged. Based on the AgDRIFT model, no more than 0.0058 of the application rate would be expected to drift 100 m offsite after low boom ground applications. The AgDrift model is discussed further in Section 4.2.3.2.

In order to encompass a wide range of field conditions, GLEAMS simulations were conducted for clay, loam, and sand at annual rainfall rates from 5 to 250 inches. Under arid conditions (i.e., annual rainfall of about 10 inches or less), there is no or very little runoff. Under these conditions, degradation, not dispersion, accounts for the decrease of sethoxydim concentrations in soil. At higher rainfall rates, plausible offsite movement of sethoxydim results in runoff losses that range from about negligible up to about 0.5 of the application rate, depending primarily on the amount of rainfall rather than differences in soil type.

Exposures to aquatic species are impacted by the same factors that influence terrestrial plants except the directions of the impact are reversed. In other words, in very arid environments substantial contamination of water is unlikely. In areas with increasing levels of rainfall, exposures to aquatic organisms are more likely to occur. The anticipated concentrations in ambient water encompass a very broad range, 0.000094 to 0.003 mg/L, depending primarily on differences in rainfall rates.

4.2.2. Terrestrial Animals. Terrestrial animals might be exposed to any applied herbicide from direct spray, the ingestion of contaminated media (vegetation, prey species, or water), grooming activities, or indirect contact with contaminated vegetation.

In this exposure assessment, estimates of oral exposure are expressed in the same units as the available toxicity data (i.e., oral LD_{50} and similar values). As in the human health risk assessment, these units are usually expressed as mg of agent per kg of body weight and abbreviated as mg/kg body weight. For dermal exposure, the units of measure usually are expressed in mg of agent per cm^2 of surface area of the organism and abbreviated as mg/cm^2. In estimating dose, however, a distinction is made between the exposure dose and the absorbed dose. The *exposure dose* is the amount of material on the organism (i.e., the product of the residue level in mg/cm^2 and the amount of surface area exposed), which can be expressed either as mg/organism or mg/kg body weight. The *absorbed dose* is the proportion of the exposure dose that is actually taken in or absorbed by the animal.

For the exposure assessments discussed below, general allometric relationships are used to model exposure. In the biological sciences, allometry is the study of the relationship of body size or mass to various anatomical, physiological, or pharmacological parameters (e.g., Boxenbaum and D'Souza 1990). Allometric relationships take the general form:

$$y = aW^x$$

where ***W*** is the weight of the animal, ***y*** is the variable to be estimated, and the model parameters are **a** and **x**.

For most allometric relationships used in this exposure assessment, **x** ranges from approximately 0.65 to 0.75. These relationships dictate that, for a fixed level of exposure (e.g., levels of a chemical in food or water), small animals will receive a higher dose, in terms of mg/kg body weight, than large animals.

Estimates of exposure are given for both a small and a large mammal as well as a small and a large bird. For many compounds, allometric relationships for interspecies sensitivity to toxicants indicate that for exposure levels expressed as mg toxicant per kg body weight (mg/kg body weight), large animals, compared with small animals, are more sensitive.

As discussed in Sections 3.1.2 and 3.1.3, the limited data on sethoxydim do suggest that larger mammals, specifically the dog, appear to be more sensitive to sethoxydim than smaller mammals (i.e., rats and mice) but the data are not adequate to support the development of quantitative allometric relationships for toxicity. There are no data to assess species sensitivity in small and large birds.

The exposure assessments for terrestrial animals are summarized in Table 4-1. As with the human health exposure assessment, the computational details for each exposure assessment presented in this section are provided in the attached worksheets (worksheets F01 through F14).

4.2.2.1. Direct Spray – In the broadcast application of any herbicide, wildlife species may be sprayed directly. This scenario is similar to the accidental exposure scenarios for the general public discussed in section 3.2.3.2. In a scenario involving exposure to direct spray, the extent of dermal contact depends on the application rate, the surface area of the organism, and the rate of absorption.

For this risk assessment, three groups of direct spray exposure assessments are conducted. The first, which is defined in worksheet F01, involves a 20 g mammal that is sprayed directly over one half of the body surface as the chemical is being applied. The range of application rates as well as the typical application rate is used to define the amount deposited on the organism. The absorbed dose over the first day (i.e., a 24-hour period) is estimated using the assumption of first-order dermal absorption. In the absence of any data regarding dermal absorption in a small mammal, the estimated absorption rate for humans is used (see section 3.1.7). An empirical relationship between body weight and surface area (Boxenbaum and D'Souza 1990) is used to estimate the surface area of the animal. The estimates of absorbed doses in this scenario may bracket plausible levels of exposure for small mammals based on uncertainties in the dermal absorption rate of sethoxydim.

Other, perhaps more substantial, uncertainties affect the estimates for absorbed dose. For example, the estimate based on first-order dermal absorption does not consider fugitive losses from the surface of the animal and may overestimate the absorbed dose. Conversely, some animals, particularly birds and mammals, groom frequently, and grooming may contribute to the total absorbed dose by direct ingestion of the compound residing on fur or feathers. Furthermore, other vertebrates, particularly amphibians, may have skin that is far more permeable than the skin of most mammals (Moore 1964).

Quantitative methods for considering the effects of grooming or increased dermal permeability are not available. As a conservative upper limit, the second exposure scenario, detailed in worksheet F02a, is developed in which complete absorption over day 1 of exposure is assumed.

Because of the relationship of body size to surface area, very small organisms, like bees and other terrestrial insects, might be exposed to much greater amounts of sethoxydim per unit body weight, compared with small mammals. Consequently, a third exposure assessment is developed using a body weight of 0.093 g for the honey bee (USDA/APHIS 1993). Because there is no information regarding the dermal absorption rate of sethoxydim by bees or other invertebrates, this exposure scenario, detailed in worksheet F02b, also assumes complete absorption over the first day of exposure.

Direct spray scenarios are not given for large mammals. As noted above, allometric relationships dictate that large mammals will be exposed to lesser amounts per unit body weight of a compound in any direct spray scenario than smaller mammals. As detailed further in Section 4.4, the direct spray scenarios for the small mammal are substantially below a level of concern. Consequently, elaborating direct spray scenarios for a large mammal would have no impact on the characterization of risk.

4.2.2.2. Indirect Contact – As in the human health risk assessment (see section 3.2.3.3), the only approach for estimating the potential significance of indirect dermal contact is to assume a relationship between the application rate and dislodgeable foliar residue. The study by Harris and Solomon (1992) is used to estimate that the dislodgeable residue will be approximately 10 times less than the nominal application rate.

Unlike the human health risk assessment in which transfer rates for humans are available, there are no transfer rates available for wildlife species. As discussed in Durkin et al. (1995), the transfer rates for humans are based on brief (e.g., 0.5- to 1-hour) exposures that measure the transfer from contaminated soil to uncontaminated skin. Species of wildlife are likely to spend longer periods of time, compared to humans, in contact with contaminated vegetation.

It is reasonable to assume that for prolonged exposures a steady-state may be reached between levels on the skin, rates of absorption, and levels on contaminated vegetation, although there are no data regarding the kinetics of such a process. The bioconcentration data on sethoxydim (section 3.2.3.5) as well as its high water solubility and low octanol/water partition coefficient suggest that sethoxydim is not likely to partition from the surface of contaminated vegetation to the surface of skin, feathers, or fur. Thus, a plausible partition coefficient is unity (i.e., the concentration of the chemical on the surface of the animal will be equal to the dislodgeable residue on the vegetation).

Under these assumptions, the absorbed dose resulting from contact with contaminated vegetation will be one-tenth that associated with comparable direct spray scenarios. As discussed in the risk characterization for ecological effects (section 4.4), the direct spray scenarios result in exposure levels far below those of toxicological concern. Consequently, details of the indirect exposure scenarios for contaminated vegetation are not further elaborated in this document.

4.2.2.3. Ingestion of Contaminated Vegetation or Prey – Since sethoxydim will be applied to vegetation, the consumption of contaminated vegetation is an obvious concern and separate exposure scenarios are developed for acute and chronic exposure scenarios for a small mammal (Worksheets F04a and F04b) and large mammal (Worksheets F10, F11a, and F11b) as well as large birds (Worksheets F12, F13a, and F13b).

A small mammal is used because allometric relationships indicate that small mammals will ingest greater amounts of food per unit body weight, compared with large mammals. The amount of food consumed per day by a small mammal (i.e., an animal weighing approximately 20 g) is equal to about 15% of the mammal's total body weight (U.S. EPA/ORD 1989). When applied generally, this value may overestimate or underestimate exposure in some circumstances. For example, a 20 g herbivore has a caloric requirement of about 13.5 kcal/day. If the diet of the herbivore consists largely of seeds (4.92 kcal/g), the animal would have to consume a daily amount of food equivalent to approximately 14% of its body weight [(13.5 kcal/day ÷ 4.92 kcal/g)÷20g = 0.137]. Conversely, if the diet of the herbivore consists largely of vegetation (2.46 kcal/g), the animal would have to consume a daily amount of food equivalent to approximately 27% of its body weight [(13.5 kcal/day ÷ 2.46 kcal/g)÷20g = 0.274] (U.S. EPA/ORD 1993, pp.3-5 to 3-6). For this exposure assessment, the amount of food consumed per day by a small mammal is estimated at about 3.6 g/day from the general allometric relationship for food consumption in rodents (U.S. EPA/ORD 1993, p. 3-6). As detailed in Section 4.4, this variability in food consumption estimates has little impact on the characterization of risk because any plausible levels of exposure are far below levels of concern.

A large herbivorous mammal is included because empirical relationships of concentrations of pesticides in vegetation, discussed below, indicate that grasses may have substantially higher pesticide residues than other types of vegetation such as forage crops or fruits (Worksheet A04). Grasses are an important part of the diet for some large herbivores, but small mammals do not consume grasses as a substantial proportion of their diet. Thus, even though using residues from grass to model exposure for a small mammal is the most conservative approach, it is not generally applicable to the assessment of potential adverse effects. Hence, in the exposure scenarios for large mammals, the consumption of contaminated range grass is modeled for a 70 kg herbivore, like a deer. Caloric requirements for herbivores and the caloric content of vegetation are used to estimate food consumption based on data from U.S. EPA/ORD (1993). Details of these exposure scenarios are given in worksheets F10 for acute exposures as well as Worksheets F11a and F11b for longer-term exposures.

For the acute exposures, the assumption is made that the vegetation is sprayed directly – i.e., the animal grazes on site – and that 100% of the diet is contaminated (Worksheet F10). While appropriately conservative for acute exposures, neither of these assumptions are plausible for longer-term exposures. Thus, for the longer-term exposure scenarios for the large mammal, two sub-scenarios are given. The first is an on-site scenario that assumes that a 70 kg herbivore consumes short grass for a 90 day period after application of the chemical. The contaminated vegetation accounts for 10 to 100% of the diet assuming that the animal would spend 10 to 100% of the grazing time at the application site. Because the animal is assumed to be feeding at the application site, drift is set to unity - i.e., direct spray. This scenario is detailed in Worksheet F11a. The second sub-scenario is similar except the assumption is made that the animal is grazing at distances of 25 to 100 feet from the application site (lowing risk) but that the animal consumes 100% of the diet from the contaminated area (increasing risk). For this scenario, detailed in Worksheet F11b, AgDRIFT is used to estimate deposition on the off-site vegetation. Drift estimates from AgDrift are summarized in Worksheet A06 and this model is discussed further in Section 4.2.3.2.

The consumption of contaminated vegetation is also modeled for a large bird. For these exposure scenarios, the consumption of range grass by a 4 kg herbivorous bird, like a Canada Goose, is modeled for both acute (Worksheet F12) and chronic exposures (Worksheets F13a and F13b). As with the large mammal, the two chronic exposure scenarios involve sub-scenarios for on-site as well as off-site exposure.

For this component of the exposure assessment, the estimated amounts of pesticide residue in vegetation are based on the relationship between application rate and residue rates on different types of vegetation. As summarized in worksheet A04, these residue rates are based on the re-analysis of the data from Hoerger and Kenaga (1972) conducted by Fletcher et al. (1994). This is the same approach taken by U.S. EPA in their ecological risk assessment of sethoxydim (Bryceland et al. 1997).

Similarly, the consumption of contaminated insects is modeled for a small (10g) bird. No monitoring data have been encountered on the concentrations of sethoxydim in insects. Following the approach used by Bryceland et al. (1997), the empirical relationships recommended by Fletcher et al. (1994) are used as surrogates as detailed in worksheet F14.

In addition to the consumption of contaminated vegetation and insects, sethoxydim may reach ambient water and bioconcentrate in fish. Thus, a separate exposure scenario is developed for the consumption of contaminated fish by a predatory bird in both acute (Worksheet F08) and chronic (Worksheet F09) exposures. Because predatory birds usually consume more food per unit body weight than do predatory mammals (U.S. EPA/ORD 1993, pp. 3-4 to 3-6), separate exposure scenarios for the consumption of contaminated fish by predatory mammals are not developed.

4.2.3. Terrestrial Plants. In general, the primary hazard to non-target terrestrial plants associated with the application of most herbicides is unintended direct deposition or spray drift. In addition, herbicides may be transported off-site by percolation or runoff or by wind erosion of soil.

4.2.3.1. Direct Spray – Unintended direct spray will result in an exposure level equivalent to the application rate. For many types of herbicide applications - e.g., rights-of-way management, it is plausible that some non-target plants immediately adjacent to the application site could be sprayed directly. This type of scenario is modeled in the human health risk assessment for the consumption of contaminated vegetation. As with any effective herbicide, it is likely that any non-target vegetation sprayed directly with sethoxydim at or near the range of recommended application rates would be damaged.

4.2.3.2. Off-Site Drift – Data regarding the drift of sethoxydim during ground applications were not found in the literature. Because off-site drift is more or less a physical process that depends on droplet size and meteorological conditions rather than the specific properties of the herbicide, estimates of off-site drift can be made based on data for other compounds.

Off-site drift will be estimated using AGDRIFT (Teske et al. 2001). AGDRIFT is a model developed as a joint effort by the EPA Office of Research and Development and the Spray Drift Task Force, a coalition of pesticide registrants. AGDRIFT is based on the algorithms in FSCBG (Teske and Curbishley. 1990), a drift model previously used by USDA. AGDRIFT represents a detailed evaluation of a very large number of field studies and is likely to provide plausible estimates of drift. Further details of AGDRIFT, including the executable file, are available at http://www.agdrift.com/. For aerial applications, AGDRIFT permits very detailed modeling of drift based on the chemical and physical properties of the applied product, the configuration of the aircraft, as well as wind speed and temperature. For ground applications, AGDRIFT provides estimates of drift based solely on distance downwind as well as the types of ground application: low boom spray, high boom spray, and orchard airblast. Representative estimates based on AGDRIFT (Version 1.16) are given in Worksheet A06b).

Estimates of drift for ground applications is given in Worksheet A06. Sethoxydim will typically be applied by low boom ground spray and thus these estimates are used in the current risk assessment.

Drift distance can be estimated from a consideration of Stoke's law, which describes the viscous drag on a moving sphere. According to Stoke's law:

$$v = \frac{D^2 \cdot g}{18n}$$

or

$$v = 2.87 \cdot 10^5 \cdot D^2$$

where ***v*** is the velocity of fall (cm sec^{-1}), ***D*** is the diameter of the sphere (cm), ***g*** is the force of gravity (980 cm sec^{-2}), and ***n*** is the viscosity of air ($1.9 \cdot 10^{-4}$ g sec^{-1} cm^{-1} at 20°C) (Goldstein et al. 1974).

In typical backpack ground sprays, droplet sizes are greater than 100 μ, and the distance from the spray nozzle to the ground is 3 feet or less. In mechanical sprays, raindrop nozzles might be used. These nozzles generate droplets that are usually greater than 400 μ, and the maximum distance above the ground is about 6 feet. In both cases, the sprays are directed downward.

Thus, the amount of time required for a 100 μ droplet to fall 3 feet (91.4 cm) is approximately 3.2 seconds,

$$91.4 \div (2.87 \cdot 10^5 (0.01)^2).$$

The comparable time for a 400 μ droplet to fall 6 feet (182.8 cm) is approximately 0.4 seconds,

$$182.8 \div (2.87 \cdot 10^5 (0.04)^2).$$

For most applications, the wind velocity will be no more than 5 miles/hour, which is equivalent to approximately 7.5 feet/second (1 mile/hour = 1.467 feet/second). Assuming a wind direction perpendicular to the line of application, 100 μ particles falling from 3 feet above the surface could drift as far as 23 feet (3 seconds · 7.5 feet/second). A raindrop or 400 μ particle applied at 6 feet above the surface could drift about 3 feet (0.4 seconds · 7.5 feet/second).

For backpack applications, wind speeds of up to 15 miles/hour are allowed in Forest Service programs. At this wind speed, a 100 μ droplet can drift as far as 68 feet (3 seconds · 15 · 1.5 feet/second). Smaller droplets will of course drift further, and the proportion of these particles in the spray as well as the wind speed will affect the proportion of the applied herbicide that drifts off-site.

4.2.3.3. Runoff – Sethoxydim or any other herbicide may be transported to off-site soil by runoff or percolation. Both runoff and percolation are considered in estimating contamination of ambient water. For assessing off-site soil contamination, however, only runoff is considered. The approach is reasonable because off-site runoff will contaminate the off-site soil surface and could impact non-target plants. Percolation, on the other hand, represents the amount of the herbicide that is transported below the root zone and thus may impact water quality but should not affect off-site vegetation.

Based on the results of the GLEAMS modeling (Section 3.2.3.4.2), the proportion of the applied sethoxydim was estimated for clay, loam, and sand at rainfall rates ranging from 5 inches to 250 inches per year. These results are summarized in Worksheet G04.

4.2.3.4. Wind Erosion – Wind erosion is a major transport mechanism for soil (e.g., Winegardner 1996) and is associated with the environmental transport of herbicides (Buser 1990). Although numerous models were developed for wind erosion (e.g., Strek and Spaan 1997, Strek and Stein 1997), the quantitative aspects of soil erosion by wind are extremely complex and site specific. Field studies conducted on agricultural sites found that annual wind erosion may account for soil losses ranging from 2 to 6.5 metric tons/ha (Allen and Fryrear 1977). The upper range reported by Allen and Fryrear (1977) is nearly the same as the rate of 2.2 tons/acre (5.4 tons/ha) recently reported by the USDA (1998). The temporal sequence of soil loss (i.e., the amount lost after a specific storm event involving high winds) depends heavily on soil characteristics as well as meteorological and topographical conditions.

This risk assessment uses average soil losses ranging from 1 to 10 tons/ha·year, with a typical value of 5 tons/ha·year. The value of 5 tons/ha·year is equivalent to 500 g/m^2 [1 ton=1000 kg and 1 ha = 10,000 m^2] or 0.05 g/cm^2 [$1m^2$=10,000 cm^2]. Thus, using a soil bulk density of 1.5 g/cm^3 (Knisel et al. 1992, p. 56), the depth of soil removed from the surface per year would be 0.033 cm[(0.05 g/cm^2)÷ (1.5 g/cm^3)]. The average amount per day would be about 0.00007 cm/day [0.033 cm per year ÷ 365 days/year]. The upper range of the typical daily loss would thus be about 0.00009 cm/day.

The amount of sethoxydim that might be transported by wind erosion depends on several factors, including the application, the depth of incorporation into the soil, the persistence in the soil, the wind speed, and the topographical and surface conditions of the soil. Under desirable conditions, like relatively deep (10 cm) soil incorporation, low wind speed, and surface conditions that inhibit wind erosion, it is likely that wind transport of sethoxydim would be neither substantial nor significant.

Any number of undesirable exposure scenarios could be constructed. As a reasonable 'worst case' scenario, it is assumed that sethoxydim is applied to arid soil, that it is incorporated into the top 1 cm of soil, that minimal rainfall occurs for a 2-month period, that the degradation and dispersion of sethoxydim in the soil is negligible over the 2-month period, and that local conditions favor a high rate of soil loss (i.e., smooth, sandy surface with high wind speeds) that is a factor at the upper limit of the typical rate (i.e., 0.00009 cm/day). Under those conditions, 0.0054 [0.00009 cm/day × 60 days ÷ 1 cm] of the applied sethoxydim would be lost due to wind erosion. This is virtually identical to the estimates of off-site contamination from low-boom applications at a distance of 100 feet from the application site and is greater than drift that would be expected 500 feet offsite (0.0015 for low-boom applications from Worksheet A06) by a factor 3.6 [0.0054 ÷ 0.0015 = 3.6]. Thus, in areas where wind erosion of soil may occur, wind erosion could be a more important mode of offsite movement than drift during application.

The deposition of the sethoxydim contaminated soil also will vary substantially with local conditions. Under desirable conditions, the soil might be dispersed over a very large area and be of no toxicological consequence. In some cases, however, local topographical conditions might favor the deposition and concentration of contaminated dust from a large treated area into a relatively small off-site area. An objective approach for modeling these types of events was not available in the literature. For this risk assessment, neither concentration nor dispersion is considered quantitatively.

4.2.4. Aquatic Organisms. The potential for effects on aquatic species are based on estimated concentrations of sethoxydim in water that are identical to those used in the human health risk assessment (Section 3.2.3.4). Thus, for an accidental spill, the central estimate for the concentration of sethoxydim in a small pond is estimated at about 2.7 mg/L with a range from 0.4 to 6.8 mg/L (Section 3.2.3.4.1). For longer term exposure scenarios, the expected concentrations of sethoxydim in ambient water range from 0.0001 to 0.003 mg/L with a central value of 0.0015 mg/L. (Section 3.2.3.4.2).

4.3. DOSE-RESPONSE ASSESSMENT

4.3.1. Overview. A summary of all toxicity values used in this risk assessment is given in Table 4-2. For terrestrial mammals, the dose-response assessment is based on the same data as the human health risk assessment (i.e., an estimated chronic NOAEL of 9 mg/kg/day and an acute NOAEL of 180 mg/kg/day. For birds, a chronic NOAEL of 10 mg/kg bw/day is used from a subchronic feeding study that assayed for both signs of systemic toxicity as well as reproductive capacity. The potential effects of acute exposures of birds are characterized using an acute NOAEL of 500 mg/kg/day. For terrestrial invertebrates, the dose-response assessment is based on a study in honey bees in which a dose of 107 mg/kg bw caused no apparent adverse effects.

Sethoxydim is a herbicide that causes adverse effects in a variety of target and non-target plant species. In general, grasses are much more sensitive to sethoxydim than broad-leaved plants. For exposures associated with direct sprays or drift, NOAELs for sensitive and tolerant species are 0.006 lbs/acre and 0.03 lbs/acre, respectively. With respect to soil contamination, the NOAEL for sensitive species is 0.059 lbs/acre and the NOAEL for tolerant species is 0.235 lbs/acre.

Sethoxydim has a low order of acute toxicity to fish and aquatic invertebrates, with LC_{50} values of 1.2 and 2.6 mg/L, respectively. Aquatic macrophytes are much more sensitive to sethoxydim than fish or invertebrates. For aquatic plants, a NOAEL of 0.25 mg/L is used to assess the consequences of sethoxydim exposure.

4.3.2. Toxicity to Terrestrial Organisms.

4.3.2.1. Mammals– As summarized in the dose-response assessment for the human health risk assessment (Section 3.3.3.), the acute NOAEL in experimental mammals is taken as 180 mg/kg with an associated LOAEL of 480 mg/kg and the chronic NOAEL is taken as 9 mg/kg/day with an associated LOAEL of 18 mg/kg. For this risk assessment, these NOAEL's will be used to characterize risk. The acute NOAEL is based on reproductive toxicity - i.e., 23 day exposures on days 6-28 of gestation (IRDC 1980a) - and is thus a very conservative index in that many of the acute exposures estimated in Section 4.2 will be for much less than 23 days..

The U.S. EPA/OPP (1998a) has taken a somewhat different approach. Acute risks in mammals were not assessed because the acute risks to birds did not trigger concern. For the chronic risk assessment, the U.S. EPA/OPP (1998a) used a dietary NOAEL of 3000 ppm. The basis for the selection of the 3000 ppm NOAEL is unclear and is not specified in U.S. EPA/OPP (1998a). As noted in 3.3.2, dietary concentrations of 600 ppm and 3600 ppm were classified as adverse effect levels (AEL's) in dogs. In addition, longer-term dietary concentrations of 360 ppm and 1080 ppm have been associated with histopathologic changes in the liver of mice (Takaori et al. 1981 as detailed in Appendix 1).

4.3.2.2. Birds – As noted in section 4.1.2.2, sethoxydim has been classified by the U.S. EPA (Bryceland et al. 1997) as essentially non-toxic to birds in acute exposures. The lowest 5-day dietary LD_{50} for birds is >5000 ppm (Appendix 2). The U.S. EPA (Bryceland et al. 1997) uses the dietary concentration of 5000 ppm as the toxicity benchmark for the characterization of risk following acute exposure.

The U.S. EPA (Bryceland et al. 1997) uses reported dietary concentrations. This approach, however, may be under-protective. Laboratory diets generally involve the use of dry food. Dry laboratory chow usually has a higher caloric content than food consumed in the wild, if only because most food consumed in the wild has a high water content. In addition, most reported concentrations of a pesticide in environmental samples are given on a wet (natural) weight rather than a dry (dedicated) weight basis. Consequently, animals tend to eat greater amounts of food in the wild than they do under laboratory conditions (U.S. EPA/ORD 1993). Consequently, for a fixed concentration in food, ingested doses expressed as mg/kg bw/day often will be higher in free living animals than in laboratory animals.

