Water Quality Criteria Report for Diazinon

Phase III: Application of the pesticide water quality criteria methodology

Prepared for the Central Valley Regional Water Quality Control Board

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List of acronyms and abbreviations

ACE	Acute-to-Chronic Estimation
ACR	Acute-to-Chronic Ratio
APHA	American Public Health Association
ASTM	American Society for Testing and Materials
BAF	Bioaccumulation Factor
BCF	Bioconcentration Factor
BMF	Biomagnification Factor
CAS	Chemical Abstract Service
CDFG	California Department of Fish and Game
CSIRO	Commonwealth Scientific and Industrial Research Organization, Australia
CVRWQCB	Central Valley Regional Water Quality Control Board
DPR	Department of Pesticide Regulation
EC_x	Concentration that affects x% of exposed organisms
FACR	Final Acute to Chronic Ratio
FAV	Final Acute Value
FDA	Food and Drug Administration
FT	Flow-through test
GMAV	Genus Mean Acute Value
IC_x	Inhibition concentration; concentration causing *x*% inhibition
ICE	Interspecies Correlation Estimation
IUPAC	International Union of Pure and Applied Chemistry
K	Interaction Coefficient
K_H	Henry's law constant
K_{ow}	Octanol-Water partition coefficient
K_p or K_d	Solid-Water partition coefficient
LC_x	Concentration lethal to *x*% of exposed organisms
LD_x	Dose lethal to *x*% of exposed organisms
LL	Less relevant, Less reliable study
LOEC	Lowest-Observed Effect Concentration
LOEL	Lowest-Observed Effect Level
LR	Less relevant, Reliable study
MATC	Maximum Acceptable Toxicant Concentration
N	Not relevant or Not reliable study
n/a	Not applicable
NOAEL	No-Observed Adverse Effect Level
NOEC	No-Observed Effect Concentration
NR	Not reported
OECD	Organization for Economic Co-operation and Development
OP	Organophosphate
QSAR	Quantitative Structure Activity Relationship
pK_a	Acid dissociation constant
RL	Relevant, Less reliable study
RR	Relevant and Reliable study
S	Static test

SMACR	Species Mean Acute to Chronic Ratio
SMAV	Species Mean Acute Value
SR	Static renewal test
SSD	Species Sensitivity Distribution
TES	Threatened and Endangered Species
US	United States
USEPA	United States Environmental Protection Agency

1. Introduction

A new methodology for deriving freshwater water quality criteria for the protection of aquatic life was developed by the University of California - Davis (TenBrook *et al.* 2009a). The need for a new methodology was identified by the California Central Valley Regional Water Quality Control Board (CVRWQCB 2006a) and findings from a review of existing methodologies (TenBrook & Tjeerdema 2006, TenBrook *et al.* 2009b). The UC-Davis methodology is currently being used to derive aquatic life criteria for several pesticides of particular concern in the Sacramento River and San Joaquin River watersheds. The methodology report (TenBrook *et al.* 2009a) contains an introduction (Chapter 1); the rationale of the selection of specific methods (Chapter 2); detailed procedures for criteria derivation (Chapter 3); and a chlorpyrifos criteria report (Chapter 4). This criteria report for diazinon describes, section by section, the procedures used to derive criteria according to the UC-Davis methodology. Also included are references to specific sections of the methodology procedures detailed in Chapter 3 of the report so that the reader can refer to the report for further details (TenBrook *et al.* 2009a).

2. Basic information

Chemical: Diazinon (Fig. 1)
CAS Number: 333-41-5
USEPA PC Code: 057801 (PAN 2006)
CA DPR Chem Code: 198 (PAN 2006)
CAS: O,O-diethyl O-[6-methyl-2-(1-methylethyl)-4-pyrimidinyl] phosphorothioate
IUPAC: O,O-diethyl O-2-isopropyl-6-methylpyrimidin-4-yl phosphorothioate

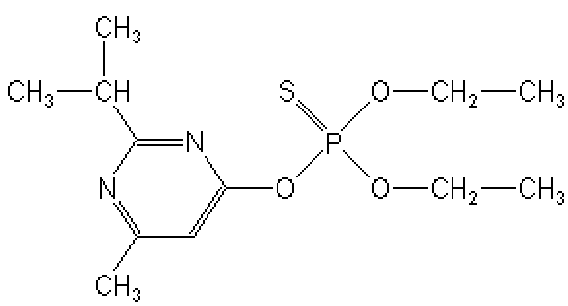

Figure 1. Structure of diazinon (Wood 2006).

Trade names: Alfa-Tox, AG-500, Basudin, Bazinon, Bazuden, Ciazinon, Dacutox, Dassitox, Dazzel, Desapon, Dianon, Diater, Diaterr-fos, Diazitol, Diazide, Diazol, Dicid, Dimpylate, Dipofene, Dizinon, Dyzol, ENT 19507, Flytrol, G 301, Gardentox, Geigy 24480, Kayazinon, Kayazol, Knox Out, NA 2763, Nedicisol, Neocidol, Nucidol, Sarolex, Spectracide, D-Z-N (Agrochemicals Handbook 1991; EXTOXNET 2007; Mackay *et al.* 1997).

3. Physical-chemical data

Molecular Weight

304.36	Mackay *et al.* 1997

Density

1.11 g/cm^3 at 20^{o}C	Worthing 1991
1.116-1.118 g/cm^3 at 20^{o}C	Milne 1995; Montgomery 1993; Tomlin 2003

Water Solubility

40 mg/L at room temperature	Martin & Worthing 1977
40 mg/L at 23.5-26.0^{o}C	Jarvinen & Tanner 1982
40.5 mg/L at 20-22 ^{o}C	Kanazawa 1981
68.8 mg/L at 22 ^{o}C	Bowman & Sans 1979; 1983b

Geometric Mean: 46.0 mg/L

Melting Point

Liquid at room temperature	Tomlin 1994

Vapor Pressure

8.2 x 10^{-5} mm Hg at 25^{o}C (0.011 Pa)	Kim *et al.* 1984
1.5 x 10 $^{-4}$ mm Hg (0.02 Pa)	Hinckley *et al.* 1990
9 x 10^{-5} mm Hg (0.012 Pa)	Tomlin 1994

Geometric Mean: 1.0 x 10^{-4} mm Hg (0.014 Pa)

Henry's constant (K_H)

0.011 Pa m^3/mol = 4.6 x 10^{-6} dimensionless (wetted-wall column, Fendinger & Glotfelty 1988)

0.0119 Pa m^3/mol = 4.8 x 10^{-6} dimensionless (mean of two values from fog chamber method, Fendinger *et al.* 1989)

Geometric Mean: 0.0114 Pa m^3/mol = 4.7 x 10^{-6} dimensionless

Organic carbon-water (K_{oc}) or organic matter-water (K_{om}) partition coefficients

132 (K_{om}, Briggs 1981)

250 (K_{om}, Sharom *et al.* 1980)

2049, 2247, 2087 (K_{oc} in natural soil, TOC = 3.8-4.3 g/kg, Iglesias-Jimenez *et al.* 1997)

5810, 5718, 6777 (K_{oc} in natural soil amended with humic acid, TOC = 13.6-15.4 g/kg, Iglesias-Jimenez *et al.* 1997)

348 (K_{om}, mean of 25 soils, Arienzo *et al.* 1994)

840 (K_{oc}, mean of 5 soils converted from K_d values using % organic carbon data, Cooke *et al.* 2004)

251 (K_{oc}; mean of 2 soils; Kanazawa 1989)

Mean (weighted) K_{om}: 336

Mean (weighted) K_{oc}: 2261

Log K_{ow}
3.79 Tsuda *et al.* 1997a
3.81 Bowman & Sans 1983a
Use: 3.81 (recommended by Sangster Research Laboratories 2004)

pK_a
2.4 Ku *et al.* 1998

Environmental Fate

Table 1. Diazinon hydrolysis and photolysis.

	Half-life (d)	Water	Temp (°C)	pH	Reference
Hydrolysis	0.49	Buffer	20	3.1	Gomaa *et al.* (1969), Faust & Gomaa (1972)
	6	Buffer	20	10.4	Gomaa *et al.* (1969), Faust & Gomaa (1972)
	17	Milli-Q	40	8.0	Noblet *et al.* (1996)
	30	Lake Superior	22.5	7.4-7.8	Jarvinen & Tanner (1982)
	31	Buffer	20	5.0	Gomaa *et al.* (1969), Faust & Gomaa (1972)
	37.2	Filtered river	NR	NR	Medina *et al.* (1999)
	52	Filtered river	22	7.3	Lartiges & Garrigues (1995)
	69	Milli-Q	22	6.1	Lartiges & Garrigues (1995)
	80	River	22	7.3	Lartiges & Garrigues (1995)
	88	Milli-Q	24	8.0	Noblet *et al.* (1996)
	136	Buffer	20	9.0	Gomaa *et al.* (1969), Faust & Gomaa (1972)
	171	Distilled	21	7.3	Mansour *et al.* (1999)
	185	Buffer	20	7.4	Gomaa *et al.* (1969), Faust & Gomaa (1972)
Aqueous photolysis	12	0 mg/L humic material	25	NR	Kamiya & Kameyama (1998)
	9-12	5 mg/L humic material	25	NR	Kamiya & Kameyama (1998)
Photolysis plus hydrolysis	31.1	Filtered river	26-35	NR	Medina *et al.* (1999)

Table 2. Bioconcentration factors (BCF) for diazinon. FT: flow-through; SR: static-renewal; S: static; values are on a wet weight basis and are not lipid normalized unless noted.

Species	BCF	Exposure	Reference
Carassius aurapus	37	FT (steady-state)	Tsuda *et al*. (1997b)
Cipangopoludina malleata	5.9	FT	Kanazawa (1978)
Cyprinus auratus	37	FT	Kanazawa (1978)
Cyprinus carpio	65	FT	Kanazawa (1978)
Cyprinus carpio (gallbladder)	39	FT (steady-state)	Tsuda *et al*. (1990)
Cyprinus carpio (kidney)	131	FT (steady-state)	Tsuda *et al*. (1990)
Cyprinus carpio (liver)	60	FT (steady-state)	Tsuda *et al*. (1990)
Cyprinus carpio (muscle)	25	FT (steady-state)	Tsuda *et al*. (1990)
Gnathopogon caerulescens	248	FT (steady-state)	Tsuda *et al*. (1989)
Indoplanorbis esustus	17	FT	Kanazawa (1978)
Labistes reticulates	17	FT	Kanazawa (1978)
Lebistes reticulates (females)	86	FT (steady-state)	Tsuda *et al*. (1997b)
Lebistes reticulates (males)	132	FT (steady-state)	Tsuda *et al*. (1997b)
Oryzias latipes	88	FT (steady-state)	Tsuda *et al*. (1997b)
Oryzias latipes	49	FT (steady-state)	Tsuda *et al*. (1997b)
Oryzias latipes	28	FT (steady-state)	Tsuda *et al*. (1995a)
Oryzias latipes	22	FT (steady-state)	Tsuda *et al*. (1995a)
Oryzias latipes	58	FT (steady-state)	Tsuda *et al*. (1995b)
Poecilia reticulata	224[a]	SR	Deneer *et al*. (1999)
Poecilia reticulata	148[a]	SR	Deneer *et al*. (1999)
Poecilia reticulata	188	SR (steady-state)	Keizer *et al*. (1993)
Poecilia reticulata	39	SR (steady-state)	Keizer *et al*. (1991)
Poecilia reticulata	46	SR (rate constant ratio)	Keizer *et al*. (1991)
Poecilia reticulata	59	SR (steady-state)	Keizer *et al*. (1991)
Poecilia reticulata	56	SR (rate constant ratio)	Keizer *et al*. (1991)
Procambarus clarkii	4.9	FT	Kanazawa (1978)
Pseudorasbora parva	152	FT (steady-state)	Kanazawa (1978; 1981)
Sarotherodon galilaeus	39	S	El Arab *et al*. (1990)
Tanichthys albonubes	36	FT (steady-state)	Tsuda *et al*. (1997b)

[a]Calculated from measured K_{ow} value and lipid content of fish

4. Human and wildlife dietary values

There are no tolerance or FDA action levels for fish tissue (USFDA 2000).

Wildlife LC_{50}s (dietary) for animals with significant food sources in water

Two studies reporting subacute dietary LC_{50} (lethal feed concentration for 50% of organisms tested) values were categorized as core studies by the USEPA, which means that the studies satisfied the established USEPA guideline for use in risk assessment. Both studies were 8-d studies, with several concentrations of diazinon in the feed given to the birds for 5-d, and clean food given for the subsequent 3-d with observation. The mallard duck dietary LC_{50} values for these two core studies are 32 and 191 mg/kg feed (USEPA 2004). Four acute oral toxicity USEPA core studies on mallard ducks are available. These studies administered an acute single dose by oral intubation or oral gavage to determine a LD_{50} for mallards for pure diazinon (not in feed). The four core oral toxicity LD_{50} values are 1.44, 3.54, 6.38, and 6.66 mg/kg body weight (USEPA 2004).

Wildlife dietary NOECs for animals with significant food sources in water

The only relevant dietary no-observed effect concentration (NOEC) for diazinon is 8.3 mg/kg feed for mallard duck reproduction (USEPA 2004). This NOEC is from a USEPA core chronic study in which diazinon was added to the breeding birds' diet throughout the breeding cycle. Two no-observed adverse effect level (NOAEL) values for diazinon are reported for mallard ducks in USEPA core studies; a subacute dietary NOAEL of 16 mg/kg feed, and an acute oral toxicity NOAEL of 0.316 mg/kg body weight (USEPA 2004).

USEPA (2004) also states that "Among pesticides, diazinon is the cause of the second most documented avian mortality incidents," but little information is available in this regard. Water may not be the route of exposure in these incidents.

5. Ecotoxicity data

Approximately 250 original studies on the effects of diazinon on aquatic life were identified and reviewed. In the review process, many parameters are rated for documentation and acceptability for each study, including, but not limited to: organism source and care, control description and response, chemical purity, concentrations tested, water quality conditions, and statistical methods (see Tables 3.6, 3.7, 3.8 in TenBrook *et al.* 2009a). Single-species effects studies that were rated relevant (R) or less relevant (L) according to the method were summarized in the data summary sheets. Information in these summaries was used to evaluate each study for reliability using the rating systems described in the methodology (section 3-2.2, TenBrook *et al.* 2009a) to give a reliability rating of reliable (R), less reliable (L), or not reliable (N). Copies of completed summaries for all studies are included in Appendix D of this report. All data rated as acceptable (RR) or supplemental (RL, LR, LL) for criteria derivation are summarized in

Tables 3 – 6, found at the end of this report. Acceptable studies rated as RR are used for numeric criteria derivation, while supplemental studies rated as RL, LR or LL are used for evaluation of the criteria to check that they are protective of particularly sensitive species and threatened and endangered species. These considerations are reviewed in section 12 and 14 of this report, respectively. Studies that were rated not relevant (N) or not reliable (RN or LN) were not used in criteria derivation.

Studies conducted according to methods described by the World Health Organization (WHO 1963) were not given credit for use of an acceptable standard method. The WHO method is unacceptable by more recent standards due to such things as allowing use of deionized water as a dilution water, using 4^{th} instar larvae (ASTM 2005 and USEPA 2000a require 2^{nd}-3^{rd} instars) and allowance of use of as much as 1 mL of carrier solvent per 100 mL test solution (various ASTM methods allow only 0.1 mL/L and 0.5 mL/L for chronic and acute tests, respectively).

Using the data evaluation criteria (section 3-2.2, TenBrook *et al.* 2009a), 22 acute toxicity studies yielding 52 toxicity values were judged reliable and relevant (RR; Tables 3 and 4). Five chronic toxicity studies yielding eight toxicity values were judged reliable and relevant (RR; Tables 5 and 6). Forty-two studies were rated RL, LR, or LL, and were used as supplemental information for evaluation of derived criteria in the Sensitive Species section 12 (Table 8).

Thirty-three mesocosm, microcosm and ecosystem (field and laboratory) studies were identified and reviewed using Table 3.9 (TenBrook *et al.* 2009a). Four of these studies were rated reliable (R) or less reliable (L) and were used as supporting data in section 14 to evaluate the derived criteria to ensure that they are protective of ecosystems. Ten more field studies that did not rate highly (because of the likely presence of other contaminants) were summarized in Appendix A. They were included because they focus mainly on toxicity in waterways in the California Central Valley. Other ecosystem-level studies were not summarized in summary sheets due to their complexity. Nine studies of diazinon effects on wildlife were identified and reviewed using Table 3.10 (TenBrook *et al.* 2009a) for consideration of bioaccumulation in section 15.

6. Data reduction

Multiple toxicity values for diazinon for the same species were reduced down to one species mean acute value (SMAV) or one species mean chronic value (SMCV) according to procedures described in the methodology (section 3-2.4, TenBrook *et al.* 2009a). Acceptable acute and chronic data that were reduced, and the reasons for their exclusion, are shown in Tables 4 and 6, respectively. Reasons for reduction of data included: tests with measured concentrations are preferred over tests with nominal concentrations, flow-through tests are preferred over static tests, a test with a more sensitive life-stage of the same species was available, longer exposure durations are preferred, and tests with more sensitive endpoints were available. The final acute and chronic data sets are shown in Tables 3 and 5, respectively. The final acute data set contains 13 SMAVs, and the final chronic set contains five SMCVs.

7. Acute criterion calculation

At least five acceptable acute toxicity values were available and fulfilled the five taxa requirements of the species sensitivity distribution (SSD) procedure (section 3-3.1, TenBrook *et al.* 2009a). The five taxa requirements are a warm water fish, a species in the family Salmonidae, a planktonic crustacean, a benthic crustacean, and an insect. Acute values were plotted in a histogram (Figure 2); the data appears to be bimodal with invertebrates encompassing the lower subset and fish and one amphibian in the upper subset. The distribution was fit to the entire data set because according to the methodology, a data set should not be split unless the fit test indicates a lack of fit to the entire data set (section 3-3.2.4, TenBrook *et al.* 2009). The Burr Type III SSD procedure (section 3-3.2.1, TenBrook *et al.* 2009a) was used for the acute criterion calculation because more than eight acceptable acute toxicity values were available in the diazinon data set (Table 3). The Burr Type III SSD consists of a family of three related distributions; the BurrliOZ software (CSIRO 2001) displays the results for the distribution that best fits the data set based on a goodness of fit based on maximum likelihood estimation. Of the three possible distributions, the Reciprocal Weibull distribution best fit the acute diazinon data set.

The Burr Type III SSD procedure was used to derive 5th percentile values (median and lower 95% confidence limit), as well as 1st percentile values (median and lower 95% confidence limit), as instructed in the methodology (section 3-3.2.1, TenBrook *et al.* 2009a). These values are reported to three significant digits as instructed by the methodology (section 3-3.2.1, TenBrook *et al.* 2009a). The median 5th percentile value is recommended for use in criteria derivation by the methodology because it is the most robust of the distributional estimates (section 3-3.2, TenBrook *et al.* 2009a). Comparing the median estimate to the lower 95% confidence limit of the 5th percentile values, it can be seen that the first significant figures of the two values are different (0.349 vs. 0.155 μg/L). Because there is uncertainty in the first significant digit, the final criterion will be reported with one significant digit (section 3-3.2.6, TenBrook *et al.* 2009a).

Reciprocal Weibull distribution (from Burr Type III distribution)
Fit parameters: alpha=2.123041; beta=0.326993. (likelihood=87.377508)

5th percentile, 50% confidence limit: 0.349 μg/L
5th percentile, 95% confidence limit: 0.155 μg/L
1st percentile, 50% confidence limit: 0.0937 μg/L
1st percentile, 95% confidence limit: 0.0392 μg/L

Recommended acute value = 0.349 μg/L (median 5th percentile value)

$$\begin{aligned}\text{Acute criterion} &= \text{acute value} \div 2 \qquad (1)\\ &= 0.349\ \mu g/L \div 2\\ &= 0.175\ \mu g/L\end{aligned}$$

Acute criterion = 0.2 µg/L

No significant lack of fit was found (X^2_{2n} = 0.1561) using a fit test based on cross validation and Fisher's combined test (section 3-3.2.4, TenBrook *et al.* 2009a), indicating that the whole data set should be used for criteria derivation. The fit test calculations are shown in Appendix C. It is preferable to use as much data as possible to characterize the distribution; therefore the acute criterion was derived using the whole data set. The fit of the Reciprocal Weibull distribution to the whole acute data set is shown in Figure 3. The acute criterion of 0.2 µg/L, calculated with the median 5th percentile value is the recommended acute criterion; this value will be evaluated for protectiveness in sections 12-14 of this report.

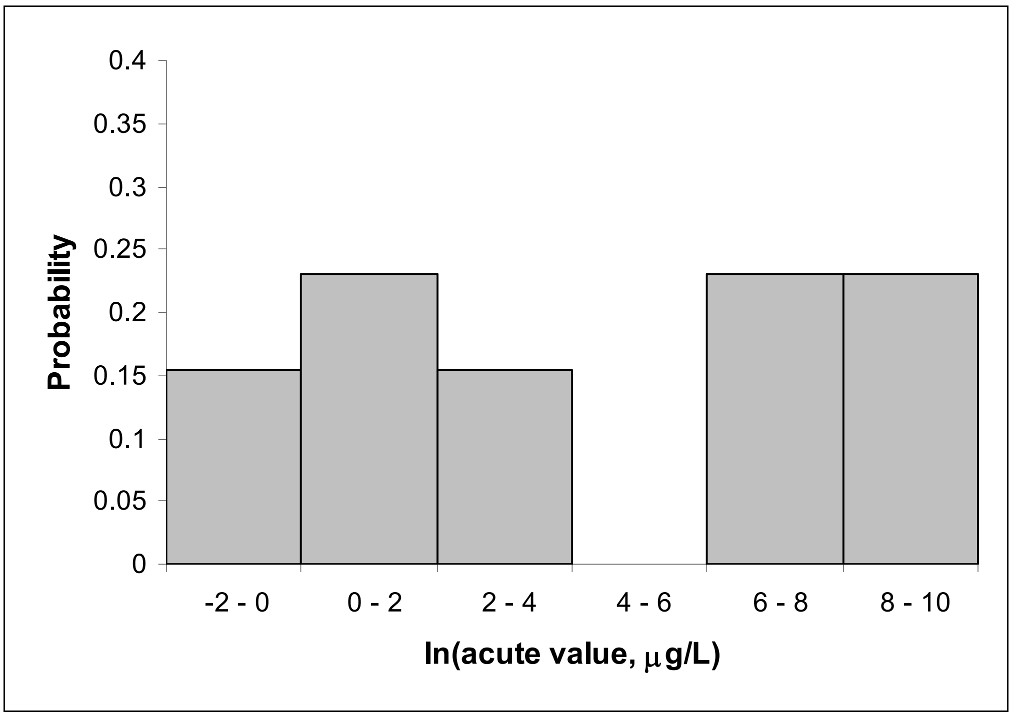

Figure 2. The natural log of the diazinon SMAVs were plotted on a histogram to show the general shape of the distribution of the data. Data are split into two groups.

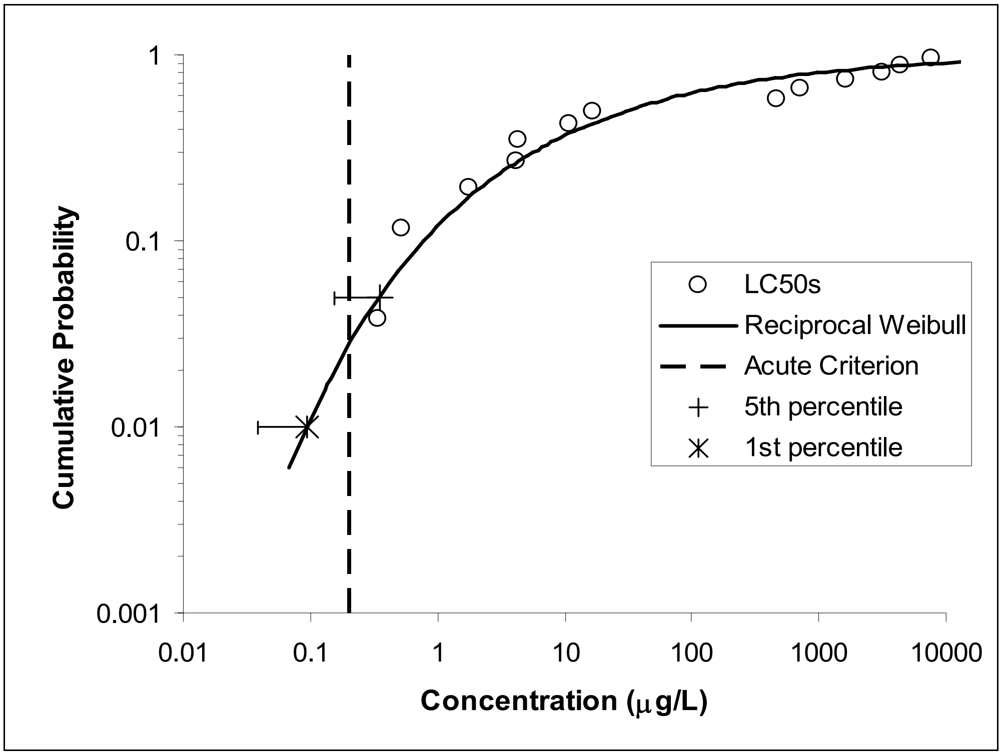

Figure 3. Plot of acute values (SMAVs of LC_{50}s) for diazinon and fit of the Reciprocal Weibull distribution. The graph shows the median 5th and 1st percentile values with the lower 95% confidence limits and the acute criterion at 0.2 µg/L.

8. Chronic criterion calculation

Chronic toxicity values from fewer than five different families were available, thus, the acute-to-chronic ratio (ACR) procedure was used to calculate the chronic criterion (section 3-4.2, TenBrook *et al.* 2009a). There are five SMCVs in the acceptable (rated RR) data set (Table 5), which satisfy three of the five taxa requirements for use of a SSD (section 3-3.1, TenBrook *et al.* 2009a): a species in the family Salmonidae (*Salvelinus fontinalis*), a warm water fish (*Pimephales promelas)* and a planktonic crustacean (*Daphnia magna)*. The two missing taxa are a benthic crustacean and an insect. Three of the chronic toxicity values could be paired with an appropriate corresponding acute toxicity value in order to calculate an ACR with measured toxicity data, satisfying the three family requirements for the ACR method: a fish, an invertebrate, and another sensitive species (section 3-4.2.1, TenBrook *et al.* 2009a).

The species mean ACRs (SMACRs) were calculated for each of the three species by dividing the acute LC_{50} value by the chronic MATC value for a given species (section 3-4.2.1, TenBrook *et al.* 2009a). There was an increasing trend of SMACRs as the SMAVs increased. Because this trend was observed, the final multispecies ACR was calculated as the geometric mean of the ACRs for species whose SMAVs are close to the acute criterion, which includes species with SMACRs within a factor of 10 of the SMACR of the species whose SMAV is nearest the 5th percentile value (part 1, section 3-4.2.1, TenBrook *et al.* 2009a). For diazinon, the species with an acute value closest to the calculated 5th percentile acute value is *Daphnia magna* (SMAV=0.52 μg/L), with a SMACR of 2.3. None of the other SMACRs are within a factor of 10 of that value; therefore the final multispecies ACR is 2.3 (part 1, section 3-4.2.1, TenBrook *et al.* 2009a). Data used to calculate the final multispecies ACR are shown in Table 7. Calculations of the chronic criterion are shown below using both the median and lower 95% confidence limit of the 5th percentile. The chronic criterion calculations are based on the acute 5th percentile values, and will therefore also be reported with one significant figure (see section 7 above). The chronic criterion calculated with the median 5th percentile estimate is the recommended chronic criterion because the median value is the most robust estimate; this value will be evaluated for protectiveness in sections 12-14 of this report.

Chronic criterion calculated with the median 5th percentile estimate:
5th percentile, 50% confidence limit: 0.349 μg/L

Chronic criterion	= acute 5th percentile value ÷ ACR	(2)
	= 0.349 μg/L ÷ (2.3)	
	= 0.152 μg/L	
Chronic criterion	= 0.2 μg/L	

Chronic criterion calculated with the lower 95% confidence interval of the 5th percentile estimate:
5th percentile, 95% confidence limit: 0.155 μg/L

Chronic criterion	= acute 5th percentile value ÷ ACR	(2)
	= 0.155 μg/L ÷ (2.3)	
	= 0.0674 μg/L	
Chronic criterion	= 0.07 μg/L	

9. Bioavailability

Few studies were identified that investigated the bioavailability of diazinon, with even fewer pertaining to bioavailability to organisms in the water column. The bioavailability of diazinon to *Daphnia magna* was reduced in a linear relationship with increased dissolved humic material; presumably because diazinon was binding to the dissolved humic material (Steinberg *et al.* 1993). With such little information regarding the toxicity of diazinon in various phases, it is not possible to determine if the bioavailability of diazinon is predictable without site-specific, species-specific data. Until such data are available, criteria compliance should be determined on a total concentration basis, as recommended in the methodology (section 3-5.1, TenBrook *et al.* 2009a).