Because of these relationships, Forest Service risk assessments use doses expressed as mg/kg body weight for both the exposure and dose-response assessments. As detailed in the worksheets, information on caloric requirements and caloric values of different foods are used to estimate the amount of a particular food that an animal will use.

The studies summarized in Appendix 2 do not specify food consumption rates. Based on average measured food consumption and body weight from other laboratory toxicity studies on mallard ducks and pheasant, the daily food consumption rates of the birds are approximately 10% to 20% of the body weight. Taking a conservative value of 10%, the 5000 ppm benchmark dose used by U.S. EPA corresponds to a daily dose of 500 mg/kg bw and this value will be used in the current risk assessment as a benchmark dose for acute exposure.

As noted in Section 4.1.2.2, the U.S. EPA/OPP (1998a) uses a LOAEL of 100 ppm for reproductive effects in mallard ducks as a toxicity benchmark for chronic exposures. For the current risk assessment, this benchmark will be adopted and converted to a daily dose of 10 mg/kg bw/day using the 10% food consumption estimate.

4.3.2.3. Terrestrial Invertebrates – As discussed in Section 4.1.2.3, a standard bioassay was conducted on the toxicity of sethoxydim to honey bees (BASF 1982). At the highest dose tested, 10 µg/bee, mortality was observed. Using a body weight of 0.093 g for the honey bee (USDA/APHIS 1993), the 10 µg/bee dose corresponds to 107 mg/kg bw [0.010 mg/0.000093 kg]. This value will be used in the risk characterization for assessing effects on terrestrial invertebrates. Given the large number of species of terrestrial invertebrates, the use of this single study on a single species obviously leads to uncertainty in the risk assessment. The BASF (1982) study is also used by U.S. EPA as the toxicity benchmark for terrestrial invertebrates and sethoxydim is classified by U.S. EPA as "practically non-toxic to bees" (Bryceland et al. 1997).

The study by Agnello et al. (1986) on toxicity to bean beetle larvae cannot be used quantitatively in the dose-response assessment but is discussed further in the risk characterization.

4.3.2.4. Terrestrial Plants (Macrophytes)– As discussed in Section 4.1.2.4, two sets pre-emergence and post-emergence studies are available on the toxicity of sethoxydim to nontarget plants, an early study by Ludwig (1980) and a more recent study summarized by Bryceland et al. (1997). Based on the summary provided by Bryceland et al. (1997) the most sensitive species in the pre-emergence assay is ryegrass, with a NOAEL of 0.059 lb/acre and an EC_{25} of 0.065 lb/acre. The most tolerant species was corn, with a NOAEL of 0.235 lb/acre and an EC_{25} of 0.418 lb/acre. In the post-emergence (vegetative vigor) assay, ryegrass is also the most sensitive species, with a NOAEL of 0.006 lb/acre and an EC_{25} of 0.025 lb/acre. The most tolerant species was oats, with a NOAEL of 0.03 lb/acre and an EC_{25} of 0.0313 lb/acre. [Note that the NOAEL's are experimental doses whereas the EC_{25} values are estimates based on the experimental data. This accounts for the similarity between some of the NOAEL values and EC_{25} estimates.]

The U.S. EPA (Bryceland et al. 1997) use EC_{25} values for characterizing risks to terrestrial plants. For this risk assessment, the NOAEL values will be used because this approach is more closely related to the hazard index used to characterize risk to terrestrial animals. The results of the post-emergence assays will be applied to scenarios involving drift and the pre-emergence value will be applied to scenarios involving inadvertent soil contamination by runoff.

For pre-emergence exposures, the NOAEL of 0.059 lb/acre (ryegrass) will be used to characterize risk to sensitive species and the NOAEL of 0.235 lb/acre (corn) will be used to characterize risk to tolerant species. For post-emergence exposures, the NOAEL of 0.006 lb/acre (ryegrass) will be used to characterize risk to sensitive species and the NOAEL of 0.03 lb/acre (oats) will be used to characterize risk to tolerant species.

4.3.2.5. Terrestrial Microorganisms– As discussed in section 4.1.2.5, no information is available on the toxicity of sethoxydim to terrestrial microorganisms. Thus, no dose-response assessment for this group is possible.

4.3.3. Aquatic Organisms.

4.3.3.1. Animals– As discussed in Sections 4.1.3.1 and 4.1.3.3, the formulated product, Poast, is much more toxic to aquatic species than the active ingredient, technical grade sethoxydim. As detailed in Appendix 3, acute LC_{50} values for technical grade sethoxydim are on the order of 100 to 300 mg/L and 78.1 mg/L for daphnids. For Poast, however, the acute LC_{50} values (expressed as concentrations of sethoxydim in water) are about 1 to 3 mg/L for fish and 2.6 mg/L for daphnids. Thus, exposures to Poast are about 100 times more hazardous than exposures to technical grade sethoxydim. Consequently, the U.S. EPA/OPP (Bryceland et al. 1997) based all of the acute toxicity benchmarks on sethoxydim concentrations associated with exposures to Poast. This essentially considers to the extent possible the influence of the inerts in Poast on the overall toxicity to aquatic species and the same approach will be used in the current risk assessment.

The U.S. EPA (Bryceland et al. 1997) use acute exposure concentrations of 1.2 mg/L for fish (based on results in trout) and 2.6 mg/L for aquatic invertebrates (based on results in daphnids). As noted in Appendix 3, the confidence interval for trout is 1.0-1.7 mg/L and the corresponding interval for daphnids is 2.0-3.3 mg/L. Thus, while the differences are not substantial, the distinction between fish and aquatic invertebrates maintained by U.S. EPA seems justified and the values of 1.2 mg/L for fish and 2.6 mg/L for aquatic invertebrates will be used in this risk assessment to characterize risk.

No chronic studies are available on the toxicity of sethoxydim (technical grade or formulated product) to any aquatic animals. Thus, no dose-response assessment for aquatic exposures can be made.

4.3.3.2. Aquatic Plants– Aquatic macrophytes and algae appear to be somewhat more sensitive to sethoxydim than fish or invertebrates. The studies identified in the U.S. EPA/CBI files, summarized in Appendix 3, suggest NOAEL values of less than 0.56 mg/L, with *Lemna gibba* (an aquatic macrophyte commonly known as duckweed) more sensitive than algae. Bryceland et al. (1997) reference additional studies not encountered in the search of the EPA/CBI files that identify EC_{50} values of >0.281 mg/L for duckweed and >0.25 mg/L for algae. These values are very similar and, for this risk assessment, the lower value of 0.25 mg/L will be used to characterize risks for aquatic plants. Based on the data from Appendix 3, it appears that adverse effects in *Lemna gibba* and perhaps other aquatic macrophytes could be expected at concentrations of 0.56 mg/L.

4.3.3.3. Aquatic Microorganisms– As with terrestrial microorganisms, no data are available on the toxicity of sethoxydim to aquatic microorganisms other than algae and a separate dose-response assessment cannot be made for this group.

4.4. RISK CHARACTERIZATION

4.4.1. Overview. None of the hazard quotients for mammals or birds approach a level of concern, even at the upper limit of exposure. For sethoxydim, further refinement of the exposure assessment would have little impact on the risk characterization because the hazard quotients are below a level of concern by factors of at least 10 for acute exposure scenarios (a large mammal consuming vegetation) and about 7 for chronic exposure scenarios (a large bird consuming vegetation at the application site). The more plausible scenarios involving off-site exposures have hazard quotients below a level of concern by factors of about 385 (large bird) to 50,000 (small mammal). The simple verbal interpretation of this quantitative risk characterization for terrestrial animals is similar to that of the human health risk assessment: the weight of evidence suggests that no adverse effects in terrestrial animals are plausible using typical or even very conservative worst case exposure assumptions.

For terrestrial plants, runoff may present a risk to some sensitive species. The extent to which this effect might be observed in the field is likely to depend on a number of site specific conditions, particularly how the runoff is distributed in areas adjacent to the application site. For sensitive species in areas with high rates of rainfall, the hazard quotients are slightly above unity - e.g., the highest hazard quotient is about 3. In arid environments - i.e., annual rainfall rates of about 15 inches per year or less - very little runoff of sethoxydim would occur and risks to any nontarget plant species would be minimal and below the level of concern. Drift, including dispersion of contaminated soil by wind, does not appear to present a major hazard to nontarget plant species. Hazard quotients for offsite drift indicate that sethoxydim is not likely to result in damage at distances as close as 25 feet from the application site. For sensitive species, the hazard quotient exceeds unity at 25 feet but not at 50 feet.

There is no indication that fish, aquatic invertebrates, or aquatic plants are likely to be exposed to concentrations of sethoxydim that will result in toxic effects, although the upper range of the hazard quotient for aquatic plants – i.e., 0.75) approaches a level of concern. A major limitation of this risk characterization for aquatic animals is the lack of any chronic toxicity studies on fish or aquatic invertebrates.

4.4.2. Terrestrial Organisms

4.4.2.1. Terrestrial Animals– The quantitative risk characterization for terrestrial animals is summarized in Table 4-3. These hazard quotients are calculated by dividing the exposure assessments summarized in Table 4-1 by the toxicity values given in Table 4-2.
None of the hazard quotients for mammals or birds approach a level of concern, even at the upper limit of exposure. For sethoxydim, further refinement of the exposure assessment would have little impact on the risk characterization because the hazard quotients are below a level of concern by factors of at least 10 for acute exposure scenarios (a large mammal consuming vegetation) and about 7 for chronic exposure scenarios (a large bird consuming vegetation at the application site). The more plausible scenarios involving off-site exposures have hazard quotients below a level of concern by factors of about 385 (large bird) to 50,000 (small mammal).

For the honey bee, the hazard quotient is based on the acute NOAEL of 107 mg/kg (BASF 1982). Even at the upper range of exposure associated with a direct spray, the hazard quotient is below the level of concern by a factor of about 2 – i.e., 1÷0.56 ≃ 1.79). Thus, there is no basis for expecting mortality in bees directly sprayed with sethoxydim. The study by Agnello et al. (1986) in coleoptera suggests that applications of sethoxydim at rates of 5-6 lbs/acre might have an effect on the life cycle of some beetles. The effect noted in this study, however, was a slight increase in days to pupation but an increase in both the number of eggs masses as well as total number of eggs produced by beetles feeding on sethoxydim treated plants relative to beetles feeding on untreated plants. Thus, it is not clear that this would be regarded as an adverse effect. In any event, the application rate used in the Agnello et al. (1986) study is substantially higher than that used in Forest Service programs.

The simple verbal interpretation of this quantitative risk characterization for terrestrial animals is similar to that of the human health risk assessment: the weight of evidence suggests that no adverse effects in terrestrial animals are plausible using typical or even very conservative worst case exposure assumptions. As with the human health risk assessment, this characterization of risk must be qualified. Sethoxydim has been tested in only a limited number of species and under conditions that may not well represent populations of free-ranging non-target animals. Given the very large number of nontarget terrestrial animal species and the limited requirements for and capacity to test nontarget species, this limitation is common to virtually all ecological risk assessments. Notwithstanding this limitation, the available data are sufficient to assert that no adverse effects can be anticipated in terrestrial animals from the use of this compound in Forest Service programs.

4.4.2.2. Terrestrial Plants– The quantitative risk characterizations for terrestrial plants are summarized in Worksheet G04 for the offsite movement of sethoxydim in runoff and Worksheet G05 for offsite movement of sethoxydim by drift and wind erosion.

The runoff estimates are based on GLEAMS modeling using three different soils (clay, loam, and sand) at annual rainfall rates of 5 to 250 inches and using the highest application rate that the Forest Service is considering, 0.0624 lb/acre. The toxicity index is based on the pre-emergence NOAEL of 0.059 lb/acre for the most sensitive species - i.e., rye grass - and the NOAEL of 0.235 to the most tolerant species (corn). Based on these indices of toxicity, some sensitive species could be effected in areas with annual rainfall rates of 50 inches and higher. Tolerant plant species are not likely to be affected by off-site runoff of sethoxydim under any conditions.

Hazard quotients for offsite drift (Worksheet G05) are based on the NOAEL value of 0.006 lb/acre for sensitive species (corn) as well as the NOAEL of 0.03 lb/acre for several tolerant species. As discussed in Section 4.2.2.4, the estimates for offsite drift encompass plausible exposures attributable to wind erosion. For relatively tolerant species, there is no indication that sethoxydim is likely to result in damage at distances as close as 25 feet from the application site. For sensitive species, there is a modest excursion about the NOAEL (a hazard quotient of 1.2) at 25 feet offsite but not at distances of 50 feet or greater.

4.4.3. Aquatic Organisms. The quantitative risk characterization for aquatic species is summarized in Table 4-4. As discussed in previous sections of this risk assessment (sections 4.1.3.1, 4.1.3.3, and 4.3.3.1), Poast is much more toxic to aquatic organisms than sethoxydim. For this reason, all of the toxicity values used in this risk assessment for aquatic species are based on exposures to Poast, the formulated product. Thus, the toxicity of the adjuvants – i.e., petroleum solvent and polyoxyethylene nonylphenol emulsified – are considered in the characterization of risk. Based on the hazard quotients summarized in Table 4-4, there is no indication that fish, aquatic invertebrates, or aquatic plants are likely to be exposed to concentrations of sethoxydim that will result in toxic effects, although the upper range of the hazard quotient for aquatic plants – i.e., 0.75) approaches a level of concern.

However, there is a very substantial limitation to the current risk assessment. As discussed in Section 4.3.3.1, no chronic toxicity studies on aquatic animals are available for either sethoxydim or Poast. The hazard quotients given in Table 4-4 for chronic exposures are based on the ratio of the longer-term concentrations of sethoxydim in water to the acute toxicity benchmarks. These ratios are provided only for comparison to the corresponding acute values and cannot be directly used to characterize longer-term risks to fish or aquatic invertebrates. Nonetheless, the upper range of the longer-term hazard quotients range from 0.0036 to 0.038. These are factors of about 25 to 275 below a level of concern. In other words, the chronic toxicity of sethoxydim would have to be greater than the acute toxicity by factors of 25 to 275 to reach a level of concern.

Aquatic plants appear to be only somewhat more sensitive to Poast than aquatic animals and there is no indication that adverse effects on aquatic plants are plausible. Unlike the case with aquatic animals, even short-term toxicity studies in aquatic plants use endpoints involving changes in population density. Thus, both the short-term and longer-term hazard quotients given in Table 4-4 can be legitimately used to characterize risk.

Table 4-1: Summary of Exposure Scenarios for Terrestrial Animals.

Scenario	Dose (mg/kg/day) Typical	Lower	Upper	Worksheet
Acute/Accidental Exposures				
Direct spray				
small mammal, first-order absorption	1.90e-01	2.55e-02	5.29e-01	F01
small animal, 100% absorption	7.27e+00	2.27e+00	9.09e+00	F02a
bee, 100% absorption	4.81e+01	1.50e+01	6.01e+01	F02b
Contaminated vegetation				
small mammal	3.75e-01	1.17e-01	1.00e+00	F03
large mammal	5.16e+00	1.61e+00	1.82e+01	F10
large bird	8.08e+00	2.52e+00	2.85e+01	F12
Contaminated water				
small mammal, spill	3.99e-01	6.21e-02	9.97e-01	F05
stream	8.78e-03	2.74e-04	2.74e-02	F06
Contaminated insects				
small bird	1.12e+01	3.51e+00	4.22e+01	F14
Contaminated fish				
predatory bird, spill	9.81e-01	7.63e-02	3.68e+00	F08
Longer-term Exposures				
Contaminated vegetation				
small mammal, on site	1.80e-03	2.82e-04	9.66e-03	F04a
off-site	1.82e-05	1.63e-06	1.81e-04	F04b
large mammal, on site	7.44e-02	7.75e-03	8.76e-01	F11a
off-site	2.51e-03	4.50e-04	1.64e-02	F11b
large bird, on site	1.17e-01	1.21e-02	1.37e+00	F13a
off-site	3.92e-03	7.04e-04	2.56e-02	F13b
Contaminated water				
small mammal	3.51e-05	2.74e-07	6.59e-05	F07
Contaminated fish				
predatory bird	5.04e-04	1.97e-06	1.42e-03	F09

Table 4-2: Summary of toxicity values used in ecological risk assessment

Animal	Type	Value	Units	Section
Mammals	Acute	180	mg/kg bw	4.3.2.1.
	Chronic	9	mg/kg bw/day	4.3.2.1.
Birds	Acute	500	mg/kg bw	4.3.2.2.
	Chronic	10	mg/kg bw/day	4.3.2.2.
Terrestrial invertebrates	Acute	107	mg/kg bw	4.3.2.3.
Terrestrial vegetation, sensitive	Drift	0.006	lb/acre	4.3.2.4.
	Pre-emergence	0.059	lb/acre	4.3.2.4.
Terrestrial vegetation, tolerant	Drift	0.03	lb/acre	4.3.2.4.
	Pre-emergence	0.235	lb/acre	4.3.2.4.
Fish	Acute	1.2	mg/L	4.3.3.1.
Aquatic invertebrates	Acute	2.6	mg/L	4.3.3.1.
Aquatic plants	Acute	0.25	mg/L	4.3.3.2.

Table 4-3: Summary of quantitative risk characterization for terrestrial animals[1]

Scenario	Hazard Quotient[2] Typical	Lower	Upper
Acute/Accidental Exposures			
Direct spray			
small mammal, first-order absorption	1.1e-03	1.4e-04	2.9e-03
small animal, 100% absorption	4.0e-02	1.3e-02	5.1e-02
bee, 100% absorption	4.5e-01	1.4e-01	5.6e-01
Contaminated vegetation			
small mammal	2.1e-03	6.5e-04	5.6e-03
large mammal	2.9e-02	9.0e-03	1.0e-01
large bird	1.6e-02	5.0e-03	5.7e-02
Contaminated water			
small mammal, spill	2.2e-03	3.4e-04	5.5e-03
small mammal, stream	4.9e-05	1.5e-06	1.5e-04
Contaminated insects			
small bird	2.2e-02	7.0e-03	8.4e-02
Contaminated fish			
predatory bird, spill	2.0e-03	1.5e-04	7.4e-03
Longer-term Exposures			
Contaminated vegetation			
small mammal, on site	2.0e-04	3.1e-05	1.1e-03
off-site	2.0e-06	1.8e-07	2.0e-05
large mammal, on site	8.3e-03	8.6e-04	9.7e-02
off-site	2.8e-04	5.0e-05	1.8e-03
large bird, on site	1.2e-02	1.2e-03	1.4e-01
off-site	3.9e-04	7.0e-05	2.6e-03
Contaminated water			
small mammal	3.9e-06	3.1e-08	7.3e-06
Contaminated fish			
predatory bird	5.0e-05	2.0e-07	1.4e-04

Toxicity Indices[3]		
Acute toxicity value for mammal - NOAEL	180	mg/kg
Chronic toxicity value for mammal - NOAEL	9	mg/kg/day
Acute toxicity value for bird - NOAEL	500	mg/kg
Chronic toxicity value for birds	10	mg/kg/day
Toxicity value for bee -NOAEL	107	mg/kg

[1] See Worksheet G01 (Table 4-1 in text) for summary of exposure assessment.
[2] Estimated dose ÷ toxicity index
[3] See Section 4.3. for a discussion of the dose-response assessments

Table 4-4: Quantitative Risk Characterization for Aquatic Species.

Risk Quotients	**Central**	**Lower**	**Upper**	**Endpoint**	
Fish					
Acute	5.0e-02	1.6e-03	1.6e-01	Mortality	
Chronic	2.0e-04	1.6e-06	3.8e-04	***Based on acute toxicity. See text for discussion.***	
Aquatic Invertebrates					
Acute	2.3e-02	7.2e-04	7.2e-02	Mortality	
Chronic	9.2e-05	7.2e-07	1.7e-04	***Based on acute toxicity. See text for discussion.***	
Aquatic Plants					
Acute	2.4e-01	7.5e-03	7.5e-01	EC_{50}	
Chronic	9.6e-04	7.5e-06	1.8e-03		
Exposures (mg/L)	Central	Lower	Upper	Worksheet	
Acute	0.060	0.0019	0.19	F06	Stream
Longer-term [1]	0.00024	0.0000019	0.00045	F09	

Toxicity values (mg/L)

	Value (mg/L)	Endpoint	Section
Fish, acute	1.2	Mortality	4.3.3.2.
Fish, chronic	1.2	No data found. Acute value used.	4.3.3.2.
Aquatic Invertebrates, acute	2.6	Mortality	4.3.3.3
Aquatic Invertebrates, chronic	2.6	No data found. Acute value used.	4.3.3.3
Aquatic plants	0.25	<EC_{50}	4.3.3.4.

SPECIAL NOTE: All risk characterizations are based on toxicity of formulated product, POAST. Sethoxydim is much less toxic to aquatic species than is POAST.

5. REFERENCES

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Appendix 1: Toxicity of Sethoxydim (NP-55) and Poast to experimental mammals [94-99% a.i. unless otherwise specified].

Animal	Dose/Exposure	Response	Reference
ORAL -acute			
Rats, Fischer 344, 6 weeks old, males (avg wgt 108.6 g) and females (avg wgt 90.2 g), 10/sex/dose group	single gavage dose of 0, 2182, 2836, 3687, 4793, 6231, or 8100 mg/kg NP-55 suspended in 0.5 % solution of CMC in distilled water w/0.2% Tween 80; 14-day observation period.	LD_{50} = 3500 mg/kg (95% cl 3125-3920 mg/kg) (males) LD_{50} = 3200 mg/kg (95% cl 2857-3584 mg/kg) (females) Mortality observed at 2836 mg/kg; all animals died at >4793 mg/kg. Reportable effects included tremors and convulsions in non-moribund rats, incontinence at 24-72 hours, and dose related depression.	Bio-Medical Research Laboratories Co, Ltd 1980 EPA/OTS 88-9200030 22

Additional notes on Bio-Medical Research Laboratories Co, Ltd 1980: Study includes acute oral, intravenous, subcutaneous, and dermal toxicity data in rats. Several detailed data tables provided.

Animal	Dose/Exposure	Response	Reference
Rats, SD-SLC, 6 weeks old, males (avg bw 106 g) and females (avg bw 133g), 10/sex/dose group. Used 94-99% a.i.	Single gavage dose of 2083, 2500, 2739, 300, 3286, or 3600 mg/kg NP-55 in males Single gavage dose of 2200, 2569, 3000, 3503, 4091, or 4777 mg/kg NP-55 in females 14-day observation period.	LD_{50} = 3125 mg/kg (95% cl 2957-3341 mg/kg) (males) LD_{50} = 2676 mg/kg (95% cl 2391-2919 mg/kg) (females) Dose-dependent signs of neurotoxicity included tremor, ataxia, and sedation. Gross pathological findings included some dark reddish lungs and hemorrhages on the mucosa of the stomach; no abnormal changes were observed in rats that survived until termination of the study.	Bio-Medical Research Laboratories Co, Ltd 1980 EPA/OTS 88-9200030 22 Also cited in Bryce-land et al. 1997

Additional notes on Bio-Medical Research Laboratories Co, Ltd 1980: This acute toxicity study in rats is appended to the other acute toxicity studies in rats performed at this laboratory.

Animal	Dose/Exposure	Response	Reference
Rats, Sprague-Dawley, males and females, 5/sex/dose group	single gavage dose of 21.5, 46.4, 100, 215, 1000, 3160, 3830, 4640, 5000, 6810 mg/kg BAS 9052 OH ***(Poast, 18% a.i.)***; 14-day observation period	LD_{50} = ≈5000 mg Poast/kg (males) LD_{50} = ≈4390 mg Poast/kg (females) LD_{50} = ≈4920 mg Poast/kg (males and females) **[900, 790, and 855.6 mg/kg as a.i.]** Possible signs of neurotoxicity included staggering and spastic gait; however, effects could be transient. Report does not indicate how long the effects persisted or the number of animals affected.	Bio-Medical Research Laboratories Co Ltd. 1979 EPA/OTS 88-9200030 89

Additional notes on Bio-Medical Research Laboratories Co Ltd. 1979: This study appears to be cited by Bryceland et al. 1997 as MRID 46326.

Appendix 1: Toxicity of Sethoxydim (NP-55) and Poast to experimental mammals [94-99% a.i. unless otherwise specified].