10. Mixtures

The effects of pesticide mixtures are evaluated and recommendations for criteria compliance determination when chemical mixtures are present are discussed according to section 3-5.2 of the methodology (TenBrook *et al.* 2009a). Definitions of additivity, synergism, antagonism, and non-additivity are available in the literature (Lydy and

Austin 2004) and more detailed descriptions of the recommended models can be found in the methodology (section 3-5.2, TenBrook *et al.* 2009a).

Diazinon often occurs in the environment with other organophosphate (OP) pesticides (TenBrook & Tjeerdema 2006). Bailey *et al.* (1997) calculated joint toxicity of diazinon and chlorpyrifos using the toxicity unit (TU) approach (see section 3-5.2.1.1, TenBrook *et al.* 2009a) and reported that these mixtures resulted in an average of 1.13 TUs, indicating additivity for these two compounds. Lydy and Austin (2004) also demonstrated additive toxicity for mixtures of chlorpyrifos and diazinon in acute toxicity tests with *Chironomus tentans.* Environmental samples collected by Hunt *et al.* (2003) were tested for *Ceriodaphnia dubia* survival, and samples that contained both chlorpyrifos and diazinon demonstrated additivity, with mean *C. dubia* survival of 97% when less than 1 TU of the two compounds was present, and mean survival was 34% when more than 1 TU was present. Since these two compounds have the same mode of action, concentration addition is a valid assumption; either the toxic unit or the relative potency factor approach can be used to determine compliance when both diazinon and chlorpyrifos are present (3-5.2.1, TenBrook *et al.* 2009a).

In a study by Laetz *et al.* (2009) Coho salmon (*Oncorhynchus kisutch*) exposed to combinations of diazinon with malathion had synergistic, rather than additive, effects on AChE activities. Mixtures were designed to produce 50% AChE inhibition based on additive interactions, however, the pairing of diazinon (7.3 µg/L) with malathion (3.7 µg/L) produced severe AChE inhibition (> 90%). Many fish species die after high rates of acute brain AChE inhibition (> 70–90%) (Fulton and Key 2001). While mixtures of diazinon with malathion were found to have synergistic toxicity effects, the study did not provide a way to incorporate this interaction quantitatively into compliance. However, in light of the recent dramatic decline of Chinook salmon and the ban on commercial salmon fishing off the coast of California, this finding has possibly very important implications for environmentally relevant concentrations of OPs in mixtures and their toxic effects on endangered Salmonids.

Diazinon toxicity was synergized by cyanazine (Lydy & Austin 2004) and atrazine (Anderson & Lydy 2002, Belden & Lydy 2000). Table 9 shows the synergistic ratios (SR) for these studies, as well as for the interaction of diazinon with ammonia. The SR is obtained by dividing the EC_{50} for the pesticide alone by the EC_{50} in the presence of a non-toxic concentration of the synergist. Thus, the SR reported in these studies is equivalent to the interaction coefficient (K), which is described in the methodology (section 2-4.2.2, TenBrook *et al.* 2009a). SR values > 1 indicate synergistic interaction; SR values < 1 indicate antagonistic interaction.

Since multiple K values are available for atrazine over a range of concentrations, these values were used to derive a quantitative relationship. Least squares regressions of the *Chironomus tentans* and *Hyalella azteca* combined data resulted in a significant relationship between atrazine concentration and K values ($p < 0.001$; JMP IN v.5.1.2; JMP 2004):

$K = 0.0095(\text{Conc. Atrazine}) + 1.05$ ($r^2 = 0.87$, $p = 0.0007$)

To determine compliance, or to assess potential for harm, equation 3 may be used to establish the effective concentration of diazinon in the presence of atrazine:

$$C_a = C_m(K) \qquad (3)$$

where:

C_a = adjusted, or effective, concentration of chemical of concern
C_m = concentration measured for chemical of concern
K = coefficient of interaction, calculated for the synergist concentration in water

The effective concentration may be compared to diazinon criteria, or may be used in one of the additivity models.

Less than additive (antagonistic) effects have been reported for the interaction of diazinon with copper and zinc (Banks *et al.* 2003, Mahar & Watzin 2005, Van Der Geest *et al.* 2000b), but data were not given that could be used to calculate interaction coefficients. Bailey *et al.* (2001) reported less than additive effects when *Ceriodaphnia dubia* were exposed to mixtures of ammonia and diazinon. The reduction in diazinon toxicity was moderate (K = 0.94) and was only calculable for a single ammonia concentration. Not enough data are available from these to allow derivation of a quantitative relationship between K values and antagonist concentration.

Ankley & Collyard (1995) reported reduced toxicity of diazinon to *Hyalella azteca* and *Chironomus tentans* in the presence of piperonyl butoxide (PBO), but antagonistic ratios were not reported. PBO is commonly used in toxicity identification evaluations because it is known to reduce the toxic effects of OPs (Ankley *et al.* 1991, Hunt *et al.* 2003). Because no interaction coefficients have been derived to describe antagonism between diazinon and PBO, it is not possible to quantify this non-additive toxicity. Consequently, there is no way to account for this interaction in compliance determination.

OP insecticides, such as diazinon, are increasingly used in combination with pyrethroids because they can synergistically increase the effects of pyrethroids, especially where pest populations have developed resistance (Perry *et al.* 2007). Denton *et al.* (2003) demonstrated that exposure to the pyrethroid esfenvalerate and diazinon resulted in greater than additive toxicity in fathead minnow larvae. These greater than additive effects were attributed to the complementary modes of toxic action of these two insecticide classes, which act on different components of nerve impulse transmission. Again, there is insufficient data to account for this interaction for compliance determination.

Interpretation of monitoring data in cases where synergists and antagonists are both present is not possible with the available models. If, for example, ammonia and a pyrethroid were both present in combination with diazinon, there would be no simple way to determine an effective concentration of diazinon that accounts for both interactions.

11. Temperature, pH, and other water quality effects

Temperature, pH, and other water quality effects on the toxicity of diazinon were examined to determine if any effects are described well enough in the literature to incorporate into criteria compliance (section 3-5.3, TenBrook *et al.* 2009a). One study showed increased diazinon toxicity with increased temperature to *Chironomus riparius* (Landrum *et al.* 1999). However, this study was rated LL for failing to report the control response and low reliability, so it cannot be used to quantify effects of temperature on diazinon toxicity. This study also investigated the effect of pH and found no clear correlation to toxicity.

Three separate acute toxicity studies on *Chironomus tentans* display increased toxicity with increased temperature. These studies resulted in LC_{50} values of 30, 19.1, 10.7 μg/L for tests performed at 20, 21 and 23°C, respectively (Ankley & Collyard 1995, Belden & Lydy 2000, Lydy & Austin 2004). However, these tests are not directly comparable because differences in important test parameters, such as life stage and nominal versus measured concentrations, could account for the differences in toxicity values. Among diazinon studies rated RR, there are no cases of chronic tests conducted at different temperatures with the same species. Data on other OPs show increased toxicity with increased temperature and no effect of pH in a variety of aquatic species (Baer *et al.* 2002, Lydy *et al.* 1999, Lydy *et al.* 1990, Patra *et al.* 2007).

Although there is evidence of temperature effects on diazinon toxicity, there is not enough data to adequately quantify the relationship at this time. Therefore, only results of tests conducted at standard temperatures are included in the data set and temperature equations are not needed for criteria expression.

12. Sensitive species

The derived criteria are compared to toxicity values for the most sensitive species in both the acceptable (RR) and supplemental (RL, LR, LL) data sets to ensure that these species will be adequately protected (section 3-6.1, TenBrook *et al.* 2009a). The acute and chronic criteria calculated with the acute median 5^{th} percentile value (both 0.2 μg/L) are below all of the toxicity values in the acute and chronic RR data sets. The lowest value in the acute RR data set is a value for *Ceriodaphnia dubia* of 0.21 μg/L, which is similar to the criterion (Table 3). This value for *Ceriodaphnia dubia* is the lowest compared to ten others used for criteria derivation (0.26, 0.29, 0.32, 0.33, 0.33, 0.35, 0.38, 0.436, 0.47, 0.507, SMAV is 0.34 μg/L). There is also a similar value in the supplemental data set of 0.25 μg/L (Norberg-King 1987, Table 8). While there is one *Ceriodaphnia dubia* toxicity value in the RR data set that is very close to the proposed acute criterion and several other values near the proposed acute criterion, the SMAV is the most robust toxicity value to represent a species. The *Ceriodaphnia dubia* SMAV is based on eleven separate tests, and is therefore a more robust and reliable value than a single test value. A SMAV is calculated for use in the SSD so that no single species or single test for a species receives undue weight in the derivation process (section 2-2.7, TenBrook *et al.* 2009a). The goal of a SSD is to utilize the whole data set to derive protective estimates. In this case, it is not recommended that the acute criterion be adjusted downward based on one of nine toxicity values for *Ceriodaphnia dubia*, because the SMAV indicates that the acute criterion of 0.2 μg/L will be protective of this species. Downward adjustment of criteria can be recommended when a proposed criterion is higher than toxicity values for a sensitive species (section 3-6.1, TenBrook *et al.* 2009a), especially when there is very little data for a species, but it is not recommended in this case because there is ample highly rated data for *Ceriodaphnia dubia.*

The lowest measured chronic value in the data set rated RR is a maximum acceptable toxicant concentration (MATC) of 0.23 μg/L for *Daphnia magna* (Surprenant 1988a), which is just above the chronic criterion (0.2 μg/L). This is the only highly rated value for *Daphnia magna* or any Cladoceran species. The supplemental data set (Table 8) contains six MATC values for *D. magna* that are approximately equivalent to the criterion (0.16, 0.16, 0.22, 0.24, 0.24 and 0.24 μg/L; Dortland 1980, Fernández Casalderrey *et al.* 1995, Sánchez *et al.* 1998) and twelve MATC values for *D. magna* of 0.07 μg/L, which are below the chronic criterion (Sánchez *et al.* 1998, 2000). These studies did not rate highly because test parameters were not documented well, but had no obvious flaws in study design or execution. Sánchez *et al.* (2000) reported the concentrations incorrectly in their original report as ng/L instead of μg/L, which was confirmed via correspondence with the authors. This was a multi-generational test, which would be expected to be more sensitive than the test rated RR that only monitored reproduction in one generation (Surprenant 1988a). The only other chronic value for a Cladoceran is 0.34 μg/L for a *Ceriodaphnia dubia* 7-d test (Norberg King 1987), in the supplemental data set. *C. dubia* is the most sensitive species in the acute distribution; thus this gap in the chronic data rated RR may lead to an underprotective criterion. The supplemental data set also contains a toxicity value of 0.13 μg/L for *Hyalella azteca*, which is below the chronic criterion, but the endpoint in this study does not have an established connection to survival, growth, or reproduction.

Highly rated chronic data are generally lacking for Cladocerans, the most sensitive taxon. There is one chronic toxicity value that was highly rated, and it is approximately the equivalent to the derived chronic criterion, while 13 supplemental values are lower, eleven of which were based on measured concentrations. There is very little data to show that the supplemental data are in error and no major problems were found with those studies (e.g., test with saltwater species, testing an endpoint not directly related to survival, growth or reproduction), aside from incorrect units and missing documentation of some parameters. Therefore, the chronic criterion, as calculated may be underprotective of Cladocerans and use of one of the lower distributional estimates for calculation of the chronic criterion is recommended. The methodology states that "if evidence suggests that the 5^{th} percentile will not be protective, criteria may be adjusted downward," (section 3-6.0, TenBrook *et al.* 2009a), based on measured data (section 3-6.1, TenBrook *et al.* 2009a). To make a downward adjustment, the methodology recommends the use of the lower 95% confidence limit of the 5th percentile for criterion calculation, or the median or 95% confidence limit of the 1st percentile (section 3-6.0, TenBrook *et al.* 2009a). The use of lower 95% confidence limit of the 5th percentile to calculate the chronic criterion yields a recommended chronic criterion of 0.07 µg/L (section 8).

13. Ecosystem and other studies

The derived criteria are compared to acceptable laboratory, field, or semi-field multispecies studies (rated R or L) to determine if the criteria will be protective of ecosystems (section 3-6.2, TenBrook *et al.* 2009a). Four studies of diazinon effects on microcosms, mesocosm and model ecosystems were rated acceptable (R or L reliability rating, using Table 3.9, TenBrook *et al.* 2009a). Most of these studies used formulations or mixtures of several pesticides, rather than technical diazinon. Also, for many of the studies, diazinon levels were not measured, and other water quality parameters were not reported.

In Giddings *et al.* (1996) diazinon was applied in a range of concentrations (2.0 - 500 µg/L) to aquatic microcosms (sediment from pond including invertebrates and plants with bluegill sunfish added). The LOEC was near the 10th percentile of single-species LC_{50} values, at 9.2 µg/L, and the NOEC was 4.3 µg/L (70-d averages). Cladoceran species were found to be the least tolerant, while gastropods and rotifers were the most tolerant species. Arthur *et al.* (1983) used three outdoor experimental channels to assess the effect of a 12 week exposure to diazinon using a low treatment of 0.3 µg/L and high treatment of 6 µg/L (nominal concentrations). Then the dose was increased for 4 weeks to higher concentrations (12 and 30 µg/L). Macroinvertebrate and insect emergence, density, drift and percent occurrence were monitored. Effects on amphipods and insects were seen in the lowest treatment with lower numbers of mayflies and damselflies emerging from treated channels. Flatworms, gastropods, isopods and chironomids were most tolerant to diazinon. Werner *et al.* (2004) exposed larval fish (fathead minnows, rainbow trout), waterfleas (*Ceriodaphnia dubia, Simocephalus vetelus*) and midge larvae (*Chironomus riparius*) to stormwater runoff collected in a California orchard after application of diazinon and esfenvalerate (in separate areas), following two consecutive rainstorms. Diazinon concentrations measured in orchard runoff were 277-340 µg/L (first rain storm), and 10.7-19.5 µg/L (second rain storm). All runoff was toxic to *C. dubia,* and toxicity to the fish and midge varied by treatment. Moore *et al.* (2007) investigated the role of organic matter in pesticide exposure in a constructed wetland by exposing leaf litter to 160 µg/L of diazinon. *Hyalella azteca* survival was affected by exposure to contaminated leaf-litter removed from the wetlands (measured diazinon residues of ≥ 60 µg/kg). The concentrations tested in these ecosystem studies are all well above the criteria, except the study by Arthur *et al.* (1983) that documented effects at 0.3 µg/L, which is only slightly above the derived criteria.