Animal	Dose/Exposure	Response	Reference
ORAL -acute (continued)			
Rats, SD, 6-weeks old, 10 males/dose group	single oral dose of 2596, 2960, 3375, 3847, or 4386 mg/kg M1-S0 or 4167, 4564, 5000, 5477, or 6000 mg/kg M2-S0 by gavage (vehicle = Tween 80) These compounds are the main metabolites of NP-55	LD_{50} = 3080 (2953-3175) mg/kg M1-S0 LD_{50} = 5573 (4942 -7435) mg/kg M2-S0 behavioral effects of M1-S0 included sedation, ataxia, lacrimation, salivation, incontinence of urine, decreased body temperature, and ptosis; behavioral effects of M2-S0 included sedation, hypotonia, ventral position, convulsion, tremor, ataxia, incontinence of urine, lacrimation, salivation, ptosis, decreased body temperature, and hematuria. Gross pathological changes in dead rats exposed to M2-S0 included hemorrhages on the mucosa of the intestine; survivors appeared normal at the time of sacrifice.	Nishibe et al. 1980 MRID 00124804
Rats, SD-SLC, 6 weeks old, 5 males	single gavage dose of 5000 mg/kg MU-1 suspended in distilled water with small amount of Tween 80 by; 14-day observation period	LD_{50} >5000 mg/kg No behavioral effects; no gross pathological changes.	Nishibe et al. 1981 MRID 00124805
Rats, S1c:SD, young adult males, mean body wgt = 171± 7 g, 5 rats/dose group	single gavage doses of 1000, 3000, or 5000 mg/kg Me-MSO dissolved in distilled water; observation period of 14 days	LD_{50} >5000 mg/kg Adverse effects included urine incontinence in one rat at 5000 mg/kg on the first day after dosing, a decrease in body weight of rats at 5000 mg/kg for 2 days after dosing with full recovery by day 7, and death in one rat at 5000 mg/kg on day 3. No gross pathological changes were observed in any rats.	Nishibe et al. 1984a MRID 00153603
Rat, NOS		LD_{50} = 2676-3125 mg/kg	BASF 1982 MRID 00100536
Mouse, NOS		LD_{50} = 5600-6500 mg/kg	BASF 1982 MRID 00100536

Appendix 1: Toxicity of Sethoxydim (NP-55) and Poast to experimental mammals [94-99% a.i. unless otherwise specified].

Animal	Dose/Exposure	Response	Reference
ORAL -acute (continued)			
Mice, ICR, 6 weeks old, males and females, 10/sex/ dose group	single gavage dose of 0, 2836, 3687, 4793, 6231, or 8100 mg/kg NP-55 suspended in 0.5 % solution of CMC in distilled water w/0.2% Tween 80; 14-day observation period.	100% mortality at high dose LD_{50} = 5600 mg/kg (95% cl 5045-6216 mg/kg) (males) LD_{50} = 6300 mg/kg (95% cl 5294-7497 mg/kg) (females) Reportable effects include dose-related ataxia, loss of spontaneous movement and depression. These effects were transient in survivors. Signs of neurotoxicity included ataxa, convulsions, and hyporeflexia. At autopsy, common findings in lethal cases included hyperemia of the lungs and fading discoloration of the spleen and kidneys; atrophy of the spleen in 1 male at 3687 mg/kg and 1 male at 8100 mg/kg; and hyperemia of the small intestine in 1 male and 1 female at 6231 mg/kg and in 2 male and 3 females at 8100 mg/kg; no particular changes were observed in survivors.	Bio-Medical Research Laboratories Co, Ltd 1979 EPA/OTS 88-9200029 76

Additional notes on Bio-Medical Research Laboratories Co, Ltd 1979: Study includes acute oral, intravenous, subcutaneous, and dermal toxicity data in mice. Several detailed data tables provided.

Appendix 1: Toxicity of Sethoxydim (NP-55) and Poast to experimental mammals [94-99% a.i. unless otherwise specified].

Animal	Dose/Exposure	Response	Reference
ORAL -acute (continued)			
Dog, beagle, 3 years old, males (bw = 9.5-14.8 kg) and females (bw = 9.6-14.0 kg), 2-3/sex/dose group	single dose in gelatin capsule of 0, 1250, 2500, or 5000 mg/kg NP-55; 14-day observation period	LD_{50} ≈5000 mg/kg (males) LD_{50} = 2500-5000 mg/kg (females) Mortality (occurred on day 1 or 2 post dosing): males - 0% (1250), 0% (2500), 50% (5000) females - 0% (1250), 0% (2500), 66.7% (5000) Ataxia, convulsions, and tremors lasting more than 24 hours were observed at 2500 and 5000 mg/kg in both sexes. Pathology revealed dark reddish lungs and hemorrhages in stomach or intestine of dead dogs.	Nisso Inst. 1980a EPA/OTS 288-920003 026
ORAL-developmental			
Rats, Sprague-Dawley, mated females (mean wgt of 224.6 g), 5/dose group	daily gavage doses of 0, 350, 450, 550, or 650 mg/kg/day sethoxydim suspension in a 1% carboxymethyl-cellulose sodium salt vehicle on days 6-15 of gestation	No mortality, 100% pregnancy rates, no maternal toxicity at dose levels up to 350 mg/kg/day; decreased body weight gain at 450, 550, and 650 mg/kg/day; fetal body weights decreased in 650 mg/kg/day group. Incidence of fetuses with malformations comparable to historical control data. Cause of excessive salivation in all treated rats was declared unknown.	Ponnock 1992 MRID 42627901
ORAL -reproduction/teratology			
Rats, Charles River, weanling, 12 males and 24 females/dose group	0, 40, 120, 360, or 1080 NP-55 ppm in the diet for 23 weeks	No effects on behavior, appearance, survival, body weights, or food consumption in parental rats at any dose level; no changes in male or female fertility indices, pup survival, or pup body weights, compared with controls.	IRDC 1980b MRID 00045867 *Cited as BASF (1980a) in IRIS*

Notes on IRDC 1980b: This is an INTERIM study. The high dose level was increased to 2160 after 5 weeks and to 3420 after 4 more weeks, due to the lack of toxicological effects. This 14-page fiche includes several tables of raw data.

Appendix 1: Toxicity of Sethoxydim (NP-55) and Poast to experimental mammals [94-99% a.i. unless otherwise specified].

Animal	Dose/Exposure	Response	Reference
Rats, Sprague-Dawley, mated females, 14 weeks old, 24/dose group, including vehicle control and positive control	0, 40, 100, or 250 mg/kg NP-55 daily by gavage on days 7-17 of gestation positive controls given 200 mg/kg aspirin	Significant decreases in body weight observed at 100 and 250 mg/kg and in positive controls; significant increases in liver weight observed at 250 mg/kg and in positive controls; decreases in adrenal weights observed at 100 and 250 mg/kg and in positive controls; no effects on number of corpora lutea, implantations, live fetuses, sex ratios, or fetal weight observed at any NP-55 dose level; and no significant abnormality observed in fetuses of any NP-55 treated group. Conclusion: These data indicate that NP-55 is not teratogenic to rats.	Nishibe and Gotoh 1980 MRID 00045863 *cited as BASF 1980b in IRIS.*
Rats, Sprague-Dawley, 14 weeks old, 24/dose group vehicle control (CMC) and positive control (200 mg/kg aspirin)	daily gavage dose of 0, 40, 100, or 250 mg/kg NP-55 on days 7-17 of gestation. vehicle control (CMC) positive control (200 mg/kg aspirin)	NOEL = 40 mg/kg (dams) NOEL = 250 mg/kg (fetuses) No teratogenic effects Maternal toxicity included significant reductions in body weight gains at 100 and 250 mg/kg and in positive controls (200 mg/kg aspirin); significant increases in liver weights at 250 mg/kg and in positive controls; and decreased adrenal weights at 100 and 250 mg/kg and in positive controls. Spleen weight increased significantly on in positive control group.	Nisso Inst. 1980b EPA/OTS 88-9200030 26
Rabbits, New Zealand White, approx. 7 months old, 6 pregnant rabbits/dose group	single daily gavage dose of 0, 40, 160, or 480 mg/kg/day on days 6-28 of gestation	No teratogenic effects were observed at dose ≤160 mg/kg/day. Adverse effects at 480 mg/kg/day included 5 death, severe losses in maternal weight gain, statistically significant and biologically meaningful decreases in the number of viable fetuses, and a slight decrease in mean fetal body weight. Investigators conclude that adverse effects in high dose group indicated that 480 mg/kg/day of NP-55 was excessive for a teratology study and that the reduced sample size for this dose level (only 2 litters) was insufficient for an evaluation of the teratogenicity of the compound.	IRDC 1980a EPA/OTS 88-9200030 26 BASF 1980 MRID 00045864 Cited as BASF 1980c in IRIS.

Appendix 1: Toxicity of Sethoxydim (NP-55) and Poast to experimental mammals [94-99% a.i. unless otherwise specified].

Animal	Dose/Exposure	Response	Reference
ORAL -chronic			
Dogs, beagle, approximately 6 months old, 6/sex/dose group	0, 300, 600, and 3600 ppm in the diet for one year. Based on measured food consumption, the male/female doses were 0, 8.86/9.41, 17.5/19.9, and 110/129 mg/kg/day). See unnumbered table on p. 21 of study.	NOEL for liver effects and possible effects on the erythroid system = 300 ppm No mortality and no clinical signs of toxicity at any dose level. Liver effects and possible effects on the erythroid system were slight but considered treatment related. Hematological effects included slight but statistically significant decreases in erythrocyte counts, hemoglobin and hematocrit in males treated with 600 or 3600 ppm (similar effects were sporadic in females at 3600 ppm), with a tendency toward recovery at 12 month interval. Absolute and relative liver weights increased in males and females at 3600 ppm. Liver lesions included trace or mild degrees of hepatocellular cytoplasmic alteration at 600 and 3600 ppm. At 3600 ppm (and in males at 600 ppm) the lesion was associated with increased liver alkaline phosphatase and high dose males also had slight increases in alanine aminotransferase.	IRDC 1984 MRID 00152669 *cited as BASF 1984 in IRIS.* **Basis for RfD.**
Rats, Fischer 344 (C.F.), 50 days old, males (weighing 94.2-172.4 g) and females (weighing 60.4-133.3 g), 55/sex/dose group	0, 40, 120, or 360 ppm NP-55 in the diet for 104 weeks.	There were no treatment-related effects noted in a comparison of the clinical signs, survival data, opthalmoscopic findings, and gross and microscopic pathology findings. At all dose levels, there were statistically significant differences noted in growth analysis, food consumption values, clinical laboratory values, and organ/body weight values, compared with controls; however, these differences were not considered treatment related.	Burdock et al. 1981 MRID 00100526

Appendix 1: Toxicity of Sethoxydim (NP-55) and Poast to experimental mammals [94-99% a.i. unless otherwise specified].

Animal	Dose/Exposure	Response	Reference
Mice, BD, 6 weeks old, males and females, 70/sex/dose group; 100/sex/control group	0, 40, 120, 360, or 1080 ppm NP-55 in diet for 104 weeks. **NB: This is an interim report (first 52 weeks in 104-week feeding study).**	***After 52 weeks***: No carcinogenicity NOEL = 120 ppm No clinical signs of toxicity; no treatment related mortality; no treatment-related hematological effects; no effects on urinalysis; Adverse effects included decreased body weight gain in both sexes at 360 and 1080 ppm; decreased food consumption in males at 360 and 1080 ppm; decreased blood glucose in males at 1080 ppm; decreased A/G ratio in males at 360 and 1080 ppm; increased ALP in females at 40 and 120 ppm; increased organ weights (heart, liver, and spleen) and significantly increased ratio of organ (liver and spleen) to body weights in males at 1080 ppm; significantly increased liver to body weight ratio in females at 360 and 1080 ppm. Pathological changes include lesions in lung (grayish zone) not otherwise specified; and ovarian lesions (cyst) at 40 and 360 ppm Histopathological findings include dose-related changes in the liver, including swollen liver cells and fatty degeneration in males at 360 and 1080 ppm; and two cystadenomas in 1 female at 40 ppm 1 female at 360 ppm.	Nisso Inst. 1980b EPA/OTS 88-9200030 23

Appendix 1: Toxicity of Sethoxydim (NP-55) and Poast to experimental mammals [94-99% a.i. unless otherwise specified].

Animal	Dose/Exposure	Response	Reference
ORAL -chronic (continued)			
Mice, BDF1, 6 weeks old, 70/sex/dose group, 100/sex/in control group	0, 40, 120, 360, or 1080 ppm NP-55(dissolved in acetone) in diet for 104 weeks. Mean intakes values equal 0, 4.48, 13.77, 41.16, and 134.6 mg/kg/day in males and 0, 4.85, 14.86, 44.33, and 142.85 mg/kg/day in females for 104 weeks.	NOEL = 120 ppm No evidence of carcinogenicity, no clinical signs of toxicity, no significant change in water consumption, no marked effects on hematology, no significant change in urinalysis, no dose-related changes observed at gross necropsy (except for increased liver weight), and no evidence of treatment-related tumors in any organs, including the liver. At 1080 ppm, growth rate was depressed in both sexes, food consumption was slightly higher in both sexes, GOT and GOT activity increased ($p<0.001$ and $p<0.01$) in males at 24 (but not 12) months, liver to body weight ratios increased in both sexes at 12 and 24 months. Histopathological findings indicate that **the liver is the target organ for NP-55 exposure in mice**. At 360 and 1080 ppm, fatty degeneration and swelling of the liver occurred frequently in males at 12 months; at 24 months, these lesions almost disappeared in the 360 ppm group but not in the 1080 ppm group. Although the incidence of focal granulomatous inflammations and hemosiderin depositions were highest in the males of the 1080 ppm group, these changes were found in the livers of all groups.	Takaori et al. 1981 MRID 00100527

Appendix 1: Toxicity of Sethoxydim (NP-55) and Poast to experimental mammals [94-99% a.i. unless otherwise specified].

Animal	Dose/Exposure	Response	Reference
DERMAL			
Rats, Sprague-Dawley, males (mean wgt 218 g) and females (mean wgt 182 g), 5/sex/dose group	single topical application to clipped skin of dorsal and lateral parts of trunk (area about 50 cm^2) of ***Poast*** as 50% aqueous preparation in a dose of 400 mg/kg and undiluted in doses of 1000, 2000, or 4000 mg/kg; application site occluded for 24 hours; observation period of 14 days	LD_{50} >4000 mg/kg No mortality; possible signs of neurotoxicity included excitation, staggering tremors, twitching, spastic gait, convulsions (rolling tonic and clonic) in non-moribund animals.	BASF 1992a EPA/OTS 88-9200030 56
Rats, Fischer 344, 6 weeks old, males (avg bw 145.9 g) and females (avg bw 109.6 g), 10/sex/dose group	topical application of 5000 mg/kg NP-55 to clipped skin (area of 2x2 cm of cervical and dorsal parts of trunk); mice wore plastic neck collars to prevent oral exposure to test substance; 14-day observation period	LD_{50} >5000 mg/kg in males and females No mortality; signs of toxicity included decrease of spontaneous movement, depression, and transitory escape reflex. No particular changes noted at autopsy.	Bio-Medical Research Laboratories Co, Ltd. 1980 EPA/OTS 88-9200030 22
Mice, ICR, 6 weeks old, males (avg bw 29.2 g) and females (avg bw 25.4 g), 10/sex/dose group	topical application of 5000 mg/kg NP-55 to clipped skin (area of 2x2 cm of cervical and dorsal parts of trunk); mice wore plastic neck collars to prevent oral exposure to test substance; 14-day observation period	LD_{50} >5000 mg/kg in males and females No mortality; signs of toxicity included slight decrease of spontaneous movement in males and females after 24 hours with recovery at 48 hours, and ptsosis of eyelid in 2 males and 4 females after 2 ½ hours, but touch escape was normal.	Bio-Medical Research Laboratories Co, Ltd. 1979 EPA/OTS 88-9200029 76

Additional notes on Bio-Medical Research Laboratories Co, Ltd 1979: Study includes acute oral, intravenous, subcutaneous, and dermal toxicity data in mice. Several detailed data tables provided.

Appendix 1: Toxicity of Sethoxydim (NP-55) and Poast to experimental mammals [94-99% a.i. unless otherwise specified].

Animal	Dose/Exposure	Response	Reference
OCULAR			
Rabbits, Japanese, white, 9 males, 3-4 months old, avg bw 3.3 kg	0.1 mL NP-55 20% EC applied to everted lower lid of the right eye; left eye served as control; treated eyes of 6 rabbits remained unwashed; remaining 3 treated eyes were flushed with lukewarm water no sooner than 20-30 minutes after instillation. 7-day observation period.	Injuries were observed on the cornea and the conjunctivae of rabbits, with more severe injury in the unwashed group than in the washed group. Mean total primary irritation scores were: **Washed** group (n=3): 6.0, 6.0, 1.3, 0.7, and 0 on respective days, 1, 2, 3, 4, and 7,). **Unwashed** group (n=6): 32.0, 31.0, 28.0, 17.0, and 7.7 on respective days, 1, 2, 3, 4, and 7).	Souma et al. 1981 MRID 00100529

Appendix 1: Toxicity of Sethoxydim (NP-55) and Poast to experimental mammals [94-99% a.i. unless otherwise specified].

Animal	Dose/Exposure	Response	Reference
OCULAR - *continued*			
Rabbit, White Vienna, 3 males (avg wgt 2.45 kg) and 3 females (avg wgt 2.80 kg)	0.1 mL unchanged BAS 9052OH into conjunctival sac of right eye; untreated eye served as control; observation period of 15 days.	Primary irritation index equals 35; all effects reversible in 15 days.	Kirsch and Hildebrand (1983) MRID 00130673
INHALATION-acute			
Rats, Wistar, males (mean bw = 260±12.0 g), females (mean bw = 187±7.2g), 8-9 weeks old, 5/sex/group	single head-nose exposure to 1.3 or 5.6 mg/L sethoxydim liquid aerosol for 4 hours; 14-day observation period.	LC_{50} > 5.6 mg/L No pathological findings at sacrifice	Gamer 1991 MRID 44021201
Rats, Sprague-Dawley, males and females, bw range 185±15 g, 10/sex/dose group	single head-nose exposure to 7.64 mg/L ***Poast*** liquid aerosol for 4 hours; 14-day observation period.	LC_{50} > 7.64 mg/L Neurotoxicity manifested as considerably staggering gait and crouching posture persisted for 6 days post dosing.	BASF 1980 EPA/OTS 88-9200030 87
INHALATION-subchronic			
Rats, Wistar, males (mean bw 253 g) and females (mean bw 184 g), about 7 weeks old, 5/sex/dose group	head-nose exposure to 0, 0.04, 0.3, or 2.4 mg/L for 6 hours/working for 1 month (21 exposures)	NOEC = 0.04 mg/L NOAEC = 0.3 mg/L At 0.3 mg/L, slight local irritation of the nose was observed but not considered an adverse effect. At 2.4 mg/L, slight irritation to the upper respiratory tract and oral cavity; slight systemic toxicity to the liver demonstrated by increased blood bilirubin and organ weights as well as centrilobular cloudy swelling of the hepatocytes.	Gamer 1993 MRID 44021202

Appendix 1: Toxicity of Sethoxydim (NP-55) and Poast to experimental mammals [94-99% a.i. unless otherwise specified].

Animal	Dose/Exposure	Response	Reference
INTRAVENOUS-acute			
Rats, Fischer 344, 6 weeks old, males (avg bw 120.0 g) and females (avg bw 25.8 g), 10/sex/dose group	single dose of 0, 415, 455, 500, 550, or 605 mg/kg NP-55 by iv injection into caudal vein; 14-day observation period NP-55 suspended in 0.5% CMC in distilled water w/0.2% Tween 80	LD_{50} = 505 mg/kg (95% cl 472-540) males LD_{50} = 505 mg/kg (95% cl 481-530) females Mortality observed at >455 mg/kg, and all mice died at 605 mg/kg. General signs of toxicity included ataxia, lack of reflex, tremor, convulsion, labored respiration (gasping), stretching of hind limb, and lacrimation. In survivors, ataxia, lack of reflex, convulsion, and gasping recovery occurred after 20 minutes; recovery of spontaneous movement occurred thereafter, and slight piloerection and urinary incontinence only appeared after 24 hours. Autopsy in lethal cases showed common occurrence of remarkable hyperemia of lungs, much serum in the thoracic cavity which flowed through nasal cavity in heavy behavior rats, and slight fading discoloration of the kidneys. In survivors, only pathological change was inflammation site of the lungs.	Bio-Medical Research Laboratories Co, Ltd. 1980 EPA/OTS 88-9200030 22
Mice, ICR, 6 weeks old, males (avg bw 32.9 g) and females (avg bw 25.8 g), 10/sex/dose group	single dose of 0, 348, 417, 500, 600, or 720 mg/kg NP-55 by iv injection into caudal vein; 14-day observation period NP-55 suspended in 0.5% CMC in distilled water w/0.2% Tween 80	LD_{50} = 485 mg/kg (95% cl 441-534) males LD_{50} = 505 mg/kg (95% cl 435-586) females Mortality observed at >417 mg/kg, and all mice died at 720 mg/kg. General signs of toxicity included dose related ataxia, loss of spontaneous movement, and depression. Effects were transient in survivors. Neurotoxic effects included ataxia, convulsions, and hyporeflexia.	Bio-Medical Research Laboratories Co, Ltd. 1979 EPA/OTS 88-9200029 76

Appendix 1: Toxicity of Sethoxydim (NP-55) and Poast to experimental mammals [94-99% a.i. unless otherwise specified].

Animal	Dose/Exposure	Response	Reference
SUBCUTANEOUS-acute			
Rats, Fischer 344, 6 weeks old, males (avg bw 130.4 g) and females (avg bw 98.9 g), 10/sex/dose group	single dose of 0, 1929, 2315, 2778, 3333, 4000, 4800, or 5760 mg/kg NP-55 by sc injection to cerival or dorsal part; 14-day observation period NP-55 suspended in 0.5% CMC in distilled water w/0.2% Tween 80	LD_{50} = 4400 mg/kg (95% cl 4074-4752) males LD_{50} = 3010 mg/kg (95% cl 2840-3191) females Mortality observed at >4000 mg/kg in males and 2778 mg/kg in females, and all rats died at 5760 mg/kg. General signs of toxicity included dose-dependent tremors and lack of reflex. Recovery occurred after 72 hours. Autopsy in non-survivors revealed common occurrence of hyperemia of the lungs and fading discoloration of the spleen and kidney hemorrhage of the stomach at 4000 mg/kg (1 male and 1 female) and at 2778 mg/kg (1 female). Autopsy in survivors revealed atrophy of the thymus at 2778 mg/kg (2 females) and 3333 mg/kg (1 female); atrophy of the lungs also was observed in surviving rats.	Bio-Medical Research Laboratories Co, Ltd. 1980 EPA/OTS 88-9200030 22
Mice, ICR, 6 weeks old, males (avg bw 29.3 g) and females (avg bw 24.0 g), 10/sex/dose group	single dose of 0, 1929, 2315, 2778, 3333, 4000, or 4800 mg/kg NP-55 by sc injection to cerival or dorsal part; 14-day observation period NP-55 suspended in 0.5% CMC in distilled water w/0.2% Tween 80	LD_{50} = 2950 mg/kg (95% cl 2611-3334) males LD_{50} = 3180 mg/kg (95% cl 2891-3498) females Mortality observed at >2315 mg/kg in males and 2778 mg/kg in females, and all mice died at 4800 mg/kg. General signs of toxicity included dose related ataxia, loss of spontaneous movement, and depression. Effects were transient in survivors. Neurotoxic effects included ataxia, convulsions, and hyporeflexia.	Bio-Medical Research Laboratories Co, Ltd. 1979 EPA/OTS 88-9200029 76

Appendix 2: Toxicity of sethoxydim to birds. [96.8 to 97.3% a.i. unless otherwise specified]

Animal	Dose	Response	Reference
ORAL			
Mallard duck	2510 mg/kg	< Acute oral LD_{50}	BASF 1982 MRID 00100536
Mallard duck	5620 ppm	< 8-day dietary LD_{50}	BASF 1982 MRID 00100536
Bobwhite quail	5620 ppm	<8-day dietary LD_{50}	BASF 1982 MRID 00100536
Mallard duck	2000 mg/kg	< Acute oral LD_{50}	Bryceland et al. 1997 – referenced to Beavers 1979, MRID 099539.
Bobwhite quail	1000 ppm	Dietary NOAEL for reproductive effects.	Munk 1996, MRID 44003401 cited in Bryceland et al. 1997.
Mallard duck	100 and 500 ppm	Decrease in the number of normal hatchlings. A NOAEL was not determined.	Beavers 1996, MRID 44003402 cited in Bryceland et al. 1997

Appendix 3: Toxicity of Poast to fish, aquatic invertebrates, and aquatic plants.

Animal	Exposure	Response	Reference
Fish			
Rainbow trout	97.3% a.i.	96-hour LC_{50} = 170.0 mg/L	BASF 1982 [1] MRID 00100536 **cited in Bryceland et al. 1997 as MRID 99539**
Rainbow trout (*Oncorhynchus mykiss*), mean net weight 0.75 g (±0.11 g), mean standard length = 38 mm (±2 mm)	Nominal concentrations of 0.20, 0.34, 0.58, 0.96, 1.6, or 2.7 mg/L BAS 9052 06H (***Poast*** [2], 19.3% a.i.) for 96 hours under static conditions (**Mean measured concentrations of 0.21, 0.37, 0.59, 1.0, 1.7, or 2.7 mg/L)**	96-hour LC_{50} = 1.2 mg/L (95% CI = 1.0-1.7 mg/L) 96-hour NOEL = 0.21 mg/L	Bowman and Howell 1991b MRID 41885902 **cited in Bryceland et al. 1997**
Catfish		BCF whole fish = 0.75 edible tissue = 0.40 nonedible tissue = 0.71	BASF 1982 [1] MRID 00100536
Bluegill sunfish (*Lepomis macrochirus*), mean net weight 0.15 g (±0.04 g), mean standard length = 20 mm (±2 mm)	Nominal concentrations of 0.20, 0.34, 0.58, 0.96, 1.6, or 2.7 mg/L BAS 9052 06H (***Poast*** [2], 19.3% a.i.) for 96 hours under static conditions (**Mean measured concentrations of 0.18, 0.33, 0.49, 0.91, 1.4, or 2.3 mg/L)**	96-hour LC_{50} = 1.6 mg/L (95% CI = 0.91-2.3 mg/L) 96-hour NOEL = 0.18 mg/L	Bowman and Howell 1991a MRID 41885901
Bluegill sunfish	97.3% a.i.	96-hour LC_{50} = 265.0 mg/L	BASF 1982 [1] MRID 00100536 **cited in Bryceland et al. 1997 as MRID 99539**
Bluegill sunfish		BCF whole fish = 6.98 edible tissue = 2.87 nonedible tissue = 7.66	BASF 1982 [1] MRID 00100536 Appears to simply summarize Vilkas and Kuc 1981a

Appendix 3: Toxicity of Poast to fish, aquatic invertebrates, and aquatic plants.