Studies that did not receive an R or L reliability rating but were considered of interest are included in Appendix A. These studies implicated various levels of diazinon in effluents and run-off in California as part of the cause of toxicity to organisms. These studies did not meet the criteria for ecosystem or mesocosm evaluations, primarily because other contaminants were often present and effects could not be related to diazinon with certainty. Most of the measured diazinon concentrations were also above the criteria. Given the results of the above studies, it appears that an acute criterion of 0.2 μg/L and a chronic criterion of 0.07 μg/L will be protective. However, effects were seen at 0.3 μg/L, as described above (Arthur *et al.* 1983), which is very close to the acute criterion. While this study is not conclusive enough to demonstrate that 0.2 μg/L will not be protective (there is no NOEC), it adds support for use of a lower chronic criterion of 0.07 μg/L, calculated from the lower confidence limit from the estimation, as discussed in sections 8 and 12.

14. Threatened and endangered species

The derived criteria are compared to measured toxicity values for threatened and endangered species (TES), as well as to predicted toxicity values for TES, to ensure that they will be protective of these species (section 3-6.3, TenBrook *et al.* 2009a). Current lists of state and federally listed threatened and endangered plant and animal species in California were obtained from the California Department of Fish and Game (CDFG) web site (www.dfg.ca.gov/hcpb/species/t_e_spp/tespp.shtml; CDFG 2006a, b). None of the listed animals or plants is represented in the acceptable acute or chronic data sets (rated RR). However, some of the listed species are represented in the acute data set by members of the same family or genus. For these, the USEPA interspecies correlation estimation (ICE v. 1.0; USEPA 2003) software was used to estimate toxicity values. Table 10 summarizes the results of the ICE analyses. The values in Table 10 range from 730 μg/L for *Oncorhynchus mykiss* (steelhead) to 2750 μg/L for *Ptychocheilus lucius* (Colorado squawfish), indicating that the acute criterion of 0.2 μg/L should be protective of these species.

Additionally, the supplemental data set (Table 8) contains data for endangered species. The supplemental data set includes LC_{50} values for *Oncorhynchus mykiss* of 90-2760 μg/L. The value estimated above for *O. mykiss* does fall within this range. *Oncorhynchus tshawytscha* (Chinook salmon) is listed as federally threatened or endangered, depending on season and location. The supplemental data set contains an LC_{50} of 545,000 μg/L and a MATC of 70,700 μg/L for embryos of *O. tshawytscha* and an LC_{50} of 29,500 μg/L for the alevins of *O. tshawytscha*. Although not as reliable, these data support that the criteria is protective of these endangered salmonids. *Cyprinella monacha* and *Notropis mekistocholae* are also threatened and endangered species, although they reside in the Southwestern U.S., not in California. The criteria in this report are protective based on the reported toxicity values for these species: an IC_{25} of 4115 μg/L for *C. monacha* and 199 μg/L for *N. mekistocholae.*

There was one algal study (the only plant value) that rated reliable and relevant for criteria derivation, but no algae species are on the state or federal endangered, threatened or rare species lists. As discussed in the chlorpyrifos criteria report of the methodology (section 4-4.0, TenBrook *et al.* 2009a), plants are relatively insensitive to OP insecticides, and therefore the calculated criteria should be protective.

Based on the available data and estimated values for animals, there is no evidence that the calculated acute and chronic criteria will be underprotective of threatened and endangered species. However, the caveat of this assessment is that no data were found for effects of diazinon on federally endangered Cladocerans or insects, or acceptable surrogates (i.e., in the same family), which are the most sensitive species in the data sets.

15. Bioaccumulation

Bioaccumulation was assessed to ensure that the derived criteria will not lead to unacceptable levels of diazinon in food items (section 3-7.1, TenBrook *et al.* 2009a). Diazinon has a log K_{ow} of 3.81 (Sangster Research Laboratories 2004), and molecular weight of 304.3, which indicates its bioaccumulative potential. There are no tolerance or FDA action levels for fish tissue (USFDA 2000). Bioaccumulation of diazinon has been measured in a number of studies (Table 2).

Palacio *et al.* (2002) found that juvenile tilapia exposed to a concentration of diazinon 10-fold lower than the determined 96-h LC_{50} (3.85 mg/L) reached steady-state accumulation (28.45 mg/kg) after 7.7 d, and that after 6 d in clean water, levels decreased to 0.29 mg/kg. Sancho *et al.* (1993) estimated biological half-lives of 25 h and 26 h for diazinon in the liver and muscle, respectively, of the freshwater eel, *Anguilla anguilla*. This study also observed elimination of diazinon once the animals were placed in clean water (over 50% eliminated after 24 h).

El Arab *et al.* (1990) studied the bioaccumulation and excretion of ^{14}C-labeled diazinon in perch (*Sarotherodon galilaeus*). In comparison with other lipophilic pesticides (e.g., DDT, lindane), the bioaccumulation factor (BAF) of diazinon was found to be lower by greater than a factor of 10, and both the compound and its metabolites were eliminated quickly (9% of bioaccumulated diazinon was left after 3 d). Kanazawa (1978) exposed seven species of freshwater organisms to 10 and 50 µg/L diazinon for 7 d, and found that the bioconcentration ratios of fishes were generally larger than those of crustaceans and gastropods, and also found that diazinon is quickly eliminated from tissues (~8 d).

Deneer *et al.* (1999) found the lethal body burden of diazinon in guppies to range from 1.8 - 2.1 µmol/g, and that the log-normalized bioconcentration factor (BCF) of diazinon ranged from 2.17-2.35, depending on exposure level. The study performed by Keizer *et al.* (1991) compared uptake in the guppy (*Poecilia reticulata*) to the zebra fish (*Danio rerio*). It was found that differences in metabolism play a pivotal role in the rate of bioaccumulation, as the LC_{50} values and BCF values between these two species varied greatly (0.8 mg/L and 39 in the guppy, 8 mg/L and > 300 in the zebra fish).

Three studies assessing the bioaccumulation of diazinon were performed by Tsuda *et al.* (1990; 1995a; 1997b). The 1990 study reported *Cyprinus carpio* BCF values for diazinon ranging from 20.9 - 111.1 in the muscle, liver, kidney, and gallbladder, and second-order excretion. In the 1995 study, it was reported that bioconcentration in the

Japanese killifish (*Oryzias latipes*) plateaued at 24 hr, and that when a mixture of pesticides, including diazinon, was tested, a bioconcentration plateau occurred more rapidly. The excretion rate of diazinon was found to be similar to other OP pesticides (fenthion, fenitrothion). The 1997 study looked at correlations between the BCF values of four fishes (guppy, killifish, goldfish, white cloud mountain fish) exposed to 2.1 - 2.9 μg/L diazinon (in addition to 10 other OP pesticides), and found that the BCF values of diazinon and other pesticides correlated more closely between different fishes than did the octanol-water partition coefficient (K_{ow}). The BCF of diazinon peaked at 120 h in all fishes with the exception of the white cloud mountain fish (72 h BCF peak), and ranged from 35.7 in the white cloud mountain fish to 132 in the male guppy.

In summary, most studies found that diazinon is relatively quickly eliminated from tissues after placing organisms in clean water (3-8 d), and that steady-state is reached within a few days. BCF values varied widely amongst different species.

To check that these criteria are protective of terrestrial animals that may consume aquatic organisms, a BAF was used to estimate the water concentration that would roughly equate to a reported toxicity value for consumption of fish by terrestrial wildlife. These calculations are further described in section 3-7.1 of the methodology (TenBrook *et al.* 2009a). The BAF of a given chemical is the product of the BCF and a biomagnification factor (BMF), such that BAF=BCF*BMF. No BAF or BMF values were found for diazinon. Chronic dietary toxicity values (NOEC or LOEC) for relevant terrestrial species are preferred for this calculation, instead of oral toxicity values. One dietary NOEC was available for reproductive effects on mallard duck of 8.3 mg/kg (USEPA 2004). Two dietary LC_{50} values were also available for mallard duck, 32 and 191 mg/kg feed (USEPA 2004), but these values are less sensitive than the chronic dietary value. A conservative estimate can be made using the lowest dietary NOEC of 8.3 mg/kg feed for mallard duck and a BCF value of 188 L/kg for *Poecilia reticulata* (Table 2). These values were translated to a water value using a default BMF value of 2, based on the log K_{ow} of diazinon (Table 3.15, TenBrook *et al.* 2009a):

$$NOEC_{water} = \frac{NOEC_{oral\_predator}}{BCF_{food\_item} * BMF_{food\_item}} \quad (4)$$

Mallard:

$$NOEC_{water} = \frac{8.3 \, {}^{mg}\!/\!_{kg}}{188 \, {}^{L}\!/\!_{kg} * 2} = 0.0221 \, {}^{mg}\!/\!_{L} = 22.1 \, {}^{\mu g}\!/\!_{L}$$

This value is well above the acute and chronic criteria of 0.2 μg/L and 0.07 μg/L, respectively, and therefore the criteria are likely to be protective of terrestrial animals feeding on aquatic organisms.

16. Harmonization with air or sediment criteria

This section addresses how the maximum allowable concentration of diazinon might impact life in other environmental compartments through partitioning (section 3-7.2, TenBrook *et al.* 2009a). The only available sediment criteria for diazinon is estimated based on partitioning from water using the USEPA water quality criteria (USEPA 2006a), making it useless to estimate back to a water concentration. There are no other federal or state sediment or air quality standards for diazinon (California Air Resources Board 2005, California Department of Water Resources 1995, USEPA 2006b). However, diazinon can be present in the atmosphere and transported via rain and fog. Diazinon was measured in rain (2.00-0.0013 μg/L), snow (up to 14 ng/L), and fog water (76.30-0.0013 μg/L) in the Sierra Nevada mountains, likely transported there from the California Central Valley (McConnell *et al.* 1998, Zabik & Seiber 1993). Diazinon has been measured in fog water at 0.1-0.3 μg/L, near Parlier, CA (Glotfelty *et al.* 1990) and rain in Europe at 0.1-0.3 μg/L by Scharf *et al.* (1992) and at 0.008-0.21 μg/L by Charizopoulos & Papadopoulou-Mourkidou (1999). Because there are no atmospheric limits for diazinon, no estimations on the partitioning from water to the atmosphere were made.

17. Assumptions, limitations, and uncertainties

The assumptions, limitations and uncertainties involved in criteria generation are available to inform environmental managers of the accuracy and confidence in criteria (section 3-8.0, TenBrook *et al.* 2009a). Chapter 2 of the methodology (TenBrook *et al.* 2009a) discusses these points for each section as different procedures were chosen, such as the list of assumptions associated with using an SSD (section 2-3.1.5.1), and reviews them in section 2-7.0. This section summarizes any data limitations that affected the procedures used to determine the final diazinon criteria. The different calculations of distributional estimates included in section 7 of this report may be used to consider the uncertainty in the resulting acute criterion.

For diazinon, the major limitation was lack of data in the chronic data set. Two of five taxa requirements were not met (the benthic crustacean and insect) which precluded the use of a SSD; therefore, an ACR was used to derive the chronic criterion. Three acceptable ACRs were available, but because of the wide range of values between fish and the Cladocerans only the ACR for the Cladoceran was used (according to section 3-4.2.1, TenBrook *et al.* 2009a). The chronic criterion was initially derived using this one ACR and the acute median 5th percentile value to give a result of 0.2 μg/L. When comparing this criterion (0.20 μg/L) to the supplemental data set it seems that chronic effects may occur at lower concentrations (0.07 - 0.16 μg/L, section 12). This is difficult to confirm as these studies lack several quality control parameters. The few other supplemental values are only slightly higher (0.22 -0.24 μg/L). The chronic criterion was calculated with an ACR, which does not quantify uncertainty, unlike the use of a SSD. As described in the method, "criteria must be protective of aquatic life, and therefore must err on the side of conservatism when data are lacking," (section 2-3.2.1, TenBrook *et al.*

2009a). To ensure adequate protection of Cladocerans, a lower chronic criterion of 0.07 µg/L, calculated with the lower 95% confidence limit of the acute 5th percentile estimate, is recommended.

Bimodality is apparent in this data set; however, the final data could be fit to a Burr Type III distribution, so the data set was not split in order to use as much data as possible in criteria derivation.

Although greater than additive effects have been observed for mixtures of pyrethroids and diazinon, there is insufficient data to account for this interaction for compliance determination. This is a significant limitation because formulations that contain both pyrethroids and diazinon are now available on the market. When additional highly rated data is available, the criteria should be recalculated to incorporate new research.

18. Comparison to national standard methods

This section is provided as a comparison between the UC-Davis methodology for criteria calculation (TenBrook *et al.* 2009a) and the current USEPA (1985) national standard. The following example diazinon criteria were generated using the USEPA (1985) methodology with the data set generated in this diazinon criteria report.

The USEPA acute methods have three additional taxa requirements beyond the five required by the SSD procedure of the UC-Davis methodology (section 3-3.1, TenBrook *et al.* 2009a). They are:

1. A third family in the phylum Chordata (e.g., fish, amphibian);
2. A family in a phylum other than Arthropoda or Chordata (e.g., Rotifera, Annelida, Mollusca);
3. A family in any order of insect or any phylum not already represented.

All three of these additional requirements are met as follows:

1. The other fish/amphibian requirement is met because there is data for three warmwater fish: *Jordanella floridae, Lepomis macrochirus,* and *Pimephales promelas.*
2. This requirement is met with data from *Physa* spp. or *Pomacea paludosa,* which are mollusks.
3. This requirement is met because *Chironomus tentans* and *Procloeon* spp. are insects from different orders.

Using the log-triangular calculation (following the USEPA 1985 guidelines) and the diazinon data set from Table 3, containing thirteen SMAVs, the following acute criterion was calculated (Note: USEPA methodology uses *genus* mean acute values, while *species* mean acute values are used in this methodology and are reported in Table 3. Since there is only one species from each genus in Table 3, this final data set would be the same in both schemes.):

Example Final Acute Value (5th percentile value) = 0.17 μg/L

Example Acute Criterion = final acute value ÷ 2
= 0.1662 μg/L ÷ 2 = 0.08310 μg/L
= 0.083 μg/L

According to the USEPA (1985) method, the criterion is rounded to two significant digits. This example acute criterion calculation is demonstrated in more detail in Appendix B. The example acute criterion is lower than the acute criterion calculated by the UCD methodology (0.2 μg/L) by approximately a factor of 2.

For the chronic criterion, the diazinon data set only has data from four species, which are not enough for use in a species sensitivity distribution by either method. The USEPA (1985) methodology contains a similar ACR procedure as the UC-Davis methodology, to be used when three acceptable ACRs are available. The same three ACR values calculated for this methodology (Table 7) were calculated according to the USEPA (1985) methodology to give a final ACR of 2.3. The chronic criterion is calculated by dividing the final acute value by the final ACR:

Example Chronic Criterion = final acute value ÷ final ACR
= 0.1662 μg/L ÷ 2.3 = 0.07226 μg/L
= 0.072 μg/L

The example chronic criterion is very similar to the one recommended by the UC-Davis methodology.

19. Final criteria statement

The final criteria statement is:

Aquatic life in the Sacramento River and San Joaquin River basins should not be affected unacceptably if the four-day average concentration of diazinon does not exceed 0.07 μg/L (70 ng/L) more than once every three years on the average and if the one-hour average concentration does not exceed 0.2 μg/L (200 ng/L) more than once every three years on the average.

Although the criteria were derived to be protective of aquatic life in the Sacramento and San Joaquin Rivers, these criteria would be appropriate for any freshwater ecosystem in North America, unless species more sensitive than are represented by the species examined in the development of these criteria are likely to occur in those ecosystems.

The final acute criterion was derived using the Burr Type III SSD procedure (section 7). The chronic criterion was derived by use of an ACR (section 8), and after reviewing the supplemental data set, a lower value was recommended (section 12 and 17) based on the calculation with the lower 95% confidence limit estimate (sections 7 and 8).

This acute criterion is slightly higher than the USEPA diazinon acute criterion of 170 ng/L (USEPA 2005); however, the difference is mostly due to rounding. The chronic value is lower than the EPA diazinon chronic freshwater criteria of 170 ng/L (USEPA 2005). The derived criteria are similar to the current acute and chronic water quality objectives of 160 and 100 ng/L, respectively, for the lower San Joaquin River (CVRWQCB 2005), which are identical to those proposed for the Sacramento and San Joaquin River Basins (CVRWQCB 2006b). The derived criteria are both higher than acute and chronic criteria of 80 and 50 ng/L, respectively, for waterways in Sacramento County (CVRWQCB 2004). These objectives are based on criteria derived by the CDFG using the USEPA (1985) methodology (Siepmann & Finlayson 2000), but with a different data set than that used by USEPA (2005).

The criteria from the different agencies are very similar overall. A detailed comparison of the diazinon criteria reports of USEPA, CDFG and this one is included in Appendix B. The small differences seem to be due to both the method used to construct the SSD and the data set used. The data that was used to calculate the acute criterion in this report were put through the USEPA log triangular calculation (USEPA 1985), as discussed in section 18, which resulted in a criterion maximum concentration (analogous to an acute criterion) of 0.083 μg/L. Fitting a Burr Type III distribution to the USEPA data set using the BurrliOZ program yielded an estimate of 0 for the 5^{th} percentile value with 50% confidence limits. This is likely due to the bimodal distribution, which is more apparent in the USEPA data set (see Appendix B, Figure B-1). Using only the eight most sensitive genus mean acute values, a 5^{th} percentile value of 0.41 μg/L was obtained, which yields an acute criterion of 0.21 μg/L. This value is similar to the acute criterion in this report.

To calculate the chronic criterion, all three reports used the same method, an ACR, and fairly similar results were obtained. The analysis done for this report yielded a chronic criterion of 0.2 μg/L, which is similar to EPA's value of 0.17 μg/L. However, in light of other information, a final chronic criterion of 0.07 μg/L was recommended. The difference between the CDFG and the EPA chronic criteria is primarily due to the use of an ACR of 3 versus 2, respectively. Table B-5 (Appendix B), lists the data that was used and the reasons agencies omitted certain studies or values in calculating the ACR.

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Data Tables

Table 3. Final acute toxicity data set for diazinon. All studies were rated relevant and reliable (RR) and were conducted at standard temperature. Values in bold are species mean acute values. S: static; SR: static renewal; FT: flow-through.

Species	Common identifier	Family	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC_{50} (µg/L)	Reference
Ceriodaphnia dubia	Cladoceran	Daphniidae	SR	Meas	87.3%	96 h	24.7	Mortality	< 24 h	0.436 (0.342-0.504)	CDFG 1998a
Ceriodaphnia dubia	Cladoceran	Daphniidae	SR	Meas	88.0%	96 h	24.4	Mortality	< 24 h	0.47	CDFG 1992b
Ceriodaphnia dubia	Cladoceran	Daphniidae	SR	Meas	88.0%	96 h	24.4	Mortality	< 24 h	0.507 (0.42-0.71)	CDFG 1992a
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Meas	99.0%	96 h	25	Mortality	< 24 h	Test 1: 0.32 (0.27-0.38) Test 2: 0.35 (0.32-0.38)	Bailey et al. 1997
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Meas	99.0%	48 h	25	Mortality	< 24 h	Test 3: 0.26 (0.21-0.32) Test 4: 0.29 (0.19-0.46)	Bailey et al. 1997
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Meas	Analytical	48 h	25	Mortality	< 24 h	0.33	Bailey et al. 2000
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Meas	99.0%	48 h	25	Mortality	< 24 h	Test 1: 0.38 Test 2: 0.33	Bailey et al. 2001
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Meas	99.8%	48 h	25	Mortality	< 24 h	0.21	Banks et al. 2005
Geomean										**0.34**	
Chironomus dilutus (formerly *tentans*)	Insect	Chironomidae	S	Nom	95.0%	96 h	23	Mortality/ Immobility	3rd instar	**10.7** (7.55-15.2)	Ankley & Collyard 1995

Species	Common identifier	Family	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC_{50} (µg/L)	Reference
Daphnia magna	Cladoceran	Daphniidae	FT	Meas	87.7%	96 h	20	Mortality/ Immobility	< 24 h	**0.52** (0.32-0.83)	Surprenant 1988a
Gammarus pseudolimnaeus	Amphipod	Gammaridae	SR	Meas	100.0%	96 h	18	Mortality	Mature	**16.82** (12.82-22.08)	Hall & Anderson 2005
Hyalella azteca	Amphipod	Hyalellidae	S	Meas	98.0%	96 h	20	Mortality	14-21 d	**4.3** (3.7-5.6)	Anderson & Lydy 2002
Jordanella floridae	Flagfish	Cyprinodontidae	FT	Meas	92.5%	96 h	25	Mortality	6-7 wk	Test 1: 1500 (1200-1900) Test 2: 1800 (1600-2000)	Allison & Hermanutz 1977
Geomean										**1643**	
Lepomis macrochirus	Bluegill	Centrarchidae	FT	Meas	92.5%	96 h	25	Mortality	1 yr	Test 1: 480 (340-670) Test 2: 440 (310-620)	Allison & Hermanutz 1977
Geomean										**460**	
Neomysis mercedis	Mysid	Mysidae	SR	Meas	88.0%	96 h	17	Mortality	< 5 d	3.57 (2.99-4.36)	CDFG 1992c
Neomysis mercedis	Mysid	Mysidae	SR	Meas	88.0%	96 h	17.5	Mortality	< 5 d	4.82 (3.95-6.00)	CDFG 1992d
Geomean										**4.15**	
Physa spp	Pond snail	Physidae	SR	Meas	87.0%	96 h	21.6	Mortality	Juvenile	**4441**	CDFG 1998b
Pimephales promelas	Fathead minnow	Cyprinidae	FT	Meas	92.5%	96 h	25	Mortality	15-20 wk	Test 1:6800 Test 2:6600 Test 3: 10,000	Allison & Hermanutz 1977

Species	Common identifier	Family	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC_{50} (µg/L)	Reference
Pimephales promelas	Fathead minnow	Cyprinidae	FT	Meas	87.1%	96 h	24.5	Mortality	31 d	9350 (8120-10800)	Geiger et al. 1988
Pimephales promelas	Fathead minnow	Cyprinidae	FT	Meas	87.1%	96 h	23.5-26	Mortality	Newly hatched	6900 (6200-7900)	Jarvinen & Tanner 1982
Geomean										**7804**	
Pomacea paludosa	Snail	Ampullariidae	FT	Meas	87.0%	96 h	26-27.4	Mortality	1d, 7 d	Test 1: 2950 Test 2: 3270 Test 3: 3390	Call 1993
Geomean										**3198**	
Procloeon sp.	Insect	Baetidae	SR	Meas	99.0%	48 h	22.1	Mortality	0.5-1 cm	Test 1: 1.53 Test 2: 2.11 Test 3: 1.77	Anderson et al. 2006
Geomean										**1.79**	
Salvelinus fontinalis	Brook trout	Salmonidae	FT	Meas	92.5%	96 h	12	Mortality	1 yr	Test 1: 800 (440-1140) Test 2: 450 (320-630) Test 3: 1050 (720-1520)	Allison & Hermanutz 1977
Geomean										**723**	

Table 4. Acceptable acute data excluded in data reduction process. S: static; SR: static renewal; FT: flow-through.

Species	Common identifier	Family	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC_{50} (µg/L)	Reference	Reason for exclusion
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Nom	99.8%	48 h	25	Mortality	< 24 h	0.45	Banks et al. 2003	1
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Meas	99.0%	24 h	25	Mortality	< 24 h	Test 1: 0.58 (0.54-0.63) Test 2: 0.75 (0.69-0.80) Test 3: 0.37 (0.29-0.42) Test 4: 0.65 (0.46-0.92)	Bailey et al. 1997	4
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Meas	99.0%	48 h	25	Mortality	< 24 h	Test 1: 0.58 (0.54-0.63) Test 2: 0.48 (0.41-0.56)	Bailey et al. 1997	4
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Meas	99.0%	72 h	25	Mortality	< 24 h	Test 1: 0.35 (0.29-0.42) Test 2: 0.40 (0.36-0.44)	Bailey et al. 1997	4
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Meas	99.0%	24 h	25	Mortality	< 24 h	Test 1: 0.46 Test 2: 0.57	Bailey et al. 2001	4
Chironomus dilutus (formerly *tentans*)	Insect	Chironomidae	S	Meas	98.0%	96 h	20	Mortality/ Immobility	4th instar	30 (24-36)	Belden & Lydy 2000	2

Chironomus dilutus (formerly *tentans*)	Insect	Chironomidae	S	Meas	99.5%	96 h	21	Mortality/ Immobility	4th instar	19.1 (13.6-24.1)	Lydy & Austin 2004	2
Daphnia magna	Cladoceran	Daphniidae	FT	Meas	87.7%	48 h	20	Mortality/ Immobility	< 24 h	0.78 (0.32-∞)	Surprenant 1988a	4
Gammarus pseudolimnaeus	Amphipod	Gammaridae	SR	Meas	100.0%	48 h	18	Mortality	Mature	27.29 (22.45-33.18)	Hall & Anderson 2005	4
Gammarus pseudolimnaeus	Amphipod	Gammaridae	SR	Meas	100.0%	72 h	18	Mortality	Mature	20.21 (15.79-25.87)	Hall & Anderson 2005	4
Pimephales promelas	Fathead minnow	Cyprinidae	SR	Meas	99.4%	96 h	20	Mortality	7 d	Test 1: 6393 Test 2: 5048 Test 3: 7969	Denton et al. 2003	3
Pimephales promelas	Fathead minnow	Cyprinidae	S	Meas	87.1%	96 h	23.5-26	Mortality	Newly hatched	2100 (1700-2900)	Jarvinen & Tanner 1982	3
Pimephales promelas	Fathead minnow	Cyprinidae	S	Meas	87.1%	96 h	23.5-26	Mortality	Newly hatched	4300 (3400-5200)	Jarvinen & Tanner 1982	3

Reasons for exclusion
1. Test with measured concentrations available
2. More sensitive lifestage available
3. Flow-through test available
4. Later exposure duration available for same test

Table 5. Final chronic toxicity data set for diazinon. All studies were rated relevant and reliable (RR). Values in bold are species mean chronic values. S: static; SR: static renewal; FT: flow-through.

Species	Common identifier	Test type	Meas/ Nom	Chemical	Duration	Temp (°C)	Endpoint	Age/size	NOEC (μg/L)	LOEC (μg/L)	MATC (μg/L)	Reference
Daphnia magna	Cladoceran	FT	Meas	87.7%	21 d	20	Mortality/ immobility	< 24 h	0.17	0.32	**0.23**	Surprenant 1988a
Pimephales promelas	Fathead minnow	FT	Meas	92.5%	274 d	25	Mortality	5-d	28	60.3	41	Allison & Hermanutz 1977
Pimephales promelas	Fathead minnow	FT	Meas	87.1%	32 d	23.5-26.0	Weight	Newly hatched	50	90	67	Jarvinen & Tanner 1982
Geomean											**54**	
Salvelinus fontinalis	Brook trout	FT	Meas	92.5%	173 d	± 1°C; variable acc. to date	Mortality	1 yr	4.8	9.6	**6.8**	Allison & Hermanutz 1977
Selenastrum capricornutum	Green algae	S	Meas	87.7%	7 d	24	Mean standing crop, cells/mL	6-8 d old culture	-----	-----	**EC_{50} 6,400**	Hughes 1988
Selenastrum capricornutum	Green algae	S	Meas	87.7%	7 d	24	Mean standing crop, cells/mL	6-8 d old culture	-----	-----	**EC_{25} 4,250**	Hughes 1988

Table 6. Acceptable chronic data excluded in data reduction process. S: static; SR: static renewal; FT: flow-through.