Animal	Exposure	Response	Reference
Bluegill sunfish (*Lepomis macrochirus*)	2.2 ppm BAS 562 H under flow-through conditions for 28 days; depuration period of 14 days	Low tendency of sethoxydim or its metabolites to concentrate in bluegill sunfish. **BCF:** whole body = 21 (elimination half-life = 3.6 days) edible tissue = 7 (elimination half-life = 3.6 days) nonedible tissue = 25 (elimination half-life = 3.6 days)	McKenna and Patel 1991 MRID 42118001-A MRID 42118001-B
Bluegill sunfish (*Lepomis macrochirus*)	2.78 ±0.30 ppm (measured concentration) of ^{14}C-labeled BAS 9052 (***Poast*** [2], 19.3% a.i.) under flow-through conditions for 30 days; depuration period of 14 days	maximum BCF in whole fish = 6.98 and maximum residue level during uptake = 16.6 ppm; maximum BCF in nonedible tissue = 7.66 and maximum residue concentration = 18.2 ppm; maximum BCF in edible tissue = 2.87 and maximum residue concentration = 6.82 ppm;	Vilkas and Kuc 1981a MRID 00100537
Sheepshead minnow (*Cyprinodon variegatus*), <24 hours old	Mean measured concentrations of 0, 6.6, 13, 25, 50 or 98 mg ai/L sethoxydim for 33 days	NOEC = 98 mg ai/L LOEC >98 mg ai/L MATC >98 mg ai/L	Graves et al. 1995 MRID 43614601
Sheepshead minnow (*Cyprinodon variegatus*)	0, 2.7, 4.5, 7.2, 10.8, or 18.0 mg/L ***Poast*** for 96 hours under static unaerated conditions. [Note: No substantial concentration related effects on dissolved oxygen or pH. Oxygen depletion with time in both exposed and control groups.]	96-hour LC_{50} = 3.5 mg/L (95% CI = 2.7-4.5 mg/L) NOEC (survival) = 2.7 mg/L (estimated) 2.7-18.0 mg/L caused loss of equilibrium and surfacing during the test.	Ward and Boeri 1989a MRID 41510602

Appendix 3: Toxicity of Poast to fish, aquatic invertebrates, and aquatic plants.

Animal	Exposure	Response	Reference
Sheepshead minnow (*Cyprinodon variegatus*)	Mean measured concentrations of 0 or 145.8 mg/L sethoxydim (BAS 9052 H; ***Poast*** [2], 19.3% a.i.) under static unaerated conditions for 96 hours	96-hour LC_{50} >145.8 mg/L No sublethal effects were observed.	Ward and Boeri 1992a MRID 42315101
Channel catfish (*Ictalurus punctatus*), 300 treated and 300 untreated	0.084±0.001 ^{14}C-labeled BAS 9052 (***Poast*** [2], 19.3% a.i.) under static conditions for 34 days; depuration period of 14 days ***water concentration was achieved by applying ^{14}C-labeled BAS 9052 to sandy loam soil at a surface application rate of 0.5 lb ai/acre*.**	maximum BCF during uptake were: 0.747 in whole fish, 0.398 in edible tissues, and 0.714 in nonedible tissues after 14-day depuration, ^{14}C-residue concentrations in whole fish = 67.9% of maximum during uptake; ^{14}C-residue concentrations in nonedible tissues =76% of maximum during uptake; residue concentration in edible tissues = 10% greater than the maximum during uptake.	Vilkas and Kuc 1981b MRID 00100538

Appendix 3: Toxicity of Poast to fish, aquatic invertebrates, and aquatic plants.

Animal	Exposure	Response	Reference
Invertebrates			
Eastern oyster (*Crassostrea virginica*), embryos	Mean measured concentrations of 0 or 109 mg/L sethoxydim tech for 48 hours under static conditions	48-hour EC_{50} >109 mg/L NOEC = 109 mg/L	Linott 1992 MRID 42537401
Eastern oyster (*Crassostrea virginica*), embryos and larvae	Nominal concentrations of 0.0-2.5 mg/L Poast for 96 hours under static unaerated conditions	48-hour EC_{50} = 0.9 mg/L (95% CI = 0.6-1.0 mg/L)	Ward amd Boeri 1990 MRID 41607207
Mysid shrimp (*Mysidopsis bahia*), <24 hours old	0 or 141.8 mg/L sethoxydim (BAS 9052 H; ***Poast*** [2], 19.3% a.i.) under static unaerated conditions for 96 hours	96-hour LC_{50} >141.8 mg/L No sublethal effects were observed	Ward and Boeri 1992b MRID 42315102
Mysid shrimp (*Mysidopsis bahia*), 11 days old	Nominal concentrations of 0.0-3.0 mg/L Poast for 96 hours under static unaerated conditions	96-hour LC_{50} = 0.8 mg/L (95% CI = 0.7-1.1 mg/L) No sublethal effects were observerd.	Ward and Boeri 1989b MRID 41510604
Daphnia magna, neonates (<24 hours old)	Nominal concentrations of 0, 0.54, 1.1, 2.2, 4.3, or 8.6 mg/L BAS 9052 06H (***Poast*** [2], 19.3% a.i.) for 48 hours under static conditions; **(mean measured concentrations of 0, 0.57, 1.1, 2.4, 4.6 or 8.9 mg/L)**	48-hour EC_{50} = 2.6 mg/L (95% CI = 2.0-3.3 mg/L) NOEC = 1.1 mg/L	Blasberg et al. 1991 MRID 41885903
Daphnia magna		48-hour LC_{50} = 78.1 mg/L	BASF 1982 [1] MRID 00100536

Appendix 3: Toxicity of Poast to fish, aquatic invertebrates, and aquatic plants.

Animal	Exposure	Response	Reference
Aquatic Plants			
Lemna gibba (duckweed) freshwater macrophyte	0, 0.56, 1.0, 1.8, 3.2, or 5.6 mg/L Tech BAS 9052 (***Poast*** [2], 19.3% a.i.) for 14 days. Static test.	NOEC <0.56 mg/L. Frond count increased at all test concentrations, no flowering was observed in treated or untreated cultures; dry weight increased at all test concentrations; and specific frond weight (dry weight/frond) increased at all test concentrations, but could not be evaluated statistically for the 5.6 mg/L concentration. Frond damage, indicated by brown translucent fronds was observed at the three highest concentrations and was greatest (14% brown) on day 14. Although not quantified, exposure at all concentrations seemed to increase root length.	Hughes 1980a MRID 41400103
Selenastrum capricornutum, freshwater green alga	0, 0.56, 1.0, 1.8, 3.2, or 5.6 mg/L Tech BAS 9052 (***Poast*** [2], 19.3% a.i.) for 14 days.	No effect on maximum standing crop (cells/mL), no effect on dry weight, and no effect on lag period, relative to controls NOEC>5.6 mg/L	Hughes 1980b MRID 41400106
Selenastrum capricornutum, freshwater green alga	0, 0.56, 1.0, 1.8, 3.2, or 5.6 mg/L Tech BAS 9052 (***Poast*** [2], 19.3% a.i.) for 14 days.	No significant growth inhibition or stimulation relative to controls NOEC>5.6 mg/L	Hughes 1981a MRID 41400104
Anabaena flos-aquae, freshwater blue-green alga	0, 0.56, 1.0, 1.8, 3.2, or 5.6 mg/L Tech BAS 9052 (***Poast*** [2], 19.3% a.i.) for 14 days.	No significant growth inhibition or stimulation relative to controls NOEC>5.6 mg/L	Hughes 1981a MRID 41400104

Appendix 3: Toxicity of Poast to fish, aquatic invertebrates, and aquatic plants.

Animal	Exposure	Response	Reference
Aquatic Plants (*continued*)			
Skeletonema costatum, marine diatom	0, 0.56, 1.0, 1.8, 3.2, or 5.6 mg/L Tech BAS 9052 (***Poast*** [2], 19.3% a.i.) for 14 days.	No significant growth inhibition or stimulation relative to controls NOEC>5.6 mg/L	Hughes 1981a MRID 41400104A
Navicula seminulum, freshwater diatom	0, 0.56, 1.0, 1.8, 3.2, or 5.6 mg/L Tech BAS 9052 (***Poast*** [2], 19.3% a.i.) for 14 days.	Significant growth stimulation at all concentrations. NOEC<0.56 mg/L	Hughes 1981a MRID 41400104
Lemna gibba G3, (duckweed), freshwater macrophyte	0, 0.56, 1.0, 1.8, 3.2, or 5.6 mg/L Tech BAS 9052 (***Poast*** [2], 19.3% a.i.) for 14 days.	Significant growth stimulation at all concentrations. NOEC<0.56 mg/L	Hughes 1981a MRID 41400104
Skeletonema costatum, marine diatom	0, 0.56, 1.0, 1.8, 3.2, or 5.6 mg/L Tech BAS 9052 (***Poast*** [2], 19.3% a.i.) for 12 days. Algal assay bottle test.	The effect on maximum standing crop (cells/mL) was decreased at 1.0 mg/L concentration but not at the three higher concentrations, no effect on dry weight, no effect on lag period. NOEC>5.6 mg/L	Hughes 1981b MRID 41400105
Navicula seminulum Grun, freshwater diatom	0, 0.56, 1.0, 1.8, 3.2, or 5.6 mg/L Tech BAS 9052 (***Poast*** [2], 19.3% a.i.) for 16 days. Algal assay bottle test.	Significant growth stimulation at all concentrations, effect on maximum standing crop (cells/mL) increased at all concentrations, effect on dry weight increased at all concentrations, except 3.2 mg/L concentration, no effect on lag period at any concentration. NOEC<0.56 mg/L	Hughes 1981c MRID 41400107
Anabaena flos-aquae, freshwater blue-green alga	0, 0.56, 1.0, 1.8, 3.2, or 5.6 mg/L Tech BAS 9052 (***Poast*** [2], 19.3% a.i.) for 14 days. Algal assay bottle test.	No effect on maximum standing crop (cells/mL), no effect on dry weight, no effect on lag period. NOEC>5.6 mg/L	Hughes 1981d MRID 41400108

[1] BASF 1982: This is a summary of studies and provides little experimental detail.

[2] All studies using Poast involve exposures to the formulation but all concentrations are expressed in units of mg sethoxydim and not mg of the formulated product.

WORKSHEETS FOR Sethoxydim WS Version 2.02

NOTE: These are based on Worksheet Version 2.02. See SERA WSD 01-2.01, *Documentation for Worksheets Version 2.02 - Human Health and Ecological Risk Assessments*, dated October 13, 2001.

These worksheets are arranged in the following order:

Most worksheets are designated by a simple alphanumeric code. For example, Worksheet D03 is the third worksheet in Series D. Some closely related worksheets as designated by an additional alphabetic sub-code. For example, Worksheets D01a and D01b are the direct spray scenarios for a child and a woman, respectively.

The worksheets in Series A and B also have short descriptive synonyms, as indicated in the table of contents. For example, Worksheet A03 contains the general assumptions used in exposure assessments for the general public and is designated as ***PUBL***.

Worksheet Table of Contents

Worksheet Table of Contents

Section/Title	Page No.

Worksheet Table of Contents

GENERAL ASSUMPTIONS, VALUES, and MODELS

Worksheet A01 [CONST]**:** Constants and conversion factors used in calculations

Conversion	ID	Value
mg/lb	mg_lb	453,600
mL/gallon	ml_gal	3,785
lb/gallon to mg/mL	lbg_mgml	119.8
lb/acre to μg/cm^2	lbac_ugcm	11.21
lb/acre to mg/cm^2	lbac_mgcm	0.01121
gallons to liters	gal_lit	3.785

Worksheet A02 [STD]**:** General Assumptions Used in Worker Exposure Assessments

Parameter	ID	Value	Units	Reference
Body Weight (General)	BW	70	kg	ICRP (1975), p. 13
Surface area of both hands	Hands	840	cm^2	U.S. EPA/ORD 1992, p. 8-11
Surface area of lower legs	LLegs	2070	cm^2	U.S. EPA/ORD 1992, p. 8-11
Weight of liquid adhering to surface of skin after a spill	Liq	0.008	mL/cm^2	Mason and Johnson 1987

Worksheet A03 [PUBL]**:** General Assumptions Used in Exposure Assessments for the General Public

Verbal Description: This table contains various values used in the exposure assessments for the general public. Three general groups of individuals are considered: adult male, adult female, and a 2 year old child. Values are specified for body weight, surface areas for various parts of the body, water intake, fish consumption, and the consumption of fruits or vegetables. Not all types of value are specified for each group. The only values specified are those used in the risk assessment.

Description	ID	Value	Units	Reference
		Body Weights		
Male, Adult	BWM	70	kg	ICRP (1975), p. 13.
Female, Adult	BWF	64	kg	See Note 1 below.
Child, 2-3 years old	BWC	13.3	kg	U.S. EPA/ORD 1996, p. 7-1, Table 7-2

[1]This is the average value (63.79 kg), rounded to the nearest kg for 3 different groups of women between 15-49 years old: control (62.07 kg), pregnant (65.90 kg), and lactating (63.48 kg). See Burnmaster 1998, Table III, p.218. This is identical to the body weight for females, 45-55 years old, 50th percentile from U.S. EPA, 1985, page 5, Table 2-2, rounded to nearest kilogram.

Description	ID	Value	Units	Reference
		Body Surface Areas		
Female, feet and lower legs	SAF1	2915	cm^2	U.S. EPA/ORD 1992, p. 8-11, Table 8-3, total for feet and lower legs
Female, exposed skin when wearing shorts and a T-shirt	SAF2	5300	cm^2	U.S. EPA/ORD 1992, p. 8-11, Table 8-3, total for arms, hands, lower legs, and feet.
Child, male, 2-3 years old, total body surface area	SAC	6030	cm^2	U.S. EPA/ORD 1996, p. 6-15, Table 6-6, 50th percentile.
		Water Intake		
Adult				
typical	WCAT	2	L/day	U.S. EPA/ORD 1996, p. 3-28, Table 3-30, midpoint of mean (1.4 L/day) and 90th percentile (2.4 L/day) rounded to one significant place.
lower range for exposure assessment	WCAL	1.4	L/day	U.S. EPA/ORD 1996, p. 3-28, Table 3-30, mean
upper range	WCAH	2.4	L/day	U.S. EPA/ORD 1996, p. 3-28, Table 3-30, 90th percentile
Child, <3 years old				
typical	WCT	1	L/day	U.S. EPA/ORD 1996, p. 3-28, Table 3-30, midpoint of mean (0.61L/day) and 90th percentile (1.5 L/day) rounded to one significant place.
lower range for exposure assessment	WCL	0.61	L/day	U.S. EPA/ORD 1996, p. 3-28, Table 3-30, mean
upper range	WCH	1.50	L/day	U.S. EPA/ORD 1996, p. 3-28, Table 3-30, 90th percentile

Worksheet A03 [PUBL]***(continued)*****:** General Assumptions Used in Exposure Assessments for the General Public

Description	ID	Value	Units	Reference
		Fish Consumption		
Freshwater anglers, typical intake per day over a prolonged period	FAT	0.010	kg/day	U.S. EPA/ORD 1996, p. 10-51, average of means from four studies rounded to one significant place.
Freshwater anglers, maximum consumption for a single day	FAU	0.158	kg/day	Ruffle et al. 1994
Native American subsistence populations, typical intake per day	FNT	0.081	kg/day	U.S. EPA/ORD 1996, p. 10-51, median value of 94 individuals
Native American subsistence populations, maximum for a single day	FNU	0.770	kg/day	U.S. EPA/ORD 1996, p. 10-51, highest value of 94 individuals
		Consumption of Fruits and Vegetables		
Consumption of fruit, total				
Central	FrTC	0.00168	kg fruit/kg bw/day	U.S. EPA/ORD 1996, Table 9-3, p. 9-11, Central and upper estimates are mean and 95th percentile, respectively. The 5th percentile is given as zero. For these worksheets, the central estimate is used for the lower bound.
Lower	FrTL	0.00168		
Upper	FrTU	0.01244		
Consumption of vegetables, total				
Central	VgTC	0.0036	kg veg/kg bw/day	U.S. EPA/ORD 1996, Table 9-12, p. 9-12, mean, 5th percentile and 95th percentile.
Lower	VgTL	0.00075		
Upper	VgTU	0.01		
Consumption of vegetables, homegrown				
Central	VgHC	0.000761	kg veg/kg bw/day	U.S. EPA/ORD 1996, Table 12-15, p. 9-14, mean, 5th percentile and 95th percentile for individuals between 20 and 39 years old..
Lower	VgHL	0.0000777		
Upper	VgHU	0.00492		
Worst-case scenario for consumption in a single day, acute exposure scenario only.	VAcute	0.454	kg food	1 lb. The approximate mid range of the above typical and upper limits based on the 64 kg body weight.
		Miscellaneous		
Estimate of dislodgeable residue as a proportion of application rate shortly after application.	DisL	0.1	none	Harris and Solomon 1992, data on 2,4-D

Worksheet A04 [HK]**:** Estimated pesticide residues on various types of vegetation shortly after an application of 1 lb/acre.

Type of Vegetation	Concentration (mg chemical/kg vegetation)			
	Typical		Upper Limit	
	ID	Value	ID	Value
The following values are from Hoerger and Kenaga (1972).				
Range grass	RGT	125	RGU	240
Grass	GST	92	GSU	110
Leaves and leafy crops	LVT	35	LVU	125
Forage crops	FCT	33	FCU	58
Pods containing seeds	PDT	3	PDU	12
Grain	GNT	3	GNU	10
Fruit	FRT	1.5	FRU	7
The following values are from Fletcher et al. (1994)				
Short grass	SGT	85	SGU	240
Tall grass	TGT	36	TGU	110
Broadleaf/forage plants and small insects	BLT	45	BLU	135
Fruits, pods, seeds, and large insects	FRT2	7	FRU2	15

Worksheet A05 [FRUIT]**:** Concentration of a chemical on spheres of various sizes at an application rate of 1 lb/acre.

Diameter (cm)	Planar Surface Area (cm^2)[a]	Amount deposited (mg)[b]	Weight of sphere (kg)[c]	Concentration (mg/kg)[d]
1	0.78540	0.00880	0.00052	16.8
5	19.63495	0.21991	0.06545	3.36
10	78.53982	0.87965	0.52360	1.68
	Application rate	1 lb/acre =	0.0112	mg/cm^2

a Planar surface area of a sphere = πr^2 where r is the radius in cm.

b Amount deposited is calculated as the application rate in mg/cm^2 multiplied by the planar surface area.

c Assumes a density of 1 g/cm^3 for the fruit. The volume of a sphere is $(1 \div 6) \times \pi \times d^3$ where d is the diameter in cm. Assuming a density of 1 g/cm^3, the weight of the sphere in kg is equal to:

$$kg = (1 \div 6) \times \pi \times d^3 \div 1000$$

d Amount of chemical in mg divided by the weight of the sphere in kg.

Worksheet A06 [OFFSITE**]:** Central estimates of off-site drift (expressed as fraction of application rate) associated with ground applications of pesticides [1] (from AgDRIFT Version 1.16, Teske et al. 2001)

Distance Down Wind (feet)	Low Boom	High Boom	Orchard Airblast (Normal)
25	0.0187	0.1034	0.0057
50	0.0101	0.0515	0.0029
100	0.0058	0.0262	0.0007
300	0.0024	0.0078	0.0001
500	0.0015	0.0038	0.0000403
900	0.0008	0.0015	0.000013
990	0.0007	0.0013	<0.0000108

[1] Estimates based on very fine to fine spray. This will over-estimate drift for applications involving larger droplets.

Worksheet A07a [KAMODEL]: Estimate of first-order absorption rate (k_a in $hour^{-1}$) and 95% confidence intervals (from SERA 1997).

Model parameters	ID	Value		
Coefficient for $k_{o/w}$	C_KOW	0.233255		
Coefficient for MW	C_MW	0.005657		
Model Constant	C	1.49615		
Number of data points	DP	29		
Degrees of Freedom (d.f.)	DF	26		
Critical value of $\boldsymbol{t}_{0.025}$ with 26 d.f.[1]	CRIT	2.056		
Standard error of the estimate	SEE	16.1125		
Mean square error or model variance	MDLV	0.619712		
Standard deviation of model (s)	MSD	0.787218	$MDLV^{0.5}$	
X′X, cross products matrix	0.307537	-0.00103089	0.00822769	
	-0.00103089	0.000004377	-0.0000944359	
	0.0082	-0.0000944359	0.0085286	

[1] Mendenhall and Scheaffer 1973, Appendix 3, 4, p. A31.

Central (maximum likelihood) estimate:

$$\log_{10} k_a = 0.233255 \log_{10}(\boldsymbol{k_{o/w}}) - 0.005657\, \boldsymbol{MW} - 1.49615$$

95% Confidence intervals for $\log_{10} k_a$

$$\log_{10} k_a \pm \boldsymbol{t}_{0.025} \times \boldsymbol{s} \times (\boldsymbol{a'X'X\,a})^{0.5}$$

where $\boldsymbol{a}$ is a column vector of {1, MW, $\log_{10}(\boldsymbol{k_{o/w}})$}.

NB: Although the equation for the central estimate is presented with $k_{o/w}$ appearing before MW to be consistent with the way a similar equation is presented by EPA, MW must appear first in column vector $\boldsymbol{a}$ because of the way the statistical analysis was conducted to derive X′X .

See following page for details of calculating $\boldsymbol{a'X'X\,a}$ without using matrix arithmetic.

Worksheet Worksheet A07a (continued)

Details of calculating a′X′X a

The term **a'**·(**X'X**)$^{-1}$·**a** requires matrix multiplication. While this is most easily accomplished using a program that does matrix arithmetic, the calculation can be done with a standard calculator.

Letting

a = {a_1, a_2, a_3}

and

(**X'X**)$^{-1}$ = {
{b_1, b_2, b_3},
{c_1, c_2, c_3},
{d_1, d_2, d_3}
},

a'·(**X'X**)$^{-1}$·**a** is equal to

Term 1: {a_1 ×([a_1×b_1] + [a_2×c_1] + [a_3×d_1])} +
Term 2: {a_2 ×([a_1×b_2] + [a_2×c_2] + [a_3×d_2])} +
Term 3: {a_3 ×([a_1×b_3] + [a_2×c_3] + [a_3×d_3])}.

Worksheet A07b [KPMODEL]: Estimate of dermal permeability (K_p in cm/hr) and 95% confidence intervals (data from U.S. EPA/ORD 1992).

Model parameters	ID	Value		
Coefficient for $k_{o/w}$	C_KOW	0.706648		
Coefficient for MW	C_MW	0.006151		
Model Constant	C	2.72576		
Number of data points	DP	90		
Degrees of Freedom (d.f.)	DF	87		
Critical value of $\boldsymbol{t}_{0.025}$ with 87 d.f.[1]	CRIT	1.96		
Standard error of the estimate	SEE	45.9983		
Mean square error or model variance	MDLV	0.528716		
Standard deviation of model (s)	MSD	0.727129	$MDLV^{0.5}$	
X′X, cross products matrix	0.0550931	-0.0000941546	-0.0103443	
	-0.0000941546	0.0000005978	-0.0000222508	
	-0.0103443	-0.0000222508	0.00740677	

[1] Mendenhall and Scheaffer, 1973, Appendix 3, Table 4, p. A31.

NOTE: The data for this analysis is taken from U.S. EPA/ORD (1992), Dermal Exposure Assessment: Principles and Applications, EPA/600/8-91/011B, Table 5-4, pp. 5-15 through 5-19. The EPA report, however, does not provide sufficient information for the calculation of confidence intervals. The synopsis of the above analysis was conducted in STATGRAPHICS Plus for Windows, Version 3.1 (Manugistics, 1995) as well as Mathematica, Version 3.0.1.1 (Wolfram Research, 1997). Although not explicitly stated in the EPA report, 3 of the 93 data points are censored from the analysis because they are statistical outliers: [Hydrocortisone-21-yl]-hemipimelate, n-nonanol, and n-propanol. The model parameters reported above are consistent with those reported by U.S. EPA but are carried out to greater number of decimal places to reduce rounding errors when calculating the confidence intervals. See notes to Worksheet A07a for details of calculating maximum likelihood estimates and confidence intervals.

CHEMICAL SPECIFIC VALUES

Worksheet B01 [APPL]**:** Anticipated Application and Dilution Rates for sethoxydim

Item		Code	Value	Units	Source
Application rate (***R***)					
	Central	Typ	0.3	lb/acre	Section 2.4
	Lower	Low	0.09375		Section 2.4
	Upper	Hi	0.375		Section 2.4
Dilution (***Dil***)					
	Central	CDil	10	gal./acre	Section 2.4
	Lower	LDil	5		
	Upper	HDil	20		
Concentration in field solutions[1]: $\mathbf{R_{(lb/acre)} \div Dil_{(gal/acre)} \times 119.8}$ **mg/mL÷lb/gal**					
	Central	TypDr	3.6	mg/mL	
	Lower	LowDr	0.56		
	Upper	HI_Dr	9		

The typical concentration in applied solution is calculated as the typical application rate (lbs/acre) divided by the typical dilution (gal/acre), yielding units of lbs/gallon. This is converted to mg/mL using the relationship of lb/gal = 119.8 mg/mL from Worksheet A01. The lowest estimated concentration is calculated as the lowest application rate divided by the highest dilution. The highest estimated concentration is calculated as highest application rate divided by the lowest dilution.

NOTE ON UNITS FOR APPLICATION RATE: In all cases, lb/acre refers to lb a.i./acre.

Worksheet B02 [CHEM]**:** Summary of chemical specific values used for sethoxydim in exposure assessment worksheets.

Parameter	ID	Value	Units	Source/Reference
Molecular weight	MW	327.50	grams/mole	Table 2-1
Water Solubility, pH 7 and 20°C	WS	4700	mg/L	Table 2-1
$K_{o/w}$, pH 7	Kow	45.1	unitless	Table 2.1, log $K_{o/w}$ = 1.65
Foliar half-time ($t_{½}$)	FT12	3	days	Table 2-1
central	FrT12C	3	days	
lower	FrT12L	3	days	
upper	FrT12U	3	days	
Dissipation coefficients on vegetation				
central	VgKC	0.231049	day^{-1}	ln(2)/half-time. The upper limit on half-time is used to calculate the lower limit on dissipation coefficient.
lower	VgKL	0.231049	day^{-1}	
upper	VgKU	0.231049	day^{-1}	
Bioconcentration factor, edible portion, acute exposure	BCFT	1.2	L/kg fish	Section 3.2.3.5.
Bioconcentration factor, edible portion, chronic exposure	BCFCh	7	L/kg fish	
Bioconcentration factor, whole fish, acute	BCFWA	3.6	L/kg fish	
Bioconcentration factor, whole fish, chronic	BCFWC	21	L/kg fish	
Chronic RfD[a]	RfDP	0.09	mg/kg bw/day	Section 3.3.3
Acute RfD	RfDA	0.6	mg/kg bw/day	Section 3.3.3

Worksheet B03 [KA_CHEM]**:** Calculation of first-order dermal absorption rate (k_a) for sethoxydim[1].

Parameters	Value	Units				Reference	
Molecular weight	327.5	g/mole					
$K_{o/w}$ at pH 7	45.1	unitless					
$\log_{10} K_{o/w}$	1.65						
Column vector ***a*** for calculating confidence intervals							
a_1	1						
a_2	327.5						
a_3	1.65						
Calculation of $\mathbf{a'} \cdot (\mathbf{X'X})^{-1} \cdot \mathbf{a}$							
Term 1	-0.016549475						
Term 2	0.0808133318						
Term 3	-0.0142359975						
$\mathbf{a'} \cdot (\mathbf{X'X})^{-1} \cdot \mathbf{a}$	0.05						
$\log_{10} k_a = 0.233255 \log_{10}(\boldsymbol{k_{o/w}}) - 0.005657\ \boldsymbol{MW} - 1.49615$							
$\log_{10}$ of first order absorption rate (k_a)							
Central estimate	-2.96297255072	±	$\boldsymbol{t}_{0.025}$	×	$\boldsymbol{s}$	×	$(\mathbf{a'} \cdot (\mathbf{X'X})^{-1} \cdot \mathbf{a})^{0.5}$
Lower limit	-3.32488467153	-	2.0560	×	0.787218	×	0.22360679775
Upper limit	-2.60106042992	+	2.0560	×	0.787218	×	0.22360679775
First order absorption rates (i.e., antilog or 10^x of above values).							
Central estimate	0.00109	$hour^{-1}$					
Lower limit	0.00047	$hour^{-1}$					
Upper limit	0.00251	$hour^{-1}$					

[1] See Worksheet A07a for details of method.

Worksheet B04 [KP_CHEM]**:** Calculation of dermal permeability rate (K_p) in cm/hour for sethoxydim [1].

Parameters	Value	Units					Reference
Molecular weight	327.5	g/mole					
$K_{o/w}$	45.1	unitless					
$\log_{10} K_{o/w}$	1.65417654188						
Column vector ***a*** for calculating confidence intervals							
a_1	1						
a_2	327.5						
a_3	1.65417654188						
Calculation of **a'** · (**X'X**)$^{-1}$ · **a**							
Term 1	0.00714617						
Term 2	0.0212279437						
Term 3	-0.008898365						
a' · (**X'X**)$^{-1}$ · **a**	0.0195						
$\log_{10} K_p = 0.706648 \log_{10}(\boldsymbol{k_{o/w}}) - 0.006151\, \boldsymbol{MW} - 2.72576$							
$\log_{10}$ of dermal permeability							
Central estimate	-3.57129195504	±	$\boldsymbol{t}_{0.025}$	×	***s***	×	**a'**·(**X'X**)$^{-1}$·**a**$^{0.5}$
Lower limit	-3.77030651145	-	1.9600	×	0.727129	×	0.13964240044
Upper limit	-3.37227739862	+	1.9600	×	0.727129	×	0.13964240044
Dermal permeability							
Central estimate	0.0002684	cm/hour					
Lower limit	0.0001697	cm/hour					
Upper limit	0.0004243	cm/hour					

[1] See Worksheet A07a for details of method.

Worksheet B05 [DERM]**:** Summary of chemical specific dermal absorption values used for sethoxydim dermal absorption.

Description	Code	Value	Units	Reference/Source
Zero-order absorption (K_p)				
Central estimate	KpC	**0.00027**	cm/hour	Worksheet KPMODEL, values rounded to two significant figures
Lower limit	KpL	**0.00017**	cm/hour	
Upper limit	KpU	**0.00042**	cm/hour	
First-order absorption rates (k_a)				
Central estimate	AbsC	**0.0011**	$hour^{-1}$	Worksheet KAMODEL, values rounded to two significant figures
Lower limit	AbsL	**0.00047**	$hour^{-1}$	
Upper limit	AbsU	**0.0025**	$hour^{-1}$	

Worksheet B06 [AMBWAT]**:** Estimates of the concentration of sethoxydim in ambient water per pound applied per acre based on monitoring data and the resulting estimated concentrations in ambient water that are used in the chronic contaminated water exposure assessments.

Scenario	GLEAMS model runs were conducted at rainfall rates of 5 to 250 inches per year and an application rate of 1 lb/acre with a 10 acre square plot adjacent to a 10 acre pond that is 1 meter deep.	ID	***WCR*** (mg/L) ÷ (lb/acre)
	Short-term Peak Concentrations in Streams (See Section 3.2.3.4.1 for details)		
Central	The typical rate is taken as 200 µg/L. This is about the peak concentrations that could be expected at rainfall rates of about 100 inches per year from sand.	AWPT	0.200
Lower	The lower limit is about the peak concentration from sandy soil at an annual rainfall rate of 15 inches per year.	AWPL	0.020
Upper	The upper limit is approximately the peak concentration from loam soils at rainfall rates of 250 inches per year.	AWPU	0.500
	Longer-term Concentrations in Lakes (See Section 3.2.3.4.2 for details)		
Central	The typical WCR is taken as 0.0008 mg/L. This is about the average concentration that could be expected at rainfall rates of about 100 inches per year from loam.	AWT	0.0008
Lower	The lower limit of the WCR is taken as 0.00002 mg/L, the average concentration from loam soil at an annual rainfall rate of 10 inches per year.	AWL	0.00002
Upper	The upper limit is taken as 0.0012 mg/L, approximately the longer-term average concentration from loam soils at rainfall rates of 250 inches per year.	AWU	0.0012

WORKER EXPOSURE ASSESSMENTS

Worksheet C01a: Worker exposure estimates for directed foliar (backpack) applications of sethoxydim [WkBkExp01]

Verbal Description: The absorbed dose for the worker is calculated from the amount handled per day and the generic absorbed dose rate from several field studies on worker applications of a number of herbicides. The amount handled per day is calculated from the application rates as well as estimates of the hours worked per day and acres treated per hour.

Parameter/Assumption		Value	Units	Source/Designation
Application rates (***R***)				
	Central	0.3	lb/acre	APPL.TYP
	Lower	0.09375		APPL.LOW
	Upper	0.375		APPL.HI
Hours of application per day (***Hrs***)				
	Central	7	hours	USDA 1989a,b,c
	Lower	6		USDA 1989a,b,c
	Upper	8		USDA 1989a,b,c
Acres treated per hour (***Acres***)				
	Central	0.625	acres/hour	USDA 1989a,b,c
	Lower	0.25		USDA 1989a,b,c
	Upper	1		USDA 1989a,b,c
Acres treated per day (**ATD**): **Hrs × Acres**				
	Central	4.375	acres/day	
	Lower	1.5		
	Upper	8		
Amount handled per day (***AHD***): **R** × **ATD**				
	Central	1.3125	lb/day	
	Lower	0.140625		
	Upper	3		
Absorbed dose rate (***ADR***):				
	Central	0.003	(mg agent/kg bw) ÷ (lbs agent handled per day)	SERA 2001
	Lower	0.0003		
	Upper	0.01		
Absorbed dose [D_{Abs}]: **AHD × ADR**				
	Central	3.94e-03	mg/kg bw/day	
	Lower	4.22e-05		
	Upper	3.00e-02		

Worksheet C01b: Worker exposure estimates for boom spray (hydraulic ground spray) applications of sethoxydim [WkHyExp01]

Verbal Description: The absorbed dose for the worker is calculated from the amount handled per day and the generic absorbed dose rate from several field studies on worker applications of a number of herbicides. The amount handled per day is calculated from the application rates as well as estimates of the hours worked per day and acres treated per hour.

Parameter/Assumption		Value	Units	Source/Designation
Application rates (***R***)				
	Central	0.3	lb/acre	APPL.TYP
	Lower	0.09375		APPL.LOW
	Upper	0.375		APPL.HI
Hours of application per day (***Hrs***)				
	Central	7	hours	USDA 1989a,b,c
	Lower	6		
	Upper	8		
Acres treated per hour (***Acres***)				
	Central	16	acres/hour	USDA 1989a,b,c.
	Lower	11		
	Upper	21		
Acres treated per day (***ATD***): **Hrs × Acres**				
	Central	112	acres/day	
	Lower	66		
	Upper	168		
Amount handled per day (***AHD***): **R × ATD**				
	Central	33.6	lb/day	
	Lower	6.1875		
	Upper	63		
Absorbed dose rate (***ADR***)				
	Central	0.0002	(mg agent/kg bw) ÷ (lbs agent handled per day)	SERA 2001
	Lower	0.00001		
	Upper	0.0009		
Absorbed dose [D_{Abs}]: **AHD × ADR**				
	Central	6.72e-03	mg/kg bw/day	
	Lower	6.19e-05		
	Upper	5.67e-02		

NOTE: THE FOREST SERVICE WILL NOT USE AERIAL APPLICATIONS. THIS WORKSHEET IS INCLUDED AS A PLACE-HOLDER BUT THE RESULTS OF THE CALCULATIONS ARE NOT INCLUDED IN THE SUMMARY TABLES - I.E., WORKSHEETS E01 AND E02.

Worksheet C01c: Worker exposure estimates for aerial applications of sethoxydim [WKAREXP01]

Verbal Description: The absorbed dose for the worker is calculated from the amount handled per day and the generic absorbed dose rate from several field studies on worker applications of a number of herbicides (SERA 2001). The amount handled per day is calculated from the application rates as well as estimates of the hours worked per day and acres treated per hour.

Parameter/Assumption		Value	Units	Source/Designation
Application rates (***R***)				
	Central	0.3	lb/acre	Appl.Typ
	Lower	0.09375		Appl.Low
	Upper	0.375		Appl.Hi
Hours of application per day (***Hrs***)				
	Central	7	hours	USDA 1989a,b,c
	Lower	6		
	Upper	8		
Acres treated per hour (***Acres***)				
	Central	70	acres/hour	USDA 1989a,b,c
	Lower	40		
	Upper	100		
Acres treated per day (***ATD***): **Hrs × Acres**				
	Central	490	acres/day	
	Lower	240		
	Upper	800		
Amount handled per day (***AHD***): **R × ATD**				
	Central	147	lb/day	
	Lower	22.5		
	Upper	300		
Absorbed dose rate (***ADR***)				
	Central	0.00003	(mg agent/kg bw) ÷ (lbs agent handled per day)	SERA 2001
	Lower	0.000001		
	Upper	0.0001		
Absorbed dose [D_{Abs}]: **AHD × ADR**				
	Central	4.41e-03	mg/kg bw	
	Lower	2.25e-05		
	Upper	3.00e-02		

Worksheet C02a: Workers: Accidental Dermal Exposure Assessments Using Zero-Order Absorption Wearing Contaminated Gloves for One Minute [WrkDrmZr01]

Verbal Description: Dermal absorption is calculated using the zero-order model from U.S. EPA/ORD (1992):

$$\text{Dose (mg/kg)} = \text{Kp} \times \text{C} \times \text{Time} \times \text{S} \div \text{W}$$

Each of the above terms are described below.

Parameter		Value	Units	Source
Body weight (***W***)		70	kg	STD.BW
Surface Area of hands (***S***)		840	cm^2	STD.Hands
Dermal permeability (K_p)				
	Central	0.00027	cm/hour	DERM.KpC
	Lower	0.00017	cm/hour	DERM.KpL
	Upper	0.00042	cm/hour	DERM.KpU
Concentration in solution (***C***) [1]				
	Central	3.6	mg/mL	APPL.TypDr
	Lower	0.56	mg/mL	APPL.LowDr
	Upper	9	mg/mL	APPL.HI_Dr
Duration of Exposure (***T***)		0.0167	hours	1÷60
Absorbed Dose (D_{Abs}): **Kp × C × T × S ÷ W**				
	Central	1.94e-04	mg/kg	
	Lower	1.90e-05	mg/kg	
	Upper	7.56e-04	mg/kg	

[1] Note that 1 mL is equal to 1 cm^3 and thus mg/mL = mg/cm^3.

Worksheet C02b: Workers: Accidental Dermal Exposure Assessments Using Zero-Order Absorption Wearing Contaminated Gloves for One Hour [WrkDrmZr60]

Verbal Description: Dermal absorption is calculated using the zero-order model from U.S. EPA/ORD (1992):

$$\text{Dose (mg/kg)} = \text{Kp} \times \text{C} \times \text{Time} \times \text{S} \div \text{W}$$

Each of the above terms are described below.

Parameter		Value	Units	Source
Body weight (***W***)		70	kg	STD.BW
Surface Area of hands (***S***)		840	cm^2	STD.Hands
Dermal permeability ($\boldsymbol{K_p}$)				
	Central	0.00027	cm/hour	DERM.KpC
	Lower	0.00017		DERM.KpL
	Upper	0.00042		DERM.KpU
Concentration in solution (***C***)[1]				
	Central	3.6	mg/mL	APPL.TypDr
	Lower	0.56		APPL.LowDr
	Upper	9		APPL.HI_Dr
Duration of Exposure (***T***)		1	hours	
Absorbed Dose (D_{Abs}): **Kp × C × T × S ÷ W**				
	Central	1.17e-02	mg/kg bw	
	Lower	1.14e-03		
	Upper	4.54e-02		

[1] Note that 1 mL is equal to 1 cm^3 and thus mg/mL = mg/cm^3.

Worksheet C03a: Accidental Spill onto the Hands for 1 Hour Based on the Assumption of First-Order Absorption [WrkDrmFrHnd]

Verbal Description: A worker spills a solution of the compound at a specified concentration (***C***) on a defined area of the skin (***A***). Based on the amount of liquid adhering to the skin (***L***), the amount of chemical absorbed (***Dose***) over a given period is calculated from the first order dermal absorption coefficient ($\boldsymbol{k_a}$), the amount of time that the chemical remains on the surface of the skin before it is effectively removed by washing (***T***) and the body weight (***W***) (Durkin et al. 1995).

Parameter		Value	Units	Source
Liquid adhering to skin after a spill (***L***)		0.008	mL/cm^2	STD.Liq
Body weight (***W***)		70	kg	STD.BW
Surface Areas (**A**)				
	Hands	840	cm^2	STD.Hands
Duration of Exposure (***T***)		1	hours	
First-order dermal absorption rates ($\boldsymbol{k_a}$)				
	Central	0.00110	hour^{-1}	DERM.ABSC
	Lower	0.000470		DERM.ABSL
	Upper	0.00250		DERM.ABSU
Concentration in solution (***C***)				
	Central	3.6	mg/mL	APPL.TypDr
	Lower	0.56		APPL.LowDr
	Upper	9		APPL.HI_Dr
Amount Deposited on Skin (***Amnt***): L × A × C				
	Central	24.192	mg	
	Lower	3.7632		
	Upper	60.48		
Proportion absorbed over period ***T*** (***Prop***): $1-e^{-k\,T}$				
	Central	0.0010994	unitless	
	Lower	0.0004699		
	Upper	0.0024969		
Absorbed Dose (D_{Abs}): **Amnt × Prop ÷ W**				
	Central	3.80e-04	mg/kg bw	
	Lower	2.53e-05		
	Upper	2.16e-03		

Worksheet C03b: Accidental Spill onto the Lower Legs for 1 Hour Based on the Assumption of First-Order Absorption [WrkDrmFrLeg]

Verbal Description: A worker spills a solution of the compound at a specified concentration (***C***) on a defined area of the skin (***A***). Based on the amount of liquid adhering to the skin (***L***), the amount of chemical absorbed (***Dose***) over a given period is calculated from the first order dermal absorption coefficient (k_a), the amount of time that the chemical remains on the surface of the skin before it is effectively removed by washing (***T***) and the body weight (***W***) (Durkin et al. 1995).

Parameter		Value	Units	Source
Liquid adhering to skin after a spill (***L***)		0.008	mL/cm^2	STD.Liq
Body weight (***W***)		70	kg	STD.BW
Surface Areas (**A**)				
	Legs	2070	cm^2	STD.LLegs
Duration of Exposure (***T***)		1	hours	
First-order dermal absorption rates (k_a)				
	Central	0.00110	hour^{-1}	DERM.ABSC
	Lower	0.000470		DERM.ABSL
	Upper	0.00250		DERM.ABSU
Concentration in solution (***C***)				
	Central	3.6	mg/mL	APPL.TypDr
	Lower	0.56		APPL.LowDr
	Upper	9		APPL.HI_Dr
Amount Deposited on Skin (***Amnt***): L × A × C				
	Central	59.616	mg	
	Lower	9.2736		
	Upper	149.04		
Proportion absorbed over period ***T*** (***Prop***): $1-e^{-k\,T}$				
	Central	0.0010994	unitless	
	Lower	0.0004699		
	Upper	0.0024969		
Absorbed Dose (D_{Abs}): **Amnt × Prop ÷ W**				
	Central	9.36e-04	mg/kg bw	
	Lower	6.23e-05		
	Upper	5.32e-03		

Worksheet D01a: Direct Spray of a Child, Assumption of First-Order Absorption [SpillFOACh01]

Verbal Description: A naked child is accidentally sprayed over the entire body surface (***A***) with a field dilution of a specified concentration (***C***). The child is effectively washed **-** i.e., all of the compound is removed **-** after a specified period of time (***T***). The absorbed dose (***D***) is calculated from the amount of liquid adhering to the skin (***L***), the first-order dermal absorption rate (k_a) and the body weight (***W***).

Parameter		Value	Units	Source
Liquid adhering to skin after a spill (***L***)		0.008	mL/cm^2	STD.Liq
Body weight (***W***)		13.3	kg	PUBL.BWC
Exposed surface area (***A***)				
	Whole Body	6030	cm^2	PUBL.SAC
Duration of Exposure (***T***)		1	hours	
First-order dermal absorption rates (k_a)				
	Central	0.00110	hour^{-1}	DERM.ABSC
	Lower	0.000470		DERM.ABSL
	Upper	0.00250		DERM.ABSU
Concentration in solution (***C***)				
	Central	3.6	mg/mL	APPL.TypDr
	Lower	0.56		APPL.LowDr
	Upper	9		APPL.HI_Dr
Amount Deposited on Skin (***Amnt***): L × A × C				
	Central	173.664	mg	
	Lower	27.0144		
	Upper	434.16		
Proportion absorbed over period ***T*** (***Prop***): $1-e^{-k\,T}$				
	Central	0.0010994	unitless	
	Lower	0.0004699		
	Upper	0.0024969		
Absorbed Dose (D_{Abs}): **Amnt × Prop ÷ W**				
	Central	1.44e-02	mg/kg bw	
	Lower	9.54e-04		
	Upper	8.15e-02		

Worksheet D01b: Direct Spray of a Woman, Assumption of First-Order Absorption [SpillFOAWm01]

Verbal Description: A woman is sprayed over the feet and lower legs (***A***) with a field dilution of a specified concentration (***C***). The woman effectively washes - i.e., all of the compound is removed - after a specified period of time (***T***). The absorbed dose (***D***) is calculated from the amount of liquid adhering to the skin (***L***), the first-order dermal absorption rate (k_a) and the body weight (***W***).

Parameter	Value	Units	Source
Liquid adhering to skin after a spill (***L***)	0.008	mL/cm^2	STD.Liq
Body weight (***W***)	64	kg	PUBL.BWF
Exposed surface area (***A***)			
Feet and lower legs	2915	cm^2	PUBL.SAF1
Duration of Exposure (***T***)	1	hours	
First-order dermal absorption rates (k_a)			
Central	0.00110	$hour^{-1}$	DERM.ABSC
Lower	0.000470		DERM.ABSL
Upper	0.00250		DERM.ABSU
Concentration in solution (***C***)			
Central	3.6	mg/mL	APPL.TypDr
Lower	0.56		APPL.LowDr
Upper	9		APPL.HI_Dr
Amount Deposited on Skin (***Amnt***): L × A × C			
Central	83.952	mg	
Lower	13.0592		
Upper	209.88		
Proportion absorbed over period ***T*** (***Prop***): $1-e^{-k\,T}$			
Central	0.0010994	unitless	
Lower	0.0004699		
Upper	0.0024969		
Absorbed Dose (D_{Abs}): **Amnt × Prop ÷ W**			
Central	1.44e-03	mg/kg	
Lower	9.59e-05		
Upper	8.19e-03		

Worksheet D02: Dermal contact with contaminated vegetation by a young woman [VegC_FOA01].

***Verbal Description**: A woman wearing shorts and a short sleeved shirt is in contact with contaminated vegetation for 1 hour shortly after application of the compound **-** i.e. no dissipation or degradation is considered. The chemical is effectively removed from the surface of the skin **-** i.e., washing **-** after 24 hours.*

Parameter/Assumption		Value	Units	Source/Reference
Contact time (***Tc***)		1	hour	N/A
Exposure time (***Te***)		24	hours	N/A
Body weight (***W***)		64	kg	PUBL.BWF
Exposed surface area (***A***)		5300	cm^2	PUBL.SAF2
Application Rates in lb/acre (***Rlb***)				
	Central	0.3	lb/acre	APPL.TYP
	Lower	0.09375		APPL.LOW
	Upper	0.375		APPL.HI
First-order dermal absorption rate (***k***)				
	Central	0.00110	$hour^{-1}$	DERM.AbsC
	Lower	0.000470		DERM.AbsL
	Upper	0.00250		DERM.AbsU
Application Rates in $\mu g/cm^2$ (***Rμg***): Rlb × Const.lbac_ugcm				
	Central	3.363	$\mu g/cm^2$	
	Lower	1.0509375		
	Upper	4.20375		
Proportion dislodgeable (***PropDr***)		0.1	none	PUBL.DisL
Dislodgeable residue (***Dr***): ***Rμg*** × ***PropDr***				
	Central	0.3363	$\mu g/cm^2$	
	Lower	0.10509375		
	Upper	0.420375		
Transfer Rate (***Tr***): ***Tr*** $= 10^{(1.09 \times \log10(Dr) + 0.05)} \div 1000$ μg/mg				
	Central	3.42e-04	$mg/(cm^2\ hr)$	The method of Durkin et al. (1995, p. 68, equation 4) is used to calculate the transfer rate (***Tr***) in units of $\mu g/(cm^2 \cdot hr)$) based on the dislodgeable residue ***(Dr***) in units of $\mu g/cm^2$. This is converted to units of $mg/(cm^2 \cdot hr)$) by dividing by 1000 μg/mg.
	Lower	9.63e-05		
	Upper	4.36e-04		
Amount Transferred to Skin Surface (***Amnt***): ***Tr*** × ***Tc*** × ***A***				
	Central	1.81304	mg	
	Lower	0.51026		
	Upper	2.31228		
Proportion Absorbed (***PropAbs***): $1 - e^{-ka \times Te}$				
	Central	2.61e-02	unitless	
	Lower	1.12e-02		
	Upper	5.82e-02		
Absorbed dose (D_{Abs}): **Amnt** × **PropAbs** ÷ **W**				
	Central	7.38e-04	mg/kg bw	
	Lower	8.94e-05		
	Upper	2.10e-03		

Worksheet D03: Consumption of contaminated fruit, acute exposure scenario [VegAcHHRA01].