Species	Common identifier	Test type	Meas/ Nom	Chemical	Duration	Temp (°C)	Endpoint	Age/size	NOEC (µg/L)	LOEC (µg/L)	MATC (µg/L)	Reference	Reason for exclusion
Pimephales promelas	Fathead minnow	FT	Meas	87.1%	32 d	23.5-26.0	Mortality	Newly hatched	140	290	200	Jarvinen & Tanner 1982	1
Pimephales promelas	Fathead minnow	FT	Meas	87.7%	34 d	25	Length	Embryo	92	170	125	Surprenant 1988b	1
Salvelinus fontinalis	Brook trout	FT	Meas	92.5%	91 d	± 1°C; variable acc. to date	Mortality	1 yr	4.8	9.6	6.8	Allison & Hermanutz 1977	2

Reasons for exclusion

1. More sensitive endpoint available
2. Later exposure duration available for same test

Table 7. Calculation of the species mean acute-to-chronic ratios.

Species	Common identifier	Reference	LC_{50} (µg/L)	Chronic Endpoint	MATC (µg/L)	ACR (LC_{50}/MATC)	Species Mean ACR
Daphnia magna	Cladoceran	Surprenant 1988a	0.52	21-d Mortality/ immobility	0.23	2.3	**2.3**
Pimephales promelas	Fathead minnow	Allison & Hermanutz 1977	7800	274-d Mortality	41	190	
Pimephales promelas	Fathead minnow	Jarvinen & Tanner 1982	6900	32-d Weight	67	103	**140**
Salvelinus fontinalis	Brook trout	Allison & Hermanutz 1977	723	173-d Mortality	6.8	106	**106**

Table 8. Studies excluded from criteria derivation (rated RL, LR, or LL; L = less relevant or less reliable). S = static, SR = static renewal, FT = flow-through; NR = not reported

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC_{50} (µg/L)	MATC (µg/L)	Reference	Rating	Reason for rating
Anguilla anguilla	European eel	S	Nom	92.0%	96 h	20	Mortality	20-30 g	80	--------	Ferrando et al. 1991	LL	3,6
Various	Bacteria	S	Nom	Reagent	22 h	21	Dissolved oxygen depletion	NR	--------	--------	Bauer et al. 1981	LL	5,6
Brachionus calyciflorus	Rotifer	S	Nom	92.0%	24 h	25	Mortality	Newly hatched	29,220 (28470-29960)	--------	Fernández-Casalderrey et al. 1992a	RL	6
Brachionus calyciflorus	Rotifer	SR	Nom	92.0%	10-11 d	25	Net reproductive rate	Neonates	5,200	--------	Fernández-Casalderrey et al. 1992b	RL	6
Brachionus calyciflorus	Rotifer	SR	Nom	92.0%	10-11 d	25	Generation time	Neonates	8,490	--------	Fernández-Casalderrey et al. 1992b	RL	6
Brachionus calyciflorus	Rotifer	SR	Nom	92.0%	10-11 d	25	Life expectancy	Neonates	12,330	--------	Fernández-Casalderrey et al. 1992b	RL	6
Brachionus calyciflorus	Rotifer	S	Nom	96.0%	5 hr	NR	Filtration rate	Neonates	14,390	9,900	Fernández-Casalderrey et al. 1992c	RL	2,6
Brachionus calyciflorus	Rotifer	S	Nom	96.0%	5 hr	NR	Ingestion rate	Neonates	14,220	9,900	Fernández-Casalderrey et al. 1992c	RL	2,6
Brachionus calyciflorus	Rotifer	S	Nom	NR	48 h	25	Intrinsic rate of increase	< 2 h	11,000	10,000	Snell & Moffat 1992	LL	1,6

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC_{50} (µg/L)	MATC (µg/L)	Reference	Rating	Reason for rating
Brachydanio rerio	Zebrafish	FT	Meas	Analytical	42 d	26	Mortality	Embryos	--------	--------	Bresch 1991	LR	5
Carassius auratus	Goldfish	------	------	Technical	48 h	------	Mortality	------	5,100	--------	Nishiuki & Hashimoto 1967	LL	6
Carassius auratus	Goldfish	S	Nom	91%	96 h	11-17	Mortality	2.5-6 cm	9000	--------	Beliles 1965	RL	6
Caridina laevis	Shrimp	S	Nom	60%	24 h	26-27	Mortality	Juvenile 8-10mm	0.76 (0.67-0.87)	--------	Sucahyo et al. 2008	LR	1
Caridina laevis	Shrimp	S	Nom	60%	96 h	26-27	Mortality	Juvenile 8-10mm	0.59 (0.51-0.69)	--------	Sucahyo et al. 2008	LR	1
Ceriodaphnia dubia	Cladoceran	SR	Nom	99.0%	3 broods	25	Biomass	< 24 h	--------	--------	Dwyer et al. 2005	LL	5,6
Ceriodaphnia dubia	Cladoceran	S	Nom	85.0%	48 h	25	Mortality	< 24 h	0.57 (0.47-0.70)	--------	Norberg King 1987	LL	6
Ceriodaphnia dubia	Cladoceran	S	Nom	85.0%	48 h	25	Mortality	< 24 h	0.66 (0.58-0.75)	--------	Norberg King 1987	LL	6
Ceriodaphnia dubia	Cladoceran	S	Nom	85.0%	48 h	25	Mortality	< 24 h	0.57 (0.47-0.70)	--------	Norberg King 1987	LL	6

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (^oC)	Endpoint	Age/size	LC/EC_{50} (µg/L)	MATC (µg/L)	Reference	Rating	Reason for rating
Ceriodaphnia dubia	Cladoceran	S	Nom	85.0%	48 h	25	Mortality	< 48 h	0.35 (0.31-0.45)	--------	Norberg King 1987	LL	6
Ceriodaphnia dubia	Cladoceran	S	Nom	85.0%	48 h	25	Mortality	< 48 h	0.35	--------	Norberg King 1987	LL	6
Ceriodaphnia dubia	Cladoceran	S	Nom	85.0%	48 h	25	Mortality	< 6 h	0.25 (0.22-0.29)	--------	Norberg King 1987	LL	6
Ceriodaphnia dubia	Cladoceran	S	Nom	85.0%	48 h	25	Mortality	< 24 h	0.33 (0.29-0.38)	--------	Norberg King 1987	LL	6
Ceriodaphnia dubia	Cladoceran	S	Nom	85.0%	48 h	25	Mortality	< 48 h	0.35	--------	Norberg King 1987	LL	6
Ceriodaphnia dubia	Cladoceran	S	Nom	85.0%	48 h	25	Mortality	< 48 h	0.59	--------	Norberg King 1987	LL	6
Ceriodaphnia dubia	Cladoceran	S	Nom	85.0%	48 h	25	Mortality	< 48 h	0.43 (0.36-0.51)	--------	Norberg King 1987	LL	6
Ceriodaphnia dubia	Cladoceran	S	Nom	85.0%	48 h	25	Mortality	< 48 h	0.35	--------	Norberg King 1987	LL	6
Ceriodaphnia dubia	Cladoceran	S	Nom	85.0%	48 h	25	Mortality	< 24 h	0.36	--------	Norberg King 1987	LL	6
Ceriodaphnia dubia	Cladoceran	SR	Meas	85.0%	48 h	25	Mortality	< 6 h	0.66	--------	Norberg King 1987	LL	6

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC_{50} (µg/L)	MATC (µg/L)	Reference	Rating	Reason for rating
Ceriodaphnia dubia	Cladoceran	SR	Meas	85.0%	7 d	25	Survival, Number of young/ female	< 6 h	--------	0.34	Norberg King 1987	LL	6
Chironomus riparius	Insect	S	Nom	97%	24 h	11	Immobility	4th instar	64.9	--------	Landrum et al 1999	LL	4,6
Chironomus riparius	Insect	S	Nom	97%	24 h	18	Immobility	4th instar	24.4	--------	Landrum et al 1999	LL	4,6
Chironomus riparius	Insect	S	Nom	97%	24 h	25	Immobility	4th instar	11.6	--------	Landrum et al 1999	LL	4,6
Chironomus riparius	Insect	S	Meas	99.7%	48 h	20	Mortality	1st instar	32 (30.0-34.1)	--------	Stuijfzand et al. 2000	RL	6
Chironomus riparius	Insect	S	Meas	99.7%	96 h	20	Mortality	1st instar	22.8 (19.7-26.3)	--------	Stuijfzand et al. 2000	RL	6
Chironomus riparius	Insect	S	Meas	99.7%	48 h	20	Activity	1st instar	22.6 (4.8-105.8)	--------	Stuijfzand et al. 2000	RL	2,6
Chironomus riparius	Insect	S	Meas	99.7%	48 h	20	Growth	1st instar	35.2 (32.2-38.5)	--------	Stuijfzand et al. 2000	RL	6
Chironomus riparius	Insect	S	Meas	99.7%	96 h	20	Growth	1st instar	57.3 (31.7-103.7)	--------	Stuijfzand et al. 2000	RL	6
Chironomus riparius	Insect	S	Meas	99.7%	48 h	20	Mortality	4th instar	> 268	--------	Stuijfzand et al. 2000	RL	5,6

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC$_{50}$ (µg/L)	MATC (µg/L)	Reference	Rating	Reason for rating
Chironomus riparius	Insect	S	Meas	99.7%	96 h	20	Mortality	4th instar	167	--------	Stuijfzand et al. 2000	RL	6
Chironomus riparius	Insect	S	Meas	99.7%	48 h	20	Activity	4th instar	19.9	--------	Stuijfzand et al. 2000	RL	2.6
Chironomus riparius	Insect	S	Meas	99.7%	96 h	20	Activity	4th instar	17.9	--------	Stuijfzand et al. 2000	RL	2,6
Chironomus tentans	Insect	S	Nom	99.5%	96 h	21	Normal swimming motion	4th instar	31.3 (25.7-37.3)	--------	Schuler et al. 2005	LL	4,6
Chironomus tepperi	Insect	S	Nom	800g/L	24 h	25	Mortality	4th instar	35.5	--------	Stevens 1992	LL	4,6
Cyprinella monacha	Spotfin chub	SR	Nom	99.0%	7 d	25	Biomass	< 24 h	IC25: 4,115 (2281-5654)	--------	Dwyer et al. 2005	RL	6
Cyprinus carpio	Carp	SR	Nom	35.0%	96 h	25	Mortality	Juvenile	Test 1: 4974.5 Test 2: 3426.8	--------	Alam & Maughan 1992	LL	1,6
Cyprinus carpio	Carp	SR	Nom	63.0%	24 h	24	Mortality	Embryos	999 (698-1427)	--------	Aydin & Köprücü 2005	LL	1,6
Cyprinus carpio	Carp	SR	Nom	63.0%	24 h	24	Mortality	Larvae	3688 (2464-8495)	--------	Aydin & Köprücü 2005	LL	1,6

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC50 (µg/L)	MATC (µg/L)	Reference	Rating	Reason for rating
Cyprinus carpio	Carp	SR	Nom	63.0%	48 h	24	Mortality	Larvae	2903 (2019-5433)	--------	Aydin & Köprücü 2005	LL	1,6
Cyprinus carpio	Carp	SR	Nom	63.0%	72 h	24	Mortality	Larvae	2358 (1672-4005)	--------	Aydin & Köprücü 2005	LL	1,6
Cyprinus carpio	Carp	SR	Nom	63.0%	96 h	24	Mortality	Larvae	1530 (1009-3948)	--------	Aydin & Köprücü 2005	LL	1,6
Cyprinus carpio	Carp	------	------	Technical	48 h	------	Mortality	------	3200	--------	Nishiuki & Hashimoto 1967	LL	3,6
Cyrnus trimaculatus	Insect	S	Meas	99.7%	96 h	20	Mortality	2nd instar	1.1 (0.7-1.7)	--------	Van Der Geest et al. 2000b	LL	3,6
Danio rerio	Zebrafish	SR	Nom	NR	96 h	26, 28, 30, 33.5	Mortality, Heart Rate, Hatching Success	Eggs	--------	--------	Osterauer & Koehler 2008	LL	1,5
Daphnia magna	Cladoceran	S	Nom	95-99%	48 h	25	Mortality	< 48 h	0.8	--------	Ankley et al. 1991	RL	6
Daphnia magna	Cladoceran	SR	Nom	99.0%	21 d	17-19	Mortality/ Immobility	< 24 h	--------	0.24	Dortland 1980	RL	6
Daphnia magna	Cladoceran	SR	Nom	99.0%	21 d	17-19	Reproduction	< 24 h	--------	0.24	Dortland 1980	RL	6
Daphnia magna	Cladoceran	S	Nom	92.0%	24 h	22	Mortality	< 24 h	0.86	--------	Fernández-Casalderrey et al. 1995	RL	6

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC$_{50}$ (µg/L)	MATC (µg/L)	Reference	Rating	Reason for rating
Daphnia magna	Cladoceran	SR	Nom	92.0%	21 d	22	Longevity	< 24 h	--------	0.16	Fernández-Casalderrey et al. 1995	RL	6
Daphnia magna	Cladoceran	SR	Nom	92.0%	21 d	22	Mean number of broods	< 24 h	--------	0.16	Fernández-Casalderrey et al. 1995	RL	6
Daphnia magna	Cladoceran	SR	Nom	92.0%	21 d	22	Mean days to reproduction	< 24 h	--------	0.24	Fernández-Casalderrey et al. 1995	RL	6
Daphnia magna	Cladoceran	S	Nom	Analytical	48 h	21	Immobility	< 24 h	0.87 (0.74-1.0)	--------	Kikuchi et al. 2000	RL	6
Daphnia magna	Cladoceran	SR	Nom	96.1%	7 d	22	Mortality	< 24 h	--------	0.22	Sánchez et al. 1998	RL	6
Daphnia magna	Cladoceran	SR	Nom	96.1%	21 d	22	Young per adult	< 24 h	--------	0.07	Sánchez et al. 1998	RL	6
Daphnia magna	Cladoceran	SR	Nom	96.1%	21 d	22	Brood size	< 24 h	--------	0.07	Sánchez et al. 1998	RL	6
Daphnia magna	Cladoceran	SR	Nom	96.1%	21 d	22	Broods per adult	< 24 h	--------	0.07	Sánchez et al. 1998	RL	6
Daphnia magna	Cladoceran	SR	Meas	96.1%	21 d	22	Longevity, F_0 generation	< 24 h	0.67	--------	Sánchez et al. 2000	RL	6
Daphnia magna	Cladoceran	SR	Meas	96.1%	21 d	22	Young per female, F_0 generation	< 24 h	0.35	--------	Sánchez et al. 2000	RL	6