Verbal Description: Edible fruit is contaminated by drift (***Dr***). A drift of 1 (unity) indicates direct spray. The individual consumes contaminated fruit shortly after application of the chemical **-** i.e. no dissipation or degradation is considered. The concentration of the chemical in fruit (***C***) is estimated from empirical relationships relating residues on plants to application rate.

Parameters/Assumptions		Value	Units	Source/Reference
Amount of fruit consumed per Unit Body Weight (***A***):				
	Central	0.00168	kg fruit/kg bw/day	PUBL.FrTC
	Lower	0.00168		PUBL.FrTL
	Upper	0.01244		PUBL.FrTU
Application rates (***R***)				
	Central	0.3	lb/acre	APPL.Typ
	Lower	0.09375		APPL.Low
	Upper	0.375		APPL.Hi
Residue rates (***rr***)				
	Central	7	mg/kg per lb/acre	HK.FRT2
	Lower	7		HK.FRT2
	Upper	15		HK.FRU2
Drift (***Drift***)				
	Central	1	unitless	Direct spray
	Lower	1		
	Upper	1		
Proportion Removed by Washing (***Wash***)				
	Central	0	unitless	No washing is assumed for this scenario.
	Lower	0		
	Upper	0		
Concentration on fruit (***C***): ***R*** × ***rr*** × ***Drift*** × (1-**Wash**)				
	Central	2.1	mg/kg fruit	
	Lower	0.65625		
	Upper	5.625		
Dose estimates (***D***): ***C*** × ***A***				
	Central	3.53e-03	mg/kg bw	
	Lower	1.10e-03		
	Upper	7.00e-02		

Worksheet D04: Consumption of contaminated fruit, chronic exposure scenario [VegChHHRA01].

Verbal Description: An individual consumes contaminated fruit for a period of time (**t**) *starting shortly after application of the chemical.* The concentration of the chemical in fruit at time zero (C_0) is estimated from the application rate (***A***), the proportion of drift (***Drift***), and empirical residues rates (***rr***) summarized in HK. The foliar halftime (t_{50}) is used to estimate the foliar decay coefficient (***k***): **k = ln(2)÷t_{50}**. The concentration on the vegetation after time ***t*** (C_t) is calculated as $C_t = C_0e^{-kt}$. The time-weighted average of the concentration on vegetation (C_{TWA}) is calculated as the integral of the concentration after time ***t*** (C_t) divided by the duration (***t***).

Parameters/Assumptions		Value	Units	Source/Reference
Halftime on vegetation (t_{50})	Central	3	days	CHEM.FrT12C
	Lower	3		CHEM.FrT12L
	Upper	3		CHEM.FrT12U
Duration of exposure (***T***)		90	days	N/A
Amount of fruit consumed per unit body weight(***A***): Central is also used for lower.				
	Central	0.00168	kg fruit/kg bw/day	PUBL.FrTC
	Lower	0.00168		PUBL.FrTL
	Upper	0.01244		PUBL.FrTU
Application rates (***R***)				
	Central	0.3	lb/acre	APPL.Typ
	Lower	0.09375		APPL.Low
	Upper	0.375		APPL.Hi
Residue rates (***rr***):				
	Central	7	mg/kg fruit per lb/acre applied	WSA05a.FRT2
	Lower	7		WSA05a.FRT2
	Upper	15		WSA05aFRU2
Drift (***Drift***)				
	Central	1	unitless	Assume direct spray
	Lower	1		
	Upper	1		
Decay coefficient (***k***): ln(2)/t_{50}				
	Central	0.2310491	day^{-1}	Upper estimate of t_{50} used to calculate lower limit of ***k*** and lower estimate of t_{50} used to calculate upper limit of ***k***.
	Lower	0.2310491		
	Upper	0.2310491		

Worksheet D04 *(continued)*: Consumption of contaminated fruit, chronic exposure scenario [VegChHHRA01].

Initial Concentration on Vegetation (C_0): : $\mathbf{C_0 = A \times Drift \times rr}$

	Central	2.1	mg/kg veg.	
	Lower	0.65625		
	Upper	5.625		

Concentration on Vegetation at time T (C_T): $\mathbf{C_T = C_0\ e^{-kT}}$

	Central	1.96e-09	mg/kg veg.	
	Lower	6.11e-10		
	Upper	5.24e-09		

Time-weighted Average Concentration on Raw Vegetation (C_{TWA}): C_0 $\mathbf{(1 - e^{-k\,T}) \div (k\ T)}$

	Central	0.1009887	mg/kg veg.	
	Lower	0.031559		
	Upper	0.2705053		

Proportion Removed by Washing (P_{wash}):

	Central	0	unitless	Assume that washing is ineffective.
	Lower	0		
	Upper	0		

TWA Concentration on Consumed Vegetation (C_{Con}): $C_{TWA} \times 1\text{-}P_{Wash}$

	Central	1.01e-01	mg/kg veg.	
	Lower	3.16e-02		
	Upper	2.71e-01		

Dose estimates (D): $C_{Con} \times A$

	Central	1.70e-04	mg/kg bw/day	
	Lower	5.30e-05		
	Upper	3.37e-03		

Worksheet D05: Consumption of contaminated water following an accidental spill, acute exposure scenario [DWAcHHRA01].

***Verbal Description**:* A young child (2-3 years old) consumes contaminated water shortly after an accidental spill of 200 gallons of a field solution into a pond that has an average depth of 1 m and a surface area of 1000 m^2 or about one-quarter acre . No dissipation or degradation is considered.

Parameters/Assumptions		Value	Units	Source/Reference
Surface area of pond (SA)		1000	m^2	N/A
Average depth (DPTH)		1	m	N/A
Volume of pond in cubic meters (VM)		1000	m^3	N/A
Volume of pond in Liters (VL)		1000000	L	1 m^3 = 1,000 L
Volume of spill (VS)		200	gallons	N/A
		757	liters	1 gallon = 3.785 Liters
Concentrations in field solution (C_{Fld} (mg/L))				
	Central	3600	mg/L	APPL.TypDR × 1000
	Lower	560		APPL.LowDR × 1000
	Upper	9000		APPL.Hi_DR × 1000
Concentrations in ambient water (C_{Wrt}): $C_{Fld} \times VS_{(Liters)} \div VL$				
	Central	2.7252	mg/L	
	Lower	0.42392		
	Upper	6.813		
Body weight (W)		13.3	kg	PUBL.BWC
Amount of water consumed (A)				
	Central	1	L/day	PUBL.WCT
	Lower	0.61		PUBL.WCL
	Upper	1.5		PUBL.WCH
Dose estimates (D): $C_{wrt} \times A \div W$				
	Central	2.05e-01	mg/kg bw	
	Lower	1.94e-02		
	Upper	7.68e-01		

Worksheet D06: Consumption of from a stream contaminated by runoff and/or percolation, acute exposure scenario [DWAcStrmHHRA01].

Verbal Description: A young child (2-3 years old) consumes contaminated ambient water from a stream that has been contaminated from run-off and/or percolation The levels in water are estimated from modeling or monitoring data and thus dissipation, degradation and other environmental processes are implicitly considered. The calculations involve multiplying the application rate (***R***) by the water contamination rate to get the concentration in ambient water. This product is in turn multiplied by the amount of water consumed per day and then divided by the body weight to get the estimate of the absorbed dose.

Parameters/Assumptions		Value	Units	Source/Reference
Application Rates (***R***)				
	Central	0.3	lb/acre	APPL.Typ
	Lower	0.09375		APPL.Low
	Upper	0.375		APPL.Hi
Water Contamination Rate (***WCR***):				
	Central	0.2	mg/L per lb/acre applied	AMBWAT.AWPT
	Lower	0.02		AMBWAT.AWPL
	Upper	0.5		AMBWAT.AWPU
Body weight (***W***)		13.3	kg	PUBL.BWC
Amount of water consumed (***A***)				
	Central	1	L/day	PUBL.WCT
	Lower	0.61		PUBL.WCL
	Upper	1.5		PUBL.WCH
Concentration in Water (***C***): **R** × **WCR**				
	Central	0.06	mg/L	
	Lower	0.001875		
	Upper	0.1875		
Dose estimates (***D***): **C × A ÷ W**				
	Central	4.51e-03	mg/kg bw/day	
	Lower	8.60e-05		
	Upper	2.11e-02		

Worksheet D07: Consumption of contaminated water, chronic exposure scenario [DWChHHRA01].

Verbal Description: An adult (70 kg male) consumes contaminated ambient water for a lifetime. The levels in water are estimated from modeling or monitoring data and thus dissipation, degradation and other environmental processes are implicitly considered. The calculations involve multiplying the application rate by the water contamination rate to get the concentration in ambient water. This product is in turn multiplied by the amount of water consumed per day and then divided by the body weight to get the estimate of the absorbed dose.

Parameters/Assumptions		Value	Units	Source/Reference
Application Rates (***R***)				
	Central	0.3	lb/acre	APPL.Typ
	Lower	0.09375		APPL.Low
	Upper	0.375		APPL.Hi
Water Contamination Rate (***WCR***):				
	Central	0.0008	mg/L per lb/acre applied	AMBWAT.AWT
	Lower	0		AMBWAT.AWL
	Upper	0.0012		AMBWAT.AWU
Body weight (***W***)		70	kg	PUBL.BWM
Amount of water consumed (***A***)				
	Central	2	L/day	PUBL.WCAT
	Lower	1.4		PUBL.WCAL
	Upper	2.4		PUBL.WCAH
Concentration in Water (***C***): **R** × **WCR**				
	Central	0.00024	mg/L	
	Lower	0.0000019		
	Upper	0.00045		
Dose estimates (***D***): **C × A ÷ W**				
	Central	6.86e-06	mg/kg bw/day	
	Lower	3.75e-08		
	Upper	1.54e-05		

Worksheet D08a: Consumption of contaminated fish, acute exposure scenarios for recreational fisherman following an accidental spill [FishAcHHRA01].

Verbal Description: An adult angler consumes fish taken from contaminated water shortly after an accidental spill of a fixed amount of a field solution into a pond of a specified depth and surface area. No dissipation or degradation is considered. As in the acute drinking water scenario, the concentration in the pond estimated from the concentration in the spilled solution, the volume spilled and the volume of the pond, assuming instantaneous mixing. The concentration in fish is estimated as the product of the concentration in water and the chronic BCF. The dose is calculated as the product of the concentration in the fish and the amount of fish consumed divided by the body weight.

Parameters/Assumptions		Value	Units	Source/Reference
Surface area of pond [SA]		1000	m^2	N/A
Average depth [DPTH]		1	m	N/A
Volume of pond in cubic meters [VM]		1000	m^3	N/A
Volume of pond in Liters [VL]		1000000	L	1 m^3 = 1,000 L
Volume of spill [VS]		200	gallons	N/A
		757	liters	1 gallon = 3.785 Liters
Concentrations in spilled solution ($\boldsymbol{C_{Fld}}$ $_{\text{(mg/L)}}$)				
	Central	3600	mg/L	APPL.TYPDR×1000
	Lower	560		APPL.LOWDR×1000
	Upper	9000		APPL.HI_DR×1000
Concentrations in ambient water ($\boldsymbol{C_{Wat}}$): $\boldsymbol{C_{Fld} \times VS_{(Liters)} \div VL}$				
	Central	2.7252	mg/L	
	Lower	0.42392		
	Upper	6.813		
Bioconcentration factor ($\boldsymbol{BCF}_{\text{(L/kg fish)}}$)		1.2	L/kg fish	CHEM.BCFT
Concentration in fish ($\boldsymbol{C_{Fish}}$): $\boldsymbol{C_{Wat}}$ × BCF				
	Central	3.27024	mg/kg fish	
	Lower	0.508704		
	Upper	8.1756		
Body weight (***W***)		70	kg	PUBL.BWM
Amount of fish consumed (***A***)				
	Central	0.158	kg/day	PUBL.FAU
	Lower	0.158		PUBL.FAU
	Upper	0.158		PUBL.FAU
Dose estimates (***D***): $\boldsymbol{C_{Fish} \times A \div W}$				
	Central	7.38e-03	mg/kg bw	
	Lower	1.15e-03		
	Upper	1.85e-02		

Worksheet D08b: Consumption of contaminated fish, acute exposure scenarios for subsistence populations following an accidental spill [FishAcHHRA02].

***Verbal Description**:* An individual who relies on caught fish as a major source of protein consumes fish taken from contaminated water shortly after an accidental spill of a fixed amount of a field solution into a pond of a specified depth and surface area. As in the acute drinking water scenario, the concentration in the pond estimated from the concentration in the spilled solution, the volume spilled and the volume of the pond, assuming instantaneous mixing. The concentration in fish is estimated as the product of the concentration in water and the chronic BCF. The dose is calculated as the product of the concentration in the fish and the amount of fish consumed divided by the body weight.

Parameters/Assumptions		Value	Units	Source/Reference
Surface area of pond [SA]		1000	m^2	N/A
Average depth [DPTH]		1	m	N/A
Volume of pond in cubic meters [VM]		1000	m^3	N/A
Volume of pond in Liters [VL]		1000000	L	1 m^3 = 1,000 L
Volume of spill [VS]		200	gallons	N/A
		757	liters	1 gallon = 3.785 Liters
Concentrations in spilled solution ($C_{Fld\ (mg/L)}$)				
	Central	3600	mg/L	APPL.TYPDR×1000
	Lower	560		APPL.LOWDR×1000
	Upper	9000		APPL.HI_DR×1000
Concentrations in ambient water (C_{Wat}): $C_{Fld} \times VS_{(Liters)} \div VL$				
	Central	2.7252	mg/L	
	Lower	0.42392		
	Upper	6.813		
Bioconcentration factor ($BCF_{(L/kg\ fish)}$)		1.2	L/kg fish	CHEM.BCFT
Concentration in fish (C_{Fish}): $C_{Wat} \times$ BCF				
	Central	3.27024	mg/kg fish	
	Lower	0.508704		
	Upper	8.1756		
Body weight (W)		70	kg	PUBL.BWM
Amount of fish consumed (A)				
	Central	0.77	kg/day	PUBL.FNU
	Lower	0.77		PUBL.FNU
	Upper	0.77		PUBL.FNU
Dose estimates (D): $C_{Fish} \times A \div W$				
	Central	3.60e-02	mg/kg bw	
	Lower	5.60e-03		
	Upper	8.99e-02		

Worksheet D09a: Consumption of contaminated fish, chronic exposure scenario for recreational fisherman [FishChHHRA01].

Verbal Description: An adult (70 kg male) consumes fish taken from contaminated ambient water for a lifetime. The levels in water are estimated from monitoring data and thus dissipation, degradation and other environmental processes are implicitly considered. As in the chronic drinking water scenario, the concentration in water is calculated as the application rate multiplied by the water contamination rate. The concentration in fish is estimated as the product of the concentration in water and the chronic BCF. The dose is calculated as the product of the concentration in the fish and the amount of fish consumed divided by the body weight.

Parameters/Assumptions		Value	Units	Source/Reference
Application Rates (***R***)				
	Central	0.3	lb/acre	APPL.Typ
	Lower	0.09375		APPL.Low
	Upper	0.375		APPL.Hi
Water Contamination Rate (***WCR***)				
	Central	0.0008	mg/L per lb/acre applied	AMBWAT.AWT
	Lower	0.00002		AMBWAT.AWL
	Upper	0.0012		AMBWAT.AWU
Concentration in Water (C_{Wat}): $R \times WCR$				
	Central	0.00024	mg/L	
	Lower	0		
	Upper	0.00045		
Bioconcentration factor (***BCF***)		7	L/kg fish	CHEM.BCFCh
Concentration in fish (C_{Fish}): $C_{Wat} \times$ BCF)				
	Central	0.00168	mg/kg fish	
	Lower	0.000013		
	Upper	0.00315		
Body weight (***W***)		70	kg	PUBL.BWM
Amount of fish consumed (***A***)				
	Central	0.01	kg/day	PUBL.FAT
	Lower	0.01		PUBL.FAT
	Upper	0.01		PUBL.FAT
Dose estimates (***D***): $C_{Fish} \times A \div W$				
	Central	2.40e-07	mg/kg bw/day	
	Lower	1.88e-09		
	Upper	4.50e-07		

Worksheet D09b: Consumption of contaminated fish, chronic exposure scenario for subsistence populations [FishChHHRA02].

Verbal Description: An individual who relies on caught fish as a major source of protein consumes fish taken from contaminated ambient water for a lifetime. The levels in water are estimated from monitoring data and thus dissipation, degradation and other environmental processes are implicitly considered. As in the chronic drinking water scenario, the concentration in water is calculated as the application rate multiplied by the water contamination rate. The concentration in fish is estimated as the product of the concentration in water and the chronic BCF. The dose is calculated as the product of the concentration in the fish and the amount of fish consumed divided by the body weight.

Parameters/Assumptions		Value	Units	Source/Reference
Application Rates (***R***)				
	Central	0.3	lb/acre	APPL.Typ
	Lower	0.09375		APPL.Low
	Upper	0.375		APPL.Hi
Water Contamination Rate (***WCR***) : **C** ÷ ***R***				
	Central	0.0008	mg/L per lb/acre applied	AMBWAT.AWT
	Lower	0.00002		AMBWAT.AWL
	Upper	0.0012		AMBWAT.AWU
Concentration in Water (***C***): **R** × **WCR**				
	Central	0.00024	mg/L	
	Lower	0		
	Upper	0.00045		
Bioconcentration factor (***BCF***)		7	L/kg fish	CHEM.BCFCh
Concentration in fish (C_{Fish}): C_{Wat} × **BCF**				
	Central	0.00168	mg/kg fish	
	Lower	0.000013		
	Upper	0.00315		
Body weight (***W***)		70	kg	PUBL.BWM
Amount of fish consumed (***A***)				
	Central	0.081	kg/day	PUBL.FNT
	Lower	0.081		PUBL.FNT
	Upper	0.081		PUBL.FNT
Dose estimates (***D***): C_{Fish} × ***A*** ÷ ***W***				
	Central	1.94e-06	mg/kg bw/day	
	Lower	1.52e-08		
	Upper	3.65e-06		

SUMMARY TABLES FOR HUMAN HEALTH RISK ASSESSMENT

Worksheet E01: Summary of Worker Exposure Scenarios

Scenario	Dose (mg/kg/day or event) Central	Lower	Upper	Exposure Assessment Worksheet
General Exposures (dose in mg/kg/day)				
Directed ground spray (Backpack)	3.94e-03	4.22e-05	3.00e-02	C01a
Broadcast ground spray (Boom spray)	6.72e-03	6.19e-05	5.67e-02	C01b
Aerial applications		N/A		C01c
Accidental/Incidental Exposures (dose in mg/kg/event)				
Immersion of Hands, 1 minute	1.94e-04	1.90e-05	7.56e-04	C02a
Contaminated Gloves, 1 hour	1.17e-02	1.14e-03	4.54e-02	C02b
Spill on hands, 1 hour	3.80e-04	2.53e-05	2.16e-03	C03a
Spill on lower legs, 1 hour	9.36e-04	6.23e-05	5.32e-03	C03b

Worksheet E02: Summary of risk characterization (HQ's[1]) for workers.

Acute RfD	0.6	mg/kg/day	Sect. 3.3.3.
Chronic RfD	0.09	mg/kg/day	Sect. 3.3.3.

Scenario	Hazard Quotient Based on Chronic RfD			Exposure Assessment Worksheet
	Central	Lower	Upper	
General Exposures [using Chronic RfD]				
Directed ground spray (Backpack)	4e-02	5e-04	3e-01	C01a
Broadcast ground spray (Boom spray)	7e-02	7e-04	6e-01	C01b
Aerial applications		N/A		

Accidental/Incidental Exposures [using Acute RfD]

Scenario	Hazard Quotient Based on Acute RfD			Exposure Assessment Worksheet
	Central	Lower	Upper	
Immersion of Hands, 1 minute	3e-04	3e-05	1e-03	C02a
Contaminated Gloves, 1 hour	2e-02	2e-03	8e-02	C02b
Spill on hands, 1 hour	6e-04	4e-05	4e-03	C03a
Spill on lower legs, 1 hour	2e-03	1e-04	9e-03	C03b

[1] Hazard quotient is the level of exposure divided by the provisional RfD then rounded to one significant decimal place or digit. See Worksheet E01 for summary of exposure assessment.

Worksheet E03: Summary of Exposure Scenarios for the General Public

Scenario	Target	Dose (mg/kg/day)			Worksheet
		Central	Lower	Upper	
Acute/Accidental Exposures					
Direct spray, entire body	Child	1.44e-02	9.54e-04	8.15e-02	D01a
Direct spray, lower legs	Woman	1.44e-03	9.59e-05	8.19e-03	D01b
Dermal, contaminated vegetation	Woman	7.38e-04	8.94e-05	2.10e-03	D02
Contaminated fruit	Woman	3.53e-03	1.10e-03	7.00e-02	D03
Contaminated water, spill	Child	2.05e-01	1.94e-02	7.68e-01	D05
Contaminated water, stream	Child	4.51e-03	8.60e-05	2.11e-02	D06
Consumption of fish, general public	Man	7.38e-03	1.15e-03	1.85e-02	D08a
Consumption of fish, subsistence populations	Man	3.60e-02	5.60e-03	8.99e-02	D08b
Chronic/Longer Term Exposures					
Contaminated fruit	Woman	1.70e-04	5.30e-05	3.37e-03	D04
Consumption of water	Man	6.86e-06	3.75e-08	1.54e-05	D07
Consumption of fish, general public	Man	2.40e-07	1.88e-09	4.50e-07	D09a
Consumption of fish, subsistence populations	Man	1.94e-06	1.52e-08	3.65e-06	D09b

Worksheet E04: Summary of risk characterization (HQ's[1]) for the general public [1] .

Chronic RfD		0.09	mg/kg/day	Sect. 3.3.3.	
Acute RfD		0.6	mg/kg/day	Sect. 3.3.3.	
Scenario	Target	Hazard Quotient			Worksheet
		Central	Lower	Upper	
Acute/Accidental Exposures					
Direct spray, entire body	Child	2e-02	2e-03	1e-01	D01a
Direct spray, lower legs	Woman	2e-03	2e-04	1e-02	D01b
Dermal, contaminated vegetation	Woman	1e-03	1e-04	4e-03	D02
Contaminated fruit	Woman	6e-03	2e-03	1e-01	D03
Contaminated water, spill	Child	3e-01	3e-02	1.3	D05
Contaminated water, stream	Child	8e-03	1e-04	4e-02	D06
Consumption of fish, general public	Man	1e-02	2e-03	3e-02	D08a
Consumption of fish, subsistence populations	Man	6e-02	9e-03	1e-01	D08b
Chronic/Longer Term Exposures					
Contaminated fruit	Woman	2e-03	6e-04	4e-02	D04
Consumption of water	Man	8e-05	4e-07	2e-04	D07
Consumption of fish, general public	Man	3e-06	2e-08	5e-06	D09a
Consumption of fish, subsistence populations	Man	2e-05	2e-07	4e-05	D09b

[1] Hazard quotient is the level of exposure divided by the provisional RfD then rounded to one or two significant decimal places or digits. See Worksheet E01 for summary of exposure assessments. Hazard quotients >0.5 and <1.5 are shown to two significant digits. All others are rounded to one significant decimal place or integer.

EXPOSURE ASSESSMENTS FOR TERRESTRIAL SPECIES

Worksheet F01: Direct spray of small mammal assuming first order absorption kinetics [DDFOAEco01].

Verbal Description: A mammal of a specified body weight is directly sprayed over one half of the body surface as the chemical is being applied. An empirical relationship between body weight and surface area is used to estimate the surface area of the animal. The absorbed dose over the first day – i.e., a 24 hour period – is estimated using the assumption of first-order dermal absorption.

Parameter/Assumption		Value	Units	Source/Reference
Period of exposure (***T***)		24	hour	N/A
Body weight (***W***)		0.020	kg	Section 4.2.1.
Exposed surface area (***A***)		m^2=0.11 × BW(kg)$^{0.65}$		U.S. EPA/ORD 1993, eq. 3-22, p. 3-14
		0.0086509	m^2	
		86.51	cm^2	10,000 cm^2 /m^2
Application rate in lbs/acre (R_{lbs})				
	Central	0.3	lb/acre	APPL.TYP
	Lower	0.09375		APPL.LOW
	Upper	0.375		APPL.HI
Conversion Factor (***CF***) for lb/acre to mg/cm^2		0.01121		Const.LBAC_MGCM
Application rate in mg/cm^2 (R_{mg}): R_{lbs} × ***CF***				
	Central	0.003363	lb/acre	
	Lower	0.0010509		
	Upper	0.0042038		
First-order dermal absorption rate (***k***)				
	Central	0.00110	$hour^{-1}$	DERM.AbsC
	Lower	0.000470		DERM.AbsL
	Upper	0.00250		DERM.AbsU
Amount deposited on animal (***Amnt***): ***0.5 × A ×*** R_{mg}				
	Central	0.14547	mg	
	Lower	0.045458		
	Upper	0.18183		
Proportion absorbed over period ***T*** (***Prop***): $1\text{-}e^{-k\,T}$				
	Central	0.02605	unitless	
	Lower	0.011217		
	Upper	0.05824		
Estimated Absorbed Doses (***D***): **Amnt × Prop ÷ W**				
	Central	1.90e-01	mg/kg	
	Lower	2.55e-02		
	Upper	5.29e-01		

Worksheet F02a: Direct spray of small mammal assuming 100% absorption over the first 24 hour period [DDEco01].