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC_{50} (µg/L)	MATC (µg/L)	Reference	Rating	Reason for rating
Daphnia magna	Cladoceran	SR	Meas	96.1%	21 d	22	Brood size, F_0 generation	< 24 h	0.47	0.07	Sánchez et al. 2000	RL	6
Daphnia magna	Cladoceran	SR	Meas	96.1%	21 d	22	Broods per female, F_0 generation	< 24 h	0.43	0.07	Sánchez et al. 2000	RL	6
Daphnia magna	Cladoceran	SR	Meas	96.1%	21 d	22	Intrinsic rate of increase, F_0 generation	< 24 h	0.72	0.61	Sánchez et al. 2000	RL	6
Daphnia magna	Cladoceran	SR	Meas	96.1%	21 d	22	Longevity, first brood, F_1 generation	< 24 h	0.41	--------	Sánchez et al. 2000	RL	6
Daphnia magna	Cladoceran	SR	Meas	96.1%	21 d	22	Young per female, first brood, F_1 generation	< 24 h	0.20	--------	Sánchez et al. 2000	RL	6
Daphnia magna	Cladoceran	SR	Meas	96.1%	21 d	22	Brood size, first brood, F_1 generation	< 24 h	0.29	0.07	Sánchez et al. 2000	RL	6
Daphnia magna	Cladoceran	SR	Meas	96.1%	21 d	22	Broods per female, first brood, F_1 generation	< 24 h	0.29	--------	Sánchez et al. 2000	RL	6
Daphnia magna	Cladoceran	SR	Meas	96.1%	21 d	22	Intrinsic rate of increase, first brood, F_1 generation	< 24 h	0.44	0.61	Sánchez et al. 2000	RL	6

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC$_{50}$ (µg/L)	MATC (µg/L)	Reference	Rating	Reason for rating
Daphnia magna	Cladoceran	SR	Meas	96.1%	21 d	22	Longevity, third brood, F_1 generation	< 24 h	0.35	0.07	Sánchez et al. 2000	RL	6
Daphnia magna	Cladoceran	SR	Meas	96.1%	21 d	22	Young per female, third brood, F_1 generation	< 24 h	0.22	0.07	Sánchez et al. 2000	RL	6
Daphnia magna	Cladoceran	SR	Meas	96.1%	21 d	22	Time to first brood, third brood, F_1 generation	< 24 h	-----	0.07	Sánchez et al. 2000	RL	6
Daphnia magna	Cladoceran	SR	Meas	96.1%	21 d	22	Brood size, third brood, F_1 generation	< 24 h	0.27	0.07	Sánchez et al. 2000	RL	6
Daphnia magna	Cladoceran	SR	Meas	96.1%	21 d	22	Broods per female, third brood, F_1 generation	< 24 h	0.25	0.07	Sánchez et al. 2000	RL	6
Daphnia magna	Cladoceran	SR	Meas	96.1%	21 d	22	Intrinsic rate of increase, third brood, F_1 generation	< 24 h	0.47	0.07	Sánchez et al. 2000	RL	6
Daphnia magna	Cladoceran	S	Nom	Technical	48 h	17	Mortality	< 20 h	0.96 (0.83-1.10)	--------	Vilkas 1976	LL	4,6
Daphnia pulex	Cladoceran	S	Nom	Technical	48 h	15	Immobility	1st instar	0.8 (0.6-1.1)	--------	Johnson & Finley 1980	LL	4,6

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC_{50} (µg/L)	MATC (µg/L)	Reference	Rating	Reason for rating
Daphnia pulex	Cladoceran	------	------	Technical	3 h	------	Mortality	------	7.8	--------	Nishiuki & Hashimoto 1967	LL	6
Ephoron virgo	Insect	S	Meas	99.7%	96 h	20	Mortality	2-d larvae	11.8 (3.0-9.0)	--------	Van Der Geest et al. 2000a	LL	3,6
Ephoron virgo	Insect	S	Meas	99.7%	96 h	20	Mortality	0-2 d larvae	6.9 (4.7-10.1)	--------	Van Der Geest et al. 2000b	LR	3
Ephoron virgo	Insect	S	Meas	99.7%	72 h	20	Mortality	0-2 d larvae	4.7 (1.0-13.3)	--------	Van Der Geest et al. 2002	LR	3
Ephoron virgo	Insect	S	Meas	99.7%	96 h	20	Mortality	0-2 d larvae	1.1 (0.5-2.3)	--------	Van Der Geest et al. 2002	LR	3
Gammarus fasciatus	Amphipod	S	Nom	Technical	96 h	21	Mortality	Mature	2.0	--------	Johnson & Finley 1980	LL	4,6
Gillia altilis	Mollusk	SR	Nom	88.6%	96 h	20.5-23.5	Mortality	NR	11,000	--------	Robertson & Mazzella 1989	LL	4,6
Hyalella azteca	Amphipod	S	Nom	95.0%	96 h	23	Mortality/ Immobility	7-14 d	6.51 (4.90-8.66)	--------	Ankley & Collyard 1995	LR	4
Hyalella azteca	Amphipod	S	Nom	NR	96 h	25	Mortality	0-2 d	6.2	--------	Collyard et al. 1994	LL	1,6
Hyalella azteca	Amphipod	S	Nom	NR	96 h	25	Mortality	2-4 d	4.2	--------	Collyard et al. 1994	LL	1,6

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC_{50} (µg/L)	MATC (µg/L)	Reference	Rating	Reason for rating
Hyalella azteca	Amphipod	S	Nom	NR	96 h	25	Mortality	6-8 d	4.2	--------	Collyard et al. 1994	LL	1,6
Hyalella azteca	Amphipod	S	Nom	NR	96 h	25	Mortality	8-10 d	4.5	--------	Collyard et al. 1994	LL	1,6
Hyalella azteca	Amphipod	S	Nom	NR	96 h	25	Mortality	12-14 d	3.8	--------	Collyard et al. 1994	LL	1,6
Hyalella azteca	Amphipod	S	Nom	NR	96 h	25	Mortality	16-18 d	4.5	--------	Collyard et al. 1994	LL	1,6
Hyalella azteca	Amphipod	S	Nom	NR	96 h	25	Mortality	20-22 d	4.8	--------	Collyard et al. 1994	LL	1,6
Hyalella azteca	Amphipod	S	Nom	NR	96 h	25	Mortality	24-26 d	4.8	--------	Collyard et al. 1994	LL	1,6
Hyalella azteca	Amphipod	S	Nom	NR	24 h	20	Increase in heat shock proteins	NR	--------	0.13	Werner & Nagel 1997	LL	1,2,6
Hydropsyche angustipennis	Insect	S	Meas	99.7%	48 h	20	Mortality	5th instar	242.8 (123.1-478.9)	--------	Stuijfzand et al. 2000b	LL	3,6
Hydropsyche angustipennis	Insect	S	Meas	99.7%	96 h	20	Mortality	5th instar	29.4 (16.9-51.0)	--------	Stuijfzand et al. 2000	LL	3,6
Hydropsyche angustipennis	Insect	S	Meas	99.7%	48 h	20	Mortality	1st instar	2.9 (2.2-13.9)	--------	Stuijfzand et al. 2000	LL	3,6

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC_{50} (µg/L)	MATC (µg/L)	Reference	Rating	Reason for rating
Hydropsyche angustipennis	Insect	S	Meas	99.7%	96 h	20	Mortality	1st instar	1.3 (1.2-1.5)	--------	Stuijfzand et al. 2000	LL	3,6
Hydropsyche angustipennis	Insect	S	Meas	99.7%	48 h	20	Mortality	1st instar	2.9 (2.2-3.9)	--------	Van Der Geest et al. 1999	LR	3
Hydropsyche angustipennis	Insect	S	Meas	99.7%	96 h	20	Mortality	1st instar	1.3 (1.2-1.5)	--------	Van Der Geest et al. 1999	LR	3
Hydropsyche angustipennis	Insect	S	Meas	99.7%	168 h	20	Mortality	1st instar	1.0 (0.8-1.1)	--------	Van Der Geest et al. 1999	LR	3
Lepomis macrochirus	Bluegill	S	Nom	92%	96 h	18	Mortality	1.0 g	168 (120-220)	--------	Johnson & Finley 1980	LL	4,6
Lepomis macrochirus	Bluegill	S	Nom	23%	96 h	21.8	Mortality	0.7 g	28,600 (21800-37400)	--------	Pennwalt Corp. 1978	LL	1,4
Lepomis macrochirus	Bluegill	S	Meas	48%	96 h	21-22	Mortality	40 mm; 0.75 g	210 (160-290)	--------	Surprenant 1987	LR	1
Lestes congener	Insect	S	Nom	94%	96 h	25	Mortality	Late instar nymphs	50	--------	Federle & Collins 1976	RL	6
Lumbriculus variegatus	Oligochaete	S	Nom	95%	96 h	23	Mortality/ Immobility	Mixed ages	6160 (5170-7340)	--------	Ankley & Collyard 1995	LL	4,6
Moina macrocopa	Cladoceran	------	------	Technical	3 h	------	Mortality	------	26	--------	Nishiuki & Hashimoto 1967	LL	6

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC_{50} (µg/L)	MATC (µg/L)	Reference	Rating	Reason for rating
Moina macrocopa	Cladoceran	SR	Nom	60.0%	11-12 d	26	Survivorship	< 24 h	--------	0.32	Wong 1997	LL	1,6
Notropis mekistocholas	Cape Fear shiner	SR	Nom	99.0%	7 d	25	Biomass	< 24 h	IC25: 199 (57-1269)	--------	Dwyer et al. 2005	RL	6
Oncorhynchus clarki	Cutthroat trout	S	Nom	92.0%	96 h	12	Mortality	2.0 g	Test 1: 1,700 (1390-2090) Test 2: 2,760 (2280-3330)	--------	Johnson & Finley 1980	LL	4,6
Oncorhynchus mykiss	Rainbow trout	SR	Nom	98.0%	24 h	NR	Cholinesterase inhibition; muscarinic cholinergic receptor number	40 d	--------	--------	Beauvais et al. 2000	LL	2,5
Oncorhynchus mykiss	Rainbow trout	SR	Nom	98.0%	96 h	NR	Cholinesterase inhibition; muscarinic cholinergic receptor number	40 d	--------	--------	Beauvais et al. 2000	LL	2,5
Oncorhynchus mykiss	Rainbow trout	FT	Meas	Analytical	28 d	15-17	Weight	1-3 g	--------	--------	Bresch 1991	LR	5
Oncorhynchus mykiss	Rainbow trout	SR	Nom	98.0%	96 h	15	Swimming behavior	Juvenile	--------	--------	Brewer et al. 2001	LL	2,5,6

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC_{50} (µg/L)	MATC (µg/L)	Reference	Rating	Reason for rating
Oncorhynchus mykiss	Rainbow trout	SR	Nom	98.0%	96 h	15	Acetylcholin-esterase inhibition	Juvenile	--------	--------	Brewer et al. 2001	LL	2,5,6
Oncorhynchus mykiss	Rainbow trout	S	Nom	89.0%	96 h	13	Mortality	1.2 g	90	--------	Johnson & Finley 1980	LL	4,6
Oncorhynchus mykiss	Rainbow Trout	S	Nom	91%	96 h	13-18	Mortality	3-7 cm	400	--------	Beliles 1965	RL	6
Oncorhynchus mykiss	Rainbow Trout	S	Nom	99.8%	96 h	14	Mortality	6 cm, 1.5g	>100,000	--------	Grade 1993	LR	5
Oncorhynchus tshawytscha	Chinook salmon	SR	Nom	Technical	96 h	10	Mortality	Eyed eggs	545,000	--------	Viant et al. 2006	RL	6
Oncorhynchus tshawytscha	Chinook salmon	SR	Nom	Technical	96 h	10	Mortality	Alevins	29,500	--------	Viant et al. 2006	RL	6
Oncorhynchus tshawytscha	Chinook salmon	SR	Nom	Technical	96 h	10	Phospho-creatine levels	Eyed eggs	--------	70,700	Viant et al. 2006	RL	2,6
Oreochromis niloticus x Mossambicus albina	Red tilapia	SR	Nom	97.5%	24 h	22	Mortality	4.27 g	6000 (4980-30240)	--------	Palacio et al. 2002	LL	3,6
Oreochromis niloticus x Mossambicus albina	Red tilapia	SR	Nom	97.5%	48 h	22	Mortality	4.27 g	5650 (4660-13150)	--------	Palacio et al. 2002	LL	3,6

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC_{50} (µg/L)	MATC (µg/L)	Reference	Rating	Reason for rating
Oreochromis niloticus x Mossambicus albina	Red tilapia	SR	Nom	97.5%	72 h	22	Mortality	4.27 g	4360 (4090-4910)	--------	Palacio et al. 2002	LL	3,6
Oreochromis niloticus x Mossambicus albina	Red tilapia	SR	Nom	97.5%	96 h	22	Mortality	4.27 g	3850 (3660-4110)	--------	Palacio et al. 2002	LL	3,6
Oryzias latipes	Japanese medaka	S	Nom	99.0%	96 h	NR	Total hatch	1-d embryos	--------	19,300	Hamm & Hinton 2000	LL	3,6
Oryzias latipes	Japanese medaka	S	Nom	99.0%	96 h	NR	Total hatch	3-d embryos	--------	19,300	Hamm & Hinton 2000	LL	3,6
Oryzias latipes	Japanese medaka	S	Nom	99.0%	8 d	NR	Total hatch	1-d embryos	--------	14,900	Hamm & Hinton 2000	LL	3,6
Oryzias latipes	Japanese medaka	S	Nom	99.0%	6 d	NR	Total hatch	3-d embryos	--------	19,300	Hamm & Hinton 2000	LL	3,6
Oryzias latipes	Japanese medaka	S	Nom	99.0%	96 h	NR	Mean day of hatch	3-d embryos	--------	19,300	Hamm & Hinton 2000	LL	3,6
Oryzias latipes	Japanese medaka	S	Nom	99.0%	96 h	NR	Total length of larvae	1-d embryos	--------	2,200	Hamm & Hinton 2000	LL	3,6
Oryzias latipes	Japanese medaka	S	Nom	99.0%	96 h	NR	Total length of larvae	3-d embryos	--------	2,200	Hamm & Hinton 2000	LL	3,6