***Verbal Description**: A 20 g mammal is directly sprayed over one half of the body surface as the chemical is being applied. The deposited dose is assumed to be completely absorbed during the first day. An empirical relationship between body weight and surface area is used to estimate the surface area of the animal.*

Parameter/Assumption		Value	Units	Source/Reference
Period of exposure (***T***)		24	hour	N/A
Body weight (***W***)		0.020	kg	Section 4.2.1.
Exposed surface area		$m^2 = 0.011 \times BW(g)^{0.65}$		U.S. EPA/ORD 1993, eq. 3-22, p. 3-14
		0.0086509	m^2	
	(***SA***)	86.51	cm^2	m^2 = 10,000 cm^2
Application rate in lbs/acre (R_{lbs})				
	Central	0.3	lb/acre	APPL.TYP
	Lower	0.09375		APPL.LOW
	Upper	0.375		APPL.HI
Conversion Factor (***CF***) for lb/acre to mg/cm^2		0.01121		Const.LBAC_MGCM
Application rate in mg/cm^2 (R_{mg}): $R_{lbs} \times CF$				
	Central	0.003363	mg/cm^2	
	Lower	0.0010509		
	Upper	0.0042038		
Amount deposited on animal (***Amnt***): $0.5 \times SA \times R_{mg}$				
	Central	0.14547	mg	
	Lower	0.045458		
	Upper	0.18183		
Estimated Absorbed Doses (D_{Abs}): **Amnt ÷ W**				
	Central	7.27e+00	mg/kg	
	Lower	2.27e+00		
	Upper	9.09e+00		

Worksheet F02b: Direct spray of bee assuming 100% absorption over the first 24 hour period [DDEco02].

***Verbal Description**: A honeybee is directly sprayed over one half of the body surface as the chemical is being applied. The deposited dose is assumed to be completely absorbed during the first day. An empirical relationship between body weight and surface area is used to estimate the surface area of the animal.*

Parameter/Assumption		Value	Units	Source/Reference
Period of exposure (***T***)		24	hour	N/A
Body weight (***W***)		0.000093	kg	Section 4.2.1.
Exposed surface area (***SA***)		$cm^2 = 1110 \times BW(kg)^{0.65}$		Boxenbaum and D'Souza 1990
		2.6597260	cm^2	
Application rate ($\boldsymbol{R_{lbs}}$)				
	Central	0.3	lb/acre	APPL.TYP
	Lower	0.09375		APPL.LOW
	Upper	0.375		APPL.HI
Conversion Factor (***CF***) for lb/acre to mg/cm^2		0.01121		Const.LBAC_MGCM
Application rate in mg/cm^2 ($\boldsymbol{R_{mg}}$): $\boldsymbol{R_{lbs}} \times \boldsymbol{CF}$				
	Central	0.003363	mg/cm^2	
	Lower	0.0010509		
	Upper	0.0042038		
Amount deposited on animal (***Amnt***): $\boldsymbol{0.5 \times SA \times R_{mg}}$				
	Central	0.00447	mg	
	Lower	0.001398		
	Upper	0.00559		
Estimated Absorbed Doses ($\boldsymbol{D}_{Abs}$): $\boldsymbol{Amnt \div W}$				
	Central	4.81e+01	mg/kg	
	Lower	1.50e+01		
	Upper	6.01e+01		

Worksheet F03: Consumption of contaminated fruit by a small mammal, acute exposure scenario [VegAcERA01].

***Verbal Description**: A 20 g mammal consumes fruit shortly after application of the chemical - i.e. no dissipation or degradation is considered. The contaminated vegetation accounts for 100% of the diet. Residue estimates based on relationships for fruit from Hoerger and Kenaga (1972) summarized in Worksheet A05a.*

Parameters/Assumptions		Value	Units	Source/Reference
Body weight (***W***)		0.020	kg	Section 4.2.1
Allometric coefficients for food consumption in g based on body weight in g				
	a	0.621		Rodents U.S. EPA/ORD 1993, p. 3-6
	b	0.584		
Food consumed per day (***A***): **a×(W×1000)^{b}÷1000**				
		0.003572	kg	
Application rates (***R***)				
	Central	0.3	lb/acre	APPL.Typ
	Lower	0.09375		APPL.Low
	Upper	0.375		APPL.Hi
Residue rates (***rr***)				
	Central	7	mg/kg fruit per lb/acre applied	HK.FRT2
	Lower	7		HK.FRT2
	Upper	15		HK.FRU2
Concentration in food(***C***): **R × rr**				
	Central	2.1	mg/kg food	
	Lower	0.65625		
	Upper	5.625		
Dose estimates (***D***): **A × C ÷ W**				
	Central	3.75e-01	mg/kg bw	
	Lower	1.17e-01		
	Upper	1.00e+00		

Worksheet F04a: Consumption of contaminated fruit by a small mammal, chronic exposure scenario at application site [VegChSmMam01].

Verbal Description: A 20 g mammal consumes contaminated fruit for a 90 day period starting shortly after application of the chemical. Food consumption is estimated from allometric relationships. The concentration of the chemical in fruit at time zero (C_0) is estimated from the application rate (***A***), the proportion of drift (***Drift***), and empirical residues rates (***rr***) summarized in HK. Because the animal is assumed to inhabit the application site, drift is taken as unity **-** i.e., direct spray. The foliar halftime (t_{50}) is used to estimate the foliar decay coefficient (***k***): $k = \ln(2) \div t_{50}$. The concentration on the vegetation after time ***t*** (C_t) is calculated as $C_t = C_0 e^{-kt}$. The time-weighted average of the concentration on vegetation (C_{TWA}) is calculated as the integral of the concentration after time ***t*** (C_t) divided by the duration (***t***). The daily dose is calculated as the product of food consumption and the proportion of the diet that is contaminated divided by the body weight.

Parameters/Assumptions		Value	Units	Source/Reference
Duration of exposure (***T***)		90	days	N/A
Body weight (***W***)		0.02	kg	N/A
Allometric coefficients for food consumption in g based on body weight in g				
	a	0.621		U.S. EPA/ORD 1993, p. 3-6
	b	0.584		
Food consumed per day (***A***): $a \times (W \times 1000)^b \div 1000$				
		0.0035718	kg	
Foliar halftimes ($t_{½}$)	Central	3	days	CHEM.FrT12C
	Lower	3		CHEM.FrT12L
	Upper	3		CHEM.FrT12U
Application rates (***R***)				
	Central	0.3	lb/acre	APPL.Typ
	Lower	0.09375		APPL.Low
	Upper	0.375		APPL.Hi
Residue rates (***rr***):				
	Central	7	mg/kg fruit per lb/acre applied	HK.FRT2
	Lower	7		HK.FRT2
	Upper	15		HK.FRU2
Drift (***Drift***):				
	Central	1	unitless	Assume direct spray
	Lower	1		
	Upper	1		
Decay coefficient (***k***): $\ln(2)/t_{50}$				
	Central	0.2310491	day^{-1}	Upper estimate of t_{50} used to calculate lower limit of ***k*** and lower estimate of t_{50} used to calculate upper limit of ***k***.
	Lower	0.2310491		
	Upper	0.2310491		

Worksheet F04a *(continued)*: Consumption of contaminated vegetation by a small mammal, chronic exposure scenario .

Initial Concentration on Vegetation (C_0): : $\mathbf{C_0 = R \times rr \times Drift}$

Central	2.1	mg/kg veg.	
Lower	0.65625		
Upper	5.625		

Concentration on Vegetation at time T (C_T): $\mathbf{C_T = C_0\ e^{-kT}}$

Central	1.96e-09	mg/kg veg.	These values are not used directly in calculating the dose.
Lower	6.11e-10		
Upper	5.24e-09		

Time-weighted Average Concentration on Vegetation (C_{TWA}): $\mathbf{C_0 (1 - e^{-k\,T}) \div (k\ T)}$

Central	1.01e-01	mg/kg veg.	
Lower	3.16e-02		
Upper	2.71e-01		

Proportion of Diet Contaminated (***Prop***)[1]:

Central	0.1	unitless	See footnote.
Lower	0.05		
Upper	0.2		

Dose estimates (D_{Abs}): $\mathbf{C_{TWA} \times A \times Prop \div W}$

Central	1.80e-03	mg/kg/day	
Lower	2.82e-04		
Upper	9.66e-03		

[1] Based on data on the shrew (U.S. EPA/ORD 1996, p. 2-214,), the vegetation accounts for about 5% of the diet. This is used as the lower limit. The typical and upper values are judgementally set to account for incidental contamination of other contaminated food items such as insects as well as different feeding preferences among other small mammals.

Worksheet F04b: Consumption of contaminated fruit by a small mammal, chronic exposure scenario off-site [VegChSmMam02].

Verbal Description: A 20 g mammal consumes contaminated fruit for a 90 day period starting shortly after application of the chemical. Food consumption is estimated from allometric relationships. The concentration of the chemical in fruit at time zero (C_0) is estimated from the application rate (***A***), the proportion of drift (***Drift***), and empirical residues rates (***rr***) summarized in HK. Drift is estimated for distances of 25 to 100 feet from the application site. The foliar halftime (t_{50}) is used to estimate the foliar decay coefficient (***k***): **k = ln(2)÷t_{50}**. The concentration on the vegetation after time ***t*** (C_t) is calculated as $C_t = C_0 e^{-kt}$. The time-weighted average of the concentration on vegetation (C_{TWA}) is calculated as the integral of the concentration after time ***t*** (C_t) divided by the duration (***t***). The daily dose is calculated as the product of food consumption and the proportion of the diet that is contaminated divided by the body weight.

Parameters/Assumptions		Value	Units	Source/Reference
Duration of exposure (***T***)		90	days	N/A
Body weight (***W***)		0.02	kg	Section 4.2.1
Allometric coefficients for food consumption in g based on body weight in g				
	a	0.621		U.S. EPA/ORD 1993, p. 3-6
	b	0.584		
Food consumed per day (***A***): **a×(W×1000)^b÷1000**				
		0.0035718	kg	
Foliar halftimes ($t_{½}$)	Central	3	days	CHEM.FrT12C
	Lower	3		CHEM.FrT12L
	Upper	3		CHEM.FrT12U
Application rates (***R***)				
	Central	0.3	lb/acre	APPL.Typ
	Lower	0.09375		APPL.Low
	Upper	0.375		APPL.Hi
Residue rates (***rr***):				
	Central	7	mg/kg fruit per lb/acre applied	HK.FRT2
	Lower	7		HK.FRT2
	Upper	15		HK.FRU2
Drift (***Drift***):				
	50 feet	0.0101	unitless	Estimated from AgDRIFT for low-boom applications. See Worksheet A06.
	100 feet	0.0058		
	25 feet	0.0187		
Decay coefficient (***k***): ln(2)/t_{50}				
	Central	0.2310491	day^{-1}	Upper estimate of t_{50} used to calculate lower limit of ***k*** and lower estimate of t_{50} used to calculate upper limit of ***k***.
	Lower	0.2310491		
	Upper	0.2310491		

Worksheet F04b *(continued)*: Consumption of contaminated vegetation by a small mammal, chronic off-site exposure scenario .

Initial Concentration on Vegetation (C_0): $\mathbf{C_0 = R \times rr \times Drift}$

Central	0.02121	mg/kg veg.	
Lower	0.0038063		
Upper	0.1051875		

Concentration on Vegetation at time T (C_T): $\mathbf{C_T = C_0\ e^{-kT}}$

Central	1.98e-11	mg/kg veg.	
Lower	3.54e-12		
Upper	9.80e-11		

Time-weighted Average Concentration on Vegetation (C_{TWA}): $\mathbf{C_0 (1 - e^{-k T}) \div (k T)}$

Central	1.02e-03	mg/kg veg.	
Lower	1.83e-04		
Upper	5.06e-03		

Proportion of Diet Contaminated (***Prop***)[1]:

Central	0.1	unitless	See footnote.
Lower	0.05		
Upper	0.2		

Dose estimates (***D***): $\mathbf{C_{TWA} \times A \times Prop \div W}$

Central	1.82e-05	mg/kg bw/day	
Lower	1.63e-06		
Upper	1.81e-04		

[1] Based on data on the shrew (U.S. EPA/ORD 1996, p. 2-214,), the vegetation accounts for about 5% of the diet. This is used as the lower limit. The typical and upper values are judgementally set to account for incidental contamination of other food items such as insects as well as different feeding preferences among other small mammals.

Worksheet F05: Consumption of contaminated water by a small mammal, acute exposure scenario for an accidental spill. [DWAcERA01].

***Verbal Description**: An animal of a specified weight consumes contaminated water shortly after an accidental spill into a small pond. No dissipation or degradation is considered.* The amount of water consumed is estimated from allometric relationships

Parameters/Assumptions		Value	Units	Source/Reference
Surface area of pond [SA]		1000	m^2	N/A
Average depth [DPTH]		1	m	N/A
Volume of pond in cubic meters [VM]		1000	m^3	N/A
Volume of pond in Liters [VL]		1000000	L	1 m^3 = 1,000 L
Volume of spill [VS]		200	gallons	N/A
		757	liters	1 gallon = 3.785 Liters
Concentrations in field solution ($\boldsymbol{C_{Fld}}$ (mg/L))				
	Central	3600	mg/L	APPL.TypDR × 1000
	Lower	560		APPL.LowDR × 1000
	Upper	9000		APPL.Hi_DR × 1000
Concentrations in ambient water ($\boldsymbol{C_{Wrt}}$): $\boldsymbol{C_{Fld} \times VS_{(Liters)} \div VL}$				
	Central	2.7252	mg/L	
	Lower	0.42392		
	Upper	6.813		
Body weight (***W***)		0.02	kg	Section 4.2.1
Allometric coefficients for water consumption in L based on body weight in kg				
	a	0.099		All mammals. U.S. EPA/ORD 1993, Eq. 3-17, p. 3-10.
	b	0.9		
Water consumed per day (***A***): $\mathbf{a \times W^{b}}$				
		0.002928	L	
Dose estimates (***D***): $\boldsymbol{C_{wrt} \times A \div W}$				
	Central	3.99e-01	mg/kg bw	
	Lower	6.21e-02		
	Upper	9.97e-01		

Worksheet F06: Consumption of contaminated water by a small mammal, acute exposure scenario for runoff or percolation into a stream. [DWAcStrmERA01].

Verbal Description: An small mammal consumes stream water contaminated by runoff and/or percolation. The peak levels in water are estimated from modeling or monitoring data and thus dissipation, degradation and other environmental processes are implicitly considered. The calculations involve multiplying the application rate by the water contamination rate to get the concentration in ambient water. This product is in turn multiplied by the amount of water consumed per day and then divided by the body weight to get the estimate of the absorbed dose.

Parameters/Assumptions		Value	Units	Source/Reference
Application Rates (***R***)				
	Central	0.3	lb/acre	APPL.Typ
	Lower	0.09375		APPL.Low
	Upper	0.375		APPL.Hi
Peak Water Contamination Rate (***rr***):				
	Central	0.2	mg/L per lb/acre applied	AMBWAT.AWPT
	Lower	0.02		AMBWAT.AWPL
	Upper	0.5		AMBWAT.AWPU
Body weight (***W***)		0.02	kg	
Allometric coefficients for water consumption in L based on body weight in kg				
	a	0.099		All mammals. U.S. EPA/ORD 1993, Eq. 3-17, p. 3-10.
	b	0.9		
Water consumed per day (***A***): $\mathbf{a \times W^{b}}$				
		0.002928	L	
Concentration in Water (***C***): **R × rr**				
	Central	0.06	mg/L	These values are used in Worksheet G03 for characterizing acute risks to aquatic species.
	Lower	1.88e-03		
	Upper	0.1875		
Dose estimates (***D***): **C × A ÷ W**				
	Central	0.00878	mg/kg bw/day	
	Lower	0.00027		
	Upper	0.02745		

Worksheet F07: Consumption of contaminated water by a small mammal, chronic exposure scenario [DWChERA01].

Verbal Description: A small mammal consumes contaminated ambient water for an extended period of time. The levels in water are estimated from modeling or monitoring data and thus dissipation, degradation and other environmental processes are implicitly considered. The calculations involve multiplying the application rate by the water contamination rate to get the concentration in ambient water. This product is in turn multiplied by the amount of water consumed per day and then divided by the body weight to get the estimate of the absorbed dose.

Parameters/Assumptions		Value	Units	Source/Reference
Application Rates (***R***)				
	Central	0.3	lb/acre	APPL.Typ
	Lower	0.09375		APPL.Low
	Upper	0.375		APPL.Hi
Water Contamination Rate (***rr***):				
	Central	0.0008	mg/L per lb/acre applied	AMBWAT.AWT
	Lower	0.000020		AMBWAT.AWL
	Upper	0.0012		AMBWAT.AWU
Body weight (***W***)		0.02	kg	
Allometric coefficients for water consumption in L based on body weight in kg				
	a	0.099		All mammals. U.S. EPA/ORD 1993, Eq. 3-17, p. 3-10.
	b	0.9		
Water consumed per day (***A***): $\mathbf{a \times W^{b}}$				
		0.002928	L	
Concentration in Water (***C***): **R × rr**				
	Central	2.40e-04	mg/L	
	Lower	1.88e-06		
	Upper	4.50e-04		
Dose estimates (***D***): **C × A ÷ W**				
	Central	3.51e-05	mg/kg/day	
	Lower	2.74e-07		
	Upper	6.59e-05		

Worksheet F08: Consumption of contaminated fish by predatory bird, acute exposure scenario after accidental spill. *[FishBirdAcute]*

Verbal Description: A predatory bird consumes fish taken from contaminated water after an accidental spill of 200 gallons of a field solution into a pond that has an average depth of 1 m and a surface area of 1000 m^2 or about one-quarter acre . No dissipation or degradation is considered. The assumption is made that bioconcentration will reach equilibrium. This probably will overestimate exposure and subsequent risk.

Parameters/Assumptions		Value	Units	Source/Reference
Surface area of pond (SA)		1000	m^2	N/A
Average depth (DPTH)		1	m	N/A
Volume of pond in cubic meters (VM)		1000	m^3	N/A
Volume of pond in Liters (VL)		1000000	L	1 m^3 = 1,000 L
Volume of spill (VS)		200	gallons	N/A
	VS_L	757	liters	1 gallon = 3.785 liters
Concentrations in field solution (***FC***)				
	Central	3600	mg/L	APPL.TypDR×1000
	Lower	560		APPL.LowDR×1000
	Upper	9000		APPL.Hi_DR×1000
Concentrations in ambient water (***WC***): **FC × VS_L /VL**				
	Central	2.7252	mg/L	
	Lower	0.42392		
	Upper	6.813		
Bioconcentration factor (***BCF***)		3.6	L/kg fish	CHEM.BCFWA
Concentrations in fish (***C_{Fish}***): **WC × BCF**				
	Central	9.81072	mg/kg fish	
	Lower	1.526112		
	Upper	24.5268		
Fish consumed as a proportion of body weight (**P_F**)				
	Central	0.1	g fish/g bw	Various species based on values from U.S. EPA/ORD (1993).
	Lower	0.05		
	Upper	0.15		
Dose estimates (D) (**C_{Fish} × P_F**)				
	Central	9.81e-01	mg/kg bw/day	
	Lower	7.63e-02		
	Upper	3.68e+00		

Worksheet F09: Consumption of contaminated fish by predatory bird, chronic exposure scenario. *[FishBirdChronic]*

***Verbal Description**: An predatory bird consumes fish taken from contaminated ambient water for a lifetime. The levels in water are estimated from monitoring and modeling data and dissipation, degradation and other environmental processes are considered.*

Parameters/Assumptions		Value	Units	Source/Reference
Application Rates (***R***)				
	Central	0.3	lb/acre	APPL.Typ
	Lower	0.09375		APPL.Low
	Upper	0.375		APPL.Hi
Water Contamination Rate (***WCR***)				
	Central	0.0008	mg/L per lb/acre applied	AMBWAT.AWT
	Lower	0.00002		AMBWAT.AWL
	Upper	0.0012		AMBWAT.AWU
Concentration in Water (***C***): **WCR** × **R**				
	Central	0.00024	mg/L	These values are used in Worksheet G03 to characterize the longer-term risks to aquatic species.
	Lower	0.0000019		
	Upper	0.00045		
Bioconcentration factor (***BCF***)		21	L/kg fish	CHEM.BCFWhl
Concentrations in fish (***FC***): **C** × **BCF**				
	Central	0.00504	mg/kg fish	
	Lower	0.000039		
	Upper	0.00945		
Fish consumed as a proportion of body weight (P_F)				
	Central	0.1	g fish/g bw	Various species based on values from U.S. EPA/ORD (1993).
	Lower	0.05		
	Upper	0.15		
Dose estimates (***D***): **FC × P_F**				
	Central	5.04e-04	mg/kg bw/day	
	Lower	1.97e-06		
	Upper	1.42e-03		

Worksheet F10: Consumption of contaminated vegetation by a large mammal, acute exposure scenario on-site. *[VGCLMA]*

***Verbal Description**:* A 70 kg herbivore, such as a deer, consumes short grass shortly after application of the chemical **-** i.e. no dissipation or degradation is considered. Caloric requirements are used to estimate food consumption.

Parameters/Assumptions		Value	Units	Source/Reference
Body weight (***W***)		70	kg	N/A
Caloric requirement (***KR***)		5226.288	kcal/day	U.S. EPA/ORD (1993, p. 3-6)
above based on following equation: ***kcal/day = 1.518 × W(g)***$^{0.73}$				
Caloric content of vegetation (dry weight, ***KCD***)		2.46	kcal/g	U.S. EPA (1993, p. 3-5)
Water content of vegetation (proportion, ***PW***)		0.85	unitless	U.S. EPA/ORD (1993, p. 4-14)
Caloric content of vegetation (wet weight, ***KCW***)		0.37	kcal/g	***KCD*** × (1-***PW***)
Food consumed per day (wet weight, ***A***)		14.16338	kg	(***KR*** ÷ ***KCW***)/1000 g/kg
Duration of exposure (***T***)		1	day	N/A
Application rates (***R***)				
	Central	0.3	lb/acre	APPL.Typ
	Lower	0.09375		APPL.Low
	Upper	0.375		APPL.Hi
Residue rates (***rr***)				
	Central	85	mg/kg veg. per lb/acre applied	HK.SGT
	Lower	85		HK.SGT
	Upper	240		HK.SGU
Conc. in Vegetation (***C***): ***R*** **×** ***rr***				
	Central	25.5	mg/kg	Note: lower value based on typical ***rr*** and lower ***R***.
	Lower	7.96875		
	Upper	90		
Drift (***Drift***)				
	Central	1	unitless	Direct spray on-site
	Lower	1		
	Upper	1		
Proportion of Diet Contaminated (***Prop***)				
	Central	1	unitless	Assume grazing exclusively on-site.
	Lower	1		
	Upper	1		
Dose estimates (***D***): **Drift × Prop × C × A ÷W**				
	Central	5.16e+00	mg/kg bw	
	Lower	1.61e+00		
	Upper	1.82e+01		

Worksheet F11a: Consumption of contaminated vegetation by a large mammal, chronic exposure scenario on-site [VegChLrgMam01].

***Verbal Description**:* A 70 kg herbivore, such as a deer, consumes short grass for a 90 day period after application of the chemical. The contaminated vegetation accounts for 10 to 100% of the diet assuming that the animal would spend 10 to 100% of the grazing time at the application site. Because the animal is assumed to be on-site, drift is set to unity **-** i.e., direct spray. Residue estimates based on relationships for range grass. Caloric requirements are used to estimate food consumption. Dissipation is considered using the foliar halftime and taking time-weighted average concentration over the exposure period.

Parameters/Assumptions		Value	Units	Source/Reference
Duration of exposure (***T***)		90	days	N/A
Body Weight (***W***)		70	kg	
Caloric requirement (***KR***)		5226.28803	kcal/day	U.S. EPA/ORD (1993, p. 3-6)
above based on following equation: $kcal/day = 1.518 \times W(g)^{0.73}$				
Caloric content of vegetation (dry weight, ***KCD***)		2.46	kcal/g	U.S. EPA/ORD (1993, p. 3-5)
Water content of vegetation (proportion, ***PW***)		0.85	unitless	U.S. EPA/ORD (1993, p. 4-14)
Caloric content of vegetation (wet weight, ***KCW***)		0.369	kcal/g	***KCD*** × (1-***PW***)
Food consumed per day (wet weight, ***A***)		14.1633822	kg	(***KR*** ÷ ***KCW***)/1000 g/kg
Foliar halftimes ($t_{½}$)	Central	3	days	Worksheet B03
	Lower	3		
	Upper	3		
Application rates (***R***)				
	Central	0.3	lb/acre	APPL.Typ
	Lower	0.09375		APPL.Low
	Upper	0.375		APPL.Hi
Residue rates (***rr***):				
	Central	85	mg/kg veg per lb/acre	HK.SGT
	Lower	85		HK.SGU
	Upper	240		HK.SGU
Drift (***Drift***)				
	Central	1	unitless	On-site scenario assumes a function drift of 1 **-** i.e., direct spray
	Lower	1		
	Upper	1		
Decay coefficient (***k***): ln(2)/t_{50}				
	Central	0.2310491	day^{-1}	Upper estimate of t_{50} used to calculate lower limit of ***k*** and lower estimate of t_{50} used to calculate upper limit of ***k***.
	Lower	0.2310491		
	Upper	0.2310491		

Worksheet F11a *(continued)*: Consumption of contaminated vegetation by a large mammal, chronic exposure scenario on-site.

Initial Concentration on Vegetation ($\mathbf{C_0}$): **R** × **rr** × **Drift**

Central	25.5	mg/kg veg.
Lower	7.96875	
Upper	90	

Concentration on Vegetation at time ***T*** (C_T): $\mathbf{C_0 \ e^{-kT}}$

Central	2.37e-08	mg/kg veg.
Lower	7.42e-09	
Upper	8.38e-08	

Time-weighted Average Concentration on Vegetation (C_{TWA}): $\mathbf{C_0 (1 - e^{-k T}) \div (k T)}$

Central	1.22629078	mg/kg veg.
Lower	0.38321587	
Upper	4.32808512	

Proportion of Diet Contaminated (***Prop***)

Central	0.3	unitless
Lower	0.1	
Upper	1.0	

Dose estimates (***D***): $\mathbf{C_{TWA} \times A \times Prop \div W}$

Central	7.44e-02	mg/kg bw/day
Lower	7.75e-03	
Upper	8.76e-01	

Worksheet F11b: Consumption of contaminated vegetation by a large mammal, chronic exposure scenario off-site [VegChLrgMam02].

***Verbal Description**:* A 70 kg herbivore, such as a deer, consumes range grass for a 90 day period after application of the chemical. The contaminated vegetation accounts for 100% of the diet assuming that the animal would spends all of the grazing time near the application site. Drift is estimated at distances of 25 to 100 feet from the application site. Residue estimates based on relationships for range grass. Caloric requirements are used to estimate food consumption. Dissipation is considered using the foliar halftime and taking time-weighted average concentration over the exposure period.

Parameters/Assumptions		Value	Units	Source/Reference
Duration of exposure (***D***)		90	days	N/A
Body Weight (***W***)		70	kg	
Caloric requirement (***KR***)		5226.28803	kcal/day	U.S. EPA/ORD (1993, p. 3-6)
above based on following equation: $kcal/day = 1.518 \times W(g)^{0.73}$				
Caloric content of vegetation (dry weight, ***KCD***)		2.46	kcal/g	U.S. EPA/ORD (1993, p. 3-5)
Water content of vegetation (proportion, ***PW***)		0.85	unitless	U.S. EPA/ORD (1993, p. 4-14)
Caloric content of vegetation (wet weight, ***KCW***)		0.37	kcal/g	***KCD*** × (1-***PW***)
Food consumed per day (wet weight, ***A***)		14.16	kg	(***KR*** ÷ ***KCW***)/1000 g/kg
Foliar halftimes ($t_{½}$)	Central	3	days	Worksheet B03
	Lower	3		
	Upper	3		
Application rates (***R***)				
	Central	0.3	lb/acre	APPL.Typ
	Lower	0.09375		APPL.Low
	Upper	0.375		APPL.Hi
Residue rates (***rr***):				
	Central	85	mg/kg veg per lb/acre	HK.SGT
	Lower	85		HK.SGU
	Upper	240		HK.SGU
Drift (***Drift***)				
	50 feet	0.0101	unitless	Estimated from AgDRIFT for low-boom applications. See Worksheet A06.
	100 feet	0.0058		
	25 feet	0.0187		
Decay coefficient (***k***): ln(2)/t_{50}				
	Central	0.2310491	day^{-1}	Upper estimate of t_{50} used to calculate lower limit of ***k*** and lower estimate of t_{50} used to calculate upper limit of ***k***.
	Lower	0.2310491		
	Upper	0.2310491		

Worksheet F11b *(continued)*: Consumption of contaminated vegetation by a large mammal, chronic exposure scenario off-site.

Initial Concentration on Vegetation ($\mathbf{C_0}$): **R** × **rr** × **Drift**

Central	0.25755	mg/kg veg.
Lower	0.0462188	
Upper	1.683	

Concentration on Vegetation at time ***T*** (C_T): $\mathbf{C_0}$ $\mathbf{e^{-kT}}$

Central	2.40e-10	mg/kg veg.
Lower	4.30e-11	
Upper	1.57e-09	

Time-weighted Average Concentration on Vegetation (C_{TWA}): C_0 **(1 -** $\mathbf{e^{-k\,T}}$**) ÷ (k T)**

Central	0.0123855	mg/kg veg.
Lower	0.002223	
Upper	0.0809352	

Proportion of Diet Contaminated (***Prop***)

Central	1	unitless
Lower	1	
Upper	1	

Dose estimates (***D***): C_{TWA} × ***A*** × **Prop** ÷ ***W***

Central	2.51e-03	mg/kg bw/day
Lower	4.50e-04	
Upper	1.64e-02	

Worksheet F12: Consumption of contaminated vegetation by a large bird, acute exposure scenario. *[VGCLBA]*

Verbal Description: A 4 kg herbivorous bird, such as a Canada Goose, consumes grass shortly after application of the chemical **-** i.e. no dissipation or degradation is considered. The contaminated vegetation accounts for 100% of the diet. Residue estimates based on relationships for short grass summarized in Worksheet A05.

Parameters/Assumptions		Value	Units	Source/Reference
Body weight (***W***)		4	kg	N/A
Caloric requirement (***KR***)		467.5185	kcal/day	U.S. EPA/ORD (1993, Eq. 3-35, p. 3-22)
above based on following equation: ***kcal/day = 3.12 × W(g)***$^{0.604}$				
Caloric content of vegetation (dry weight, ***KCD***)		2.46	kcal/g	U.S. EPA/ORD (1993, p. 3-5)
Water content of vegetation (proportion, ***PW***)		0.85	unitless	U.S. EPA/ORD (1993, p. 4-14)
Caloric content of vegetation (wet weight, ***KCW***)		0.369	kcal/g	***KCD*** × (1-***PW***)
Food consumed per day (wet weight, ***A***)		1.266988	kg	(***KR*** ÷ ***KCW***)/1000 g/kg
Duration of exposure (***T***)		1	day	N/A
Application rates (***R***)				
	Central	0.3	lb/acre	APPL.Typ
	Lower	0.09375		APPL.Low
	Upper	0.375		APPL.Hi
Residue rates (***rr***)				
	Central	85	mg/kg vegetation per lb/acre applied	HK.SGT
	Lower	85		HK.SGT
	Upper	240		HK.SGU
Conc. in Vegetation (***C***): [**R**×**rr**]				
	Central	25.5	mg/kg	Note: lower value based on typical ***rr*** and lower ***R***.
	Lower	7.96875		
	Upper	90		
Drift (***Drift***)				
	Central	1	unitless	Direct spray on-site
	Lower	1		
	Upper	1		
Proportion of Diet Contaminated (***Prop***)				
	Central	1	unitless	Assume feeding exclusively on-site.
	Lower	1		
	Upper	1		
Dose estimates (***D***): **Drift × Prop × C × A ÷ W**				
	Central	8.08e+00	mg/kg bw	
	Lower	2.52e+00		
	Upper	2.85e+01		

Worksheet F13a: Consumption of contaminated vegetation by a large bird, chronic on-site exposure scenario. *[VegChLBrd01]*

Verbal Description: A 4 kg herbivorous bird, such as a Canada Goose, consumes grass for a 90 day period after application of the chemical. The contaminated vegetation accounts for 10 to 100% of the diet assuming that the animal spends 10% to 100% of the time feeding at the site. Because the location is the application site, drift is set to unity - i.e., direct spray. Residue estimates based on short grass. Caloric requirements are used to estimate food consumption from U.S. EPA/ORD (1993). Dissipation is considered using the foliar halftime and taking the geometric mean of the initial and day-90 residues as the measure of dose.

Parameters/Assumptions		Value	Units	Source/Reference
Body weight (***W***)		4	kg	N/A
Caloric requirement (***KR***)		467.5185	kcal/day	U.S. EPA/ORD (1993, p. 3-6)
above based on following equation: ***kcal/day = 3.12 × W(g)***$^{0.604}$				
Caloric content of vegetation (dry weight, ***KCD***)		2.46	kcal/g	U.S. EPA/ORD (1993, p. 3-5)
Water content of vegetation (proportion, ***PW***)		0.85	unitless	U.S. EPA/ORD (1993, p. 4-14)
Caloric content of vegetation (wet weight, ***KCW***)		0.369	kcal/g	***KCD*** × (1-***PW***)
Food consumed per day (wet weight, ***A***)		1.266988	kg	(***KR*** ÷ ***KCW***)/1000 g/kg
Duration of exposure (***T***)		90	days	N/A
Application rates (***R***)				
	Central	0.3	lb/acre	APPL.Typ
	Lower	0.09375		APPL.Low
	Upper	0.375		APPL.Hi
Residue rates (***rr***)				
	Central	85	mg/kg veg per lb/acre	HG.SGT
	Lower	85		HG.SGT
	Upper	240		HG.SGU
Drift (***Drift***):				
	Central	1	unitless	Set to unity for on-site assessment.
	Lower	1		
	Upper	1		
Day 0 Conc. in Vegetation (C_0): **R** × **rr** × **Drift**				
	Central	25.5	mg/kg	
	Lower	7.96875		
	Upper	90		
Foliar dissipation coefficient (***k***)				
	Central	0.2310491	day^{-1}	Worksheet B02
	Lower	0.2310491		
	Upper	0.2310491		
Conc. in Vegetation at time T (C_T) [$C_0 \times e^{-k \times T}$]				
	Central	2.37e-08	mg/kg	
	Lower	7.42e-09		
	Upper	8.38e-08		

Worksheet F13a *(continued)*: Consumption of contaminated vegetation by a large bird, chronic on-site exposure scenario.

Time-weighted Average Concentration on Vegetation (C_{TWA}): $\mathbf{C_0\ (1 - e^{-k\,T}) \div (k\ T)}$

Central	1.226291	mg/kg	
Lower	0.383216		
Upper	4.328085		

Proportion of diet contaminated (P_D)

Central	0.3	unitless	See section 4.2.2.3.
Lower	0.1		
Upper	1.0		

Dose estimates (D): $\mathbf{P_D \times C_{TWA} \times A \div W}$

Central	1.17e-01	mg/kg bw	
Lower	1.21e-02		
Upper	1.37e+00		

Worksheet F13b: Consumption of contaminated vegetation by a large bird, chronic off-site exposure scenario. *[VegChLBrd02]*

Verbal Description: A 4 kg herbivorous bird, such as a Canada Goose, consumes grass for a 90 day period after application of the chemical. The contaminated vegetation accounts for 100% of the diet assuming that the animal spends all of the feeding time near the site. Drift is estimated at 25 to 100 feet from the application site. Residue estimates are based on short grass. Caloric requirements are used to estimate food consumption. Dissipation is considered using the foliar halftime and taking the geometric mean of the initial and day-90 residues as the measure of dose.

Parameters/Assumptions		Value	Units	Source/Reference
Body weight (***W***)		4	kg	N/A
Caloric requirement (***KR***)		467.5185	kcal/day	U.S. EPA/ORD (1993, p. 3-6)
above based on following equation: $kcal/day = 3.12 \times W(g)^{0.604}$				
Caloric content of vegetation (dry weight, ***KCD***)		2.46	kcal/g	U.S. EPA/ORD (1993, p. 3-5)
Water content of vegetation (proportion, ***PW***)		0.85	unitless	U.S. EPA/ORD (1993, p. 4-14)
Caloric content of vegetation (wet weight, ***KCW***)		0.369	kcal/g	***KCD*** × (1-***PW***)
Food consumed per day (wet weight, ***A***)		1.266988	kg	(***KR*** ÷ ***KCW***)/1000 g/kg
Duration of exposure (***T***)		90	days	N/A
Application rates (***R***)				
	Central	0.3	lb/acre	APPL.Typ
	Lower	0.09375		APPL.Low
	Upper	0.375		APPL.Hi
Residue rates (***rr***)				
	Central	85	mg/kg veg per lb/acre	HG.SGT
	Lower	85		HG.SGT
	Upper	240		HG.SGU
Drift (***Drift***):				
	50 feet	0.0101	unitless	Estimated from AgDRIFT for low-boom applications. See Worksheet A06.
	100 feet	0.0058		
	25 feet	0.0187		
Day 0 Conc. in Vegetation (C_0): **R** × **rr** × **Drift**				
	Central	0.25755	mg/kg	Note: lower value based on typical ***rr*** and lower ***R***.
	Lower	0.04622		
	Upper	1.683		
Foliar dissipation coefficient (***k***)				
	Central	0.2310491	day^{-1}	Worksheet B02
	Lower	0.2310491		
	Upper	0.2310491		
Conc. in Vegetation at time T (C_T): $C_0 \times e^{-k \times T}$]				
	Central	2.40e-10	mg/kg	
	Lower	4.30e-11		

Upper	1.57e-09		

Worksheet F13b *(continued)*: Consumption of contaminated vegetation by a large bird, chronic off-site exposure scenario.

Time-weighted Average Concentration on Vegetation (C_{TWA}): $\mathbf{C_0 (1 - e^{-k\,T}) \div (k\,T)}$

Central	0.01239	mg/kg	
Lower	0.0022		
Upper	0.08094		

Proportion of diet contaminated (P_D)

Central	1.0	unitless	100% of time spent feeding near site
Lower	1.0		
Upper	1.0		

Dose estimates (***D***): $\mathbf{P_D \times C_{TWA} \times A \div W}$

Central	3.92e-03	mg/kg bw	
Lower	7.04e-04		
Upper	2.56e-02		

Worksheet F14: Consumption of contaminated insects by a small bird, acute exposure scenario. *[InsCSBA]*

***Verbal Description**: A small insectivorous bird (10g) consumes insects shortly after application of the chemical* **-** *i.e. no dissipation or degradation is considered. The contaminated food accounts for 100% of the diet. Residue estimates in insects are based on relationships for seed containing pods and forage crops from Hoerger and Kenaga (1972) summarized in Worksheet A05a.*

Parameters/Assumptions		Value	Units	Source/Reference
Body weight (***W***)		0.01	kg	N/A
Caloric requirement (***KR***)		12.53587	kcal/day	U.S. EPA/ORD 1993, Eq. 3-35, p. 3-22
above based on following equation: ***kcal/day = 3.12 × W(g)***$^{0.604}$				
Caloric content of insects (dry weight, ***KCD***)		4.3	kcal/g	U.S. EPA/ORD 1993, p. 3-5
Water content of insects (proportion, ***PW***) [1]		0.65	unitless	U.S. EPA/ORD 1993, p. 4-13
Caloric content of insects (wet weight, ***KCW***)		1.505	kcal/g	***KCD*** × (1-***PW***)
Food consumed per day (wet weight, ***A***)		0.0083	kg	(***KR*** ÷ ***KCW***)/1000 g/kg
Duration of exposure (***T***)		1	day	N/A
Application rates (***R***)				
	Central	0.3	lb/acre	APPL.Typ
	Lower	0.09375		APPL.Low
	Upper	0.375		APPL.Hi
Residue rates (***rr***)				
	Central	45	mg/kg per lb/acre applied	HK.BLT
	Lower	45		HK.BLT
	Upper	135		HK.BLU
Conc. in Vegetation (***C***): **R** × **rr**				
	Central	13.5	mg/kg	
	Lower	4.21875		
	Upper	50.625		
Drift (***Drift***)				
	Central	1	unitless	Direct spray on-site
	Lower	1		
	Upper	1		
Proportion of Diet Contaminated (***Prop***)				
	Central	1	unitless	Assume feeding exclusively on-site.
	Lower	1		
	Upper	1		
Dose estimates (***D***): **Drift × Prop × C × A ÷ W**				
	Central	1.12e+01	mg/kg bw	
	Lower	3.51e+00		
	Upper	4.22e+01		

[1] Average of beetles (61%) and grasshoppers (69%) from U.S. EPA/ORD 1993, Table 4-1, p. 4-13.

Worksheet G01: Summary of Exposure Scenarios for Terrestrial Animals.

Scenario	Dose (mg/kg/day)			Worksheet
	Central	Lower	Upper	
Acute/Accidental Exposures				
Direct spray				
small mammal, first-order absorption	1.90e-01	2.55e-02	5.29e-01	F01
small animal, 100% absorption	7.27e+00	2.27e+00	9.09e+00	F02a
bee, 100% absorption	4.81e+01	1.50e+01	6.01e+01	F02b
Contaminated vegetation				
small mammal	3.75e-01	1.17e-01	1.00e+00	F03
large mammal	5.16e+00	1.61e+00	1.82e+01	F10
large bird	8.08e+00	2.52e+00	2.85e+01	F12
Contaminated water				
small mammal, spill	3.99e-01	6.21e-02	9.97e-01	F05
stream	8.78e-03	2.74e-04	2.74e-02	F06
Contaminated insects				
small bird	1.12e+01	3.51e+00	4.22e+01	F14
Contaminated fish				
predatory bird, spill	9.81e-01	7.63e-02	3.68e+00	F08
Longer-term Exposures				
Contaminated vegetation				
small mammal, on site	1.80e-03	2.82e-04	9.66e-03	F04a
off-site	1.82e-05	1.63e-06	1.81e-04	F04b
large mammal, on site	7.44e-02	7.75e-03	8.76e-01	F11a
off-site	2.51e-03	4.50e-04	1.64e-02	F11b
large bird, on site	1.17e-01	1.21e-02	1.37e+00	F13a
off-site	3.92e-03	7.04e-04	2.56e-02	F13b
Contaminated water				
small mammal	3.51e-05	2.74e-07	6.59e-05	F07
Contaminated fish				
predatory bird	5.04e-04	1.97e-06	1.42e-03	F09

Worksheet G02: Summary of quantitative risk characterization for terrestrial animals [1]

Scenario	Hazard Quotient[2] Central	Lower	Upper
Acute/Accidental Exposures			
Direct spray			
small mammal, first-order absorption	1.1e-03	1.4e-04	2.9e-03
small animal, 100% absorption	4.0e-02	1.3e-02	5.1e-02
bee, 100% absorption	4.5e-01	1.4e-01	5.6e-01
Contaminated vegetation			
small mammal	2.1e-03	6.5e-04	5.6e-03
large mammal	2.9e-02	9.0e-03	1.0e-01
large bird	1.6e-02	5.0e-03	5.7e-02
Contaminated water			
small mammal, spill	2.2e-03	3.4e-04	5.5e-03
small mammal, stream	4.9e-05	1.5e-06	1.5e-04
Contaminated insects			
small bird	2.2e-02	7.0e-03	8.4e-02
Contaminated fish			
predatory bird, spill	2.0e-03	1.5e-04	7.4e-03
Longer-term Exposures			
Contaminated vegetation			
small mammal, on site	2.0e-04	3.1e-05	1.1e-03
off-site	2.0e-06	1.8e-07	2.0e-05
large mammal, on site	8.3e-03	8.6e-04	9.7e-02
off-site	2.8e-04	5.0e-05	1.8e-03
large bird, on site	1.2e-02	1.2e-03	1.4e-01
off-site	3.9e-04	7.0e-05	2.6e-03
Contaminated water			
small mammal	3.9e-06	3.1e-08	7.3e-06
Contaminated fish			
predatory bird	5.0e-05	2.0e-07	1.4e-04

Toxicity Indices [3]

Acute toxicity value for mammal - NOAEL	180	mg/kg
Chronic toxicity value for mammal - NOAEL	9	mg/kg/day
Acute toxicity value for bird - NOAEL	500	mg/kg
Chronic toxicity value for birds	10	mg/kg/day
Toxicity value for bee -NOAEL	107	mg/kg

[1] See Worksheet G01 (Table 4-1 in text) for summary of exposure assessment.
[2] Estimated dose ÷ toxicity index
[3] See Section 4.3. for a discussion of the dose-response assessments

Worksheet G03: Quantitative Risk Characterization for Aquatic Species.

Risk Quotients	**Central**	**Lower**	**Upper**	**Endpoint**	
Fish					
Acute	5.0e-02	1.6e-03	1.6e-01	Mortality	
Chronic	2.0e-04	1.6e-06	3.8e-04		
Aquatic Invertebrates					
Acute	2.3e-02	7.2e-04	7.2e-02	Mortality	
Chronic	9.2e-05	7.2e-07	1.7e-04		
Aquatic Plants					
Acute	2.4e-01	7.5e-03	7.5e-01	EC_{50}	
Chronic	9.6e-04	7.5e-06	1.8e-03		
Exposures (mg/L)	Central	Lower	Upper	Worksheet	
Acute	0.060	0.0019	0.19	F06	Stream
Longer-term	0.00024	0.0000019	0.00045	F09	

Toxicity values (mg/L)

	Value (mg/L)	Endpoint	Section
Fish, acute	1.2	Mortality	4.3.3.2.
Fish, chronic	1.2	No data found. Acute value used.	4.3.3.2.
Aquatic Invertebrates, acute	2.6	Mortality	4.3.3.3
Aquatic Invertebrates, chronic	2.6	No data found. Acute value used.	4.3.3.3
Aquatic plants	0.25	$<EC_{50}$	4.3.3.4.

SPECIAL NOTE: All risk characterizations are based on toxicity of formulated product, POAST. Sethoxydim is much less toxic to aquatic species than is POAST.

Worksheet G04: Summary of Exposure Assessment and Risk Characterization for Terrestrial Plants from Runoff [TerrPlntRU].

Application rate	0.375	lb/acre	Highest FS rate, Section 2.4.
Sensitive Species (Lowest NOEC, preemergence ryegrass)	0.059	lb/acre	Section 4.3.2.4.
Tolerant Species (Highest NOEC, preemergence corn)	0.235	lb/acre	Section 4.3.2.4.

Annual Rainfall	Clay	Loam	Sand
		Proportion lost in Runoff	
5	0.000000	0.00	0.00
10	0.0000003	0.010	0.013
15	0.011	0.03	0.030
20	0.023	0.055	0.046
25	0.036	0.079	0.061
50	0.098	0.18	0.12
100	0.20	0.32	0.20
150	0.29	0.40	0.25
200	0.35	0.45	0.29
250	0.41	0.49	0.33
		Functional Off-site Application Rate[1]	
5	0.00e+00	0.00e+00	0.00e+00
10	1.13e-07	0.00e+00	4.88e-03
15	4.13e-03	0.00e+00	1.13e-02
20	8.63e-03	0.00e+00	1.73e-02
25	1.35e-02	0.00e+00	2.29e-02
50	3.68e-02	0.00e+00	4.50e-02
100	7.50e-02	0.00e+00	7.50e-02
150	1.09e-01	0.00e+00	9.38e-02
200	1.31e-01	0.00e+00	1.09e-01
250	1.54e-01	0.00e+00	1.24e-01
		Sensitive Species -Hazard Quotient[2]	
5	0.0e+00	0.0e+00	0.0e+00
10	1.9e-06	0.0e+00	8.3e-02
15	7.0e-02	0.0e+00	1.9e-01
20	1.5e-01	0.0e+00	2.9e-01
25	2.3e-01	0.0e+00	3.9e-01
50	6.2e-01	**0.0e+00**	7.6e-01
100	**1.3e+00**	**0.0e+00**	**1.3e+00**
150	**1.8e+00**	**0.0e+00**	**1.6e+00**
200	**2.2e+00**	**0.0e+00**	**1.8e+00**
250	**2.6e+00**	**0.0e+00**	**2.1e+00**
		Tolerant Species - Hazard Quotient[2]	
5	0.0e+00	0.0e+00	0.0e+00
10	4.8e-07	0.0e+00	2.1e-02
15	1.8e-02	0.0e+00	4.8e-02
20	3.7e-02	0.0e+00	7.3e-02
25	5.7e-02	0.0e+00	9.7e-02
50	1.6e-01	0.0e+00	1.9e-01
100	3.2e-01	0.0e+00	3.2e-01
150	4.6e-01	0.0e+00	4.0e-01
200	5.6e-01	0.0e+00	4.6e-01
250	6.5e-01	0.0e+00	5.3e-01

[1] The functional off-site application rate is calculated as the nominal application rate (specified above after the worksheet title) multiplied by the proportion lost in runoff.

[2] The hazard quotient is calculated as the functional off-site application rate divided by the NOEC value. The NOEC's are specified above on the lines following the application rate.

Worksheet G05: Summary of Exposure Assessment and Risk Characterization for Terrestrial Plants from Drift and Wind Erosion [TerrPlntWind].

	Most Sensitive Plant (corn)	Least Sensitive Plant (several)	
Post-emergence NOEC, lb/acre	0.006	0.03	Section 3.2.4.
Application Rate, lb/acre	0.375	Highest FS use.	Section 2.4

Estimates of the proportion of offsite drift

Distance (feet)	Drift[1]	
25	0.0187	Terrestrial Drift based on AGDRIFT using a low boom ground sprayer. See section 4.2.3.2 for discussion.
50	0.0101	
100	0.0058	
300	0.0024	
500	0.0015	
900	0.0008	

Estimates of functional offsite application rate

Distance (feet)	Rate (lb/acre)	
25	0.0070125	Calculated as the product of the application rate and the estimated proportion of offsite drift.
50	0.0037875	
100	0.002175	
300	0.0009	
500	0.0005625	
900	0.0003	

Hazard Quotient - Sensitive Species

25	1.2e+00	Calculated as the offsite application rate divided by the NOEC for the most sensitive species.
50	6.3e-01	
100	3.6e-01	
300	1.5e-01	
500	9.4e-02	
900	5.0e-02	

Hazard Quotient - Tolerant Species

25	2.3e-01	Calculated as the offsite application rate divided by the NOEC for the least sensitive species.
50	1.3e-01	
100	7.3e-02	
300	3.0e-02	
500	1.9e-02	
900	1.0e-02	

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