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC_{50} (µg/L)	MATC (µg/L)	Reference	Rating	Reason for rating
Oryzias latipes	Japanese medaka	S	Nom	99.0%	96 h	NR	Total length of larvae	5-d embryos	--------	2,200	Hamm & Hinton 2000	LL	3,6
Oryzias latipes	Japanese medaka	S	Nom	99.0%	8 d	NR	Total length of larvae	1-d embryos	--------	2,200	Hamm & Hinton 2000	LL	3,6
Oryzias latipes	Japanese medaka	S	Nom	99.0%	6 d	NR	Total length of larvae	3-d embryos	--------	2,200	Hamm & Hinton 2000	LL	3,6
Oryzias latipes	Japanese medaka	------	------	Technical	48 h	------	Mortality	------	5,300	--------	Nishiuki & Hashimoto 1967	LL	6
Pimephales promelas	Fathead minnow	SR	Nom	99.0%	7 d	25	Biomass	< 24 h	IC25: 1176 (413-2261)	--------	Dwyer et al. 2005	RL	6
Pimephales promelas	Fathead minnow	FT	Meas	88.2%	32 d	NR	Growth	< 24 h embryos	--------	25	Norberg-King 1989	RL	4,6
Pimephales promelas	Fathead minnow	SR	Meas	88.2%	7 d	NR	Growth	< 24 h larvae	--------	251	Norberg-King 1989	RL	4,6
Pimephales promelas	Fathead minnow	FT	Meas	88.2%	7 d	NR	Growth	< 24 h larvae	--------	210	Norberg-King 1989	RL	4,6
Pimephales promelas	Fathead minnow	FT	Meas	88.2%	7 d	NR	Growth	< 24 h larvae	--------	122	Norberg-King 1989	RL	46
Poecilia reticulata	Guppy	SR	Nom	98.0%	96 h	20-22	Mortality	Adult females	800	--------	Keizer et al. 1991	LL	4,6

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC$_{50}$ (µg/L)	MATC (µg/L)	Reference	Rating	Reason for rating
Pteronarcys californica	Insect	S	Nom	89.0%	96 h	15	Mortality	Second year class	25 (20-30)	--------	Johnson & Finley 1980	LL	4,6
Pteronarcys californica	Insect	S	Nom	Technical	24 h	15.5	Mortality	30-35 mm	155 (115-209)	--------	Sanders & Cope 1968	LL	4,6
Pteronarcys californica	Insect	S	Nom	Technical	48 h	15.5	Mortality	30-35 mm	60 (42-84)	--------	Sanders & Cope 1968	LL	4,6
Pteronarcys californica	Insect	S	Nom	Technical	96 h	15.5	Mortality	30-35 mm	25 (20-51)	--------	Sanders & Cope 1968	LL	4,6
Rana clamitans	Green frog	SR	Nom	Technical	16 d	18.1	Growth	Embryo	--------	1.6	Harris et al. 1998	LL	1,6
Salvelinus namaycush	Brook trout	S	Nom	92.0%	96 h	12	Mortality	3.2 g	602 (400-906)	--------	Johnson & Finley 1980	LL	4,6
Selenastrum capricornutum	Green algae	S	Meas	87.7%	7 d	24	Mean standing crop, cells/mL	6-8 d old culture	--------	NOEC < 60	Hughes 1988	LR	5
Silurus glanis	European catfish	S	Nom	63%	96 h	16	Mortality	12-14 g, 10-12 cm	4.14	--------	Koprucu et al. 2006	LR	1,3
Simocephalus serrulatus	Cladoceran	S	Nom	89.0%	48 h	15	Immobility	1st instar	Test 1: 1.4 (1.2-1.6) Test 2: 1.8 (1.4-2.2)	--------	Johnson & Finley 1980	LL	4,6

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC$_{50}$ (µg/L)	MATC (µg/L)	Reference	Rating	Reason for rating

Reasons for exclusion
1. Chemical grade
2. Endpoint not linked to population effects
3. Family not in N. America
4. Control response
5. No toxicity value calculated
6. Low reliability score

Table 9. Synergistic interactions between diazinon and other pesticides.

Species	Pesticide 1 (at EC_{50} concentration)	Synergist (concentration)	SR (K)[1]	Reference
Chironomus tentans	Diazinon	Cyanazine (200 µ/L)	2.2	Lydy & Austin 2004
Hyalella azteca	Diazinon	Atrazine (10 µ/L)	1.0	Anderson & Lydy 2002
Hyalella azteca	Diazinon	Atrazine (40 µ/L)	1.0	Anderson & Lydy 2002
Hyalella azteca	Diazinon	Atrazine (80 µ/L)	2.0	Anderson & Lydy 2002
Hyalella azteca	Diazinon	Atrazine (200 µ/L)	3.0	Anderson & Lydy 2002
Chironomus tentans	Diazinon	Atrazine (10 µ/L)	1.0	Belden & Lydy 2000
Chironomus tentans	Diazinon	Atrazine (40 µ/L)	1.81	Belden & Lydy 2000
Chironomus tentans	Diazinon	Atrazine (80 µ/L)	2.11	Belden & Lydy 2000
Chironomus tentans	Diazinon	Atrazine (200 µ/L))	2.71	Belden & Lydy 2000

[1] SR = synergistic ratio, which is equivalent to K = interaction coefficient; each is the ratio of the EC_{50} of the pesticide alone to the EC_{50} of the pesticide in the presence of a non-toxic concentration of the synergist.

Table 10. Predicted LC_{50} values for threatened or endangered species

Species	Common Name	Family	LC_{50} (µg/L)	Surrogate
Gila elegans	Bonytail chub	Cyprinidae	2408	*Pimephales promelas*
Ptychocheilus lucius	Colorado squawfish	Cyprinidae	2750	*Pimephales promelas*
Oncorhynchus clarki	Cutthroat trout	Salmonidae	1205	*Salvelinus fontinalis*
Oncorhynchus kisutch	Coho salmon	Salmonidae	1382	*Salvelinus fontinalis*
Oncorhynchus mykiss	Steelhead	Salmonidae	730	*Salvelinus fontinalis*

Appendix A

Ecosystem and Field Study Supplemental Information

Amato JR, Mount DI, Durhan EJ, Lukasewycz MT, Ankley GT, Robert ED. 1992. An example of the identification of diazinon as a primary toxicant in an effluent. *Environmental Toxicology and Chemistry* 11: 209-216.
A toxicity identification evaluation (TIE) was run by performing separate tests with *Pimephales promelas* and *Ceriodaphnia dubia* using municipal effluent. Diazinon concentrations of 0.21-1.31 µg/L (impact of contaminants in most about 0.35 µg/L) were measured via gas chromatography analysis and correlated well with the toxicity of each sample.

Anderson BS, Hunt JW, Phillips BM, Nicely PA, de Vlaming V, Connor V, Richard N, Tjeerdema RS. 2003. Integrated assessment of the impacts of agricultural drainwater in the Salinas River (California, USA). *Environmental Pollution* 124:523-532.
Impact of contaminants in agricultural drainwater were examined by measuring macroinvertebrate abundances in river bottoms, toxicity tests of river water to *Ceriodaphnia dubia,* and measured pesticide concentrations. Diazinon concentrations of 3.0-0.2 µg/L correlated to low macroinvertebrate abundance (not significant) and toxicity to *Ceriodaphnia dubia.*

Bailey HC, Deanovic L, Reyes E, Kimball T, Larson K, Cortright K, Connor V, Hinton DE. 2000. Diazinon and chlorpyrifos in urban waterways in Northern California, USA. *Environmental Toxicology and Chemistry* 19:82-87.
Concentrations of diazinon were measured using enzyme-linked immunosorbent assays (ELISA) in urban streams of Sacramento and Stockton, CA, in 1994 and 1995. Most samples were collected between October and May and associated with storm water runoff events. Diazinon concentrations ranged from below detection limit to 1.5 µg/L, with a median of 0.21 µg/L (n=230 samples). TIEs indicated diazinon and chlorpyrifos as major players in observed toxicity to *Ceriodaphnia dubia*.

Burkhard L, Jenson JJ. 1993. Identification of ammonia, chlorine, and diazinon as toxicants in a municipal effluent. *Archives of Environmental Contamination and Toxicology* 25:506-515.
A toxicity identification evaluation (TIE) was run by performing separate tests with *Pimephales promelas* and *Ceriodaphnia dubia* using municipal effluent over an 8-month period. Ammonia, chlorine and diazinon were identified as the primary cause of toxicity. Toxicity occurred when the diazinon concentrations were 0.054 - 1.68 µg/L.

De Vlaming V, DiGiorgio C, Fong S, Deanovic LA, de la Paz Carpio-Obeso M, Miller JL, Miller MJ, Richard NJ. 2004. Irrigation runoff insecticide pollution of rivers in the Imperial Valley, California (USA). *Environmental Pollution* 132:213-229.
Studies on water quality of the Alamo River and New River conducted between 1993 and 2002 revealed widespread toxicity due to the OP pesticides chlorpyrifos and diazinon from agricultural applications. Diazinon was detected at 0.1-2.8 toxic units (1 toxic unit = 0.4 µg/L) in the Alamo River, and was present in every toxic sample from the New River.

Hunt JW, Anderson BS, Phillips BM, Nicely PN, Tjeerdema RS, Puckett HM, Stephenson M, Worcester K, de Vlaming V. 2003. Ambient Toxicity due to chlorpyrifos and diazinon in a Central California coastal watershed. *Environmental Monitoring and Assessment* 82:83-112.
In all samples where diazinon was detected there was no survival of *Ceriodaphnia dubia*. The highest concentration of diazinon was 5.2 µg/L and the average concentration detected was 0.87 µg/L. Other evidence indicated OPs as cause of toxicity.
NOTE: This study was also cited in Mixtures sections of Chlorpyrifos and Diazinon criteria reports.

Kuivila KM, Foe CG. 1995. Concentrations, transport and biological effects of dormant spray pesticides in the San Francisco Estuary, California. *Environmental Toxicology and Chemistry* 14:1141-1150.
This study detected distinct pulses of pesticides, including diazinon in the San Joaquin and Sacramento rivers following rainfall. Sacramento River water at Rio Vista was acutely toxic to *Ceriodaphnia dubia* for 3 consecutive days and San Joaquin River water at Vernalis for 12 consecutive days. Diazinon concentrations were high enough for most, but not all, of the observed toxicity. Measured concentrations in the Sacramento and the San Joaquin rivers were 0.037-0.281 µg/L, and 0.043-1.07 µg/L diazinon, respectively.

Teh SJ, Deng DF, Werner I, Teh FC, Hung SSO. 2005. Sublethal toxicity of orchard stormwater runoff in Sacramento splittail (*Pogonichthys macrolepidotus*) larvae. *Marine Environmental Research* 59:203-216.
This study measured survival, growth, histopathological abnormalities and stress protein expression (hsp60, hsp70) in larval fish (Sacramento splittail) exposed for 96 h to storm water runoff samples collected within a prune orchard after dormant spray application of diazinon. Fish were moved to clean water after 96 h exposures and maintained for 3 months to evaluate delayed effects. No significant mortality occurred after 96 h exposure to runoff containing a maximum concentration of 210.4 µg/L diazinon, but body weight and condition factor after 3 months were lower in fish exposed to runoff containing 210.4 µg/L diazinon than in control animals. Stress proteins were significantly above control levels in exposed fish. Histopathological abnormalities were seen one week after exposure, but not after the 3 month recovery period.

Werner I, Deanovic LA, Connor V, de Vlaming V, Bailey HC, Hinton DE. 2000. Insecticide-caused toxicity to *Ceriodaphnia dubia* (Cladocera) in the Sacramento-San Joaquin River delta, California, USA. *Environmental Toxicology and Chemistry* 19:215-227.
In this 1993-1995 monitoring study, samples were collected monthly from 24 sites in the Sacramento-San Joaquin River delta. Diazinon was identified as a primary toxicant primarily during fall and winter months, and measured concentrations in toxic samples ranged from 0.125 to 0.422 µg/L.

Werner I, Deanovic LA, Hinton DE, Henderson JD, Oliveira GH, Wilson BW, Osterli P, Krueger W, Wallender WW, Oliver MN, Zalom FG. 2002. Toxicity of stormwater runoff after dormant spray application of diazinon and esfenvalerate

(Asana) in a French Prune Orchard, Glenn County, California. ***Bulletin of Environmental Contamination and Toxicology*** **68:29-36.**
In this study, larval fish (fathead minnows, Sacramento splittail) and water fleas (*Ceriodaphnia dubia*) were exposed to storm water runoff collected in an orchard after application of dormant spray insecticides, diazinon and esfenvalerate. Diazinon concentrations measured in orchard runoff were 118-210 µg/L. Runoff from one of the four diazinon sprayed areas was toxic to minnow larvae. Inexplicably, a non-sprayed area, which had 15.6 µg/L diazinon, exhibited that same percent mortality of minnows, about 25% mortality. (Similar study to Werner *et al*. (2004) discussed in mesocosm data section.)

Appendix B

Comparison of acute data used by USEPA, CDFG, and in this report for diazinon water quality criteria

Comparison of the toxicity values used by USEPA, California Department of Fish and Game (CDFG)[1] and UC Davis (UCD) for derivation of water quality criteria for diazinon.

Objective and overview

Data used by three agencies to calculate acute water quality criteria for diazinon were tabulated for side by side comparison (Table B-1). Studies excluded by UCD, but included in either the CDFG or EPA criteria derivation were further examined to identify the reasons they were excluded. This information, described in Part I of the text below, was used to generalize the differences in the screening methods of each agency. In Part II, the reasons EPA and CDFG excluded studies were summarized as another way to compare the data quality requirements of the three agencies. Part III of the text describes a comparison of criteria derived by the Burr Type III and log-triangular distributions. Both calculations were performed using the data sets from the three agencies, plus a hypothetical combination data set, as examples of how the presence of the excluded values can affect the final criteria. The resulting criteria are presented in Table B-2. Tables B-3 and B-4 display the values used for the calculations, and the values are plotted in Figure B-1. A graph of the fit of the distributions is included in Figure B-2. Part IV is a comparison of the values used to calculate the ACR for the chronic criterion. For ease of reading all of the tables are presented at the end of this appendix.

Brief summary of comparison

The UCD criteria were very similar to those in the EPA criteria report (see Table B-2). The data selection of UCD produced a data set with fewer and lower values than the EPA data set, but the Burr Type III distribution resulted in a nearly equivalent acute criterion to that of the EPA (0.18 and 0.17 µg/L for UCD and EPA, respectively).

Summary of data selection differences: Broadly speaking, EPA and CDFG requirements for acceptable data were similar to those of UCD. For example, UCD, EPA and CDFG all exclude studies that do not report acceptable control survival. UCD selection was more stringent on the chemical grade used and not using values reported as greater than (>) or less than (<) a given concentration, but these accounted for fewer unused data than the acceptability of the control description.

The most important factor that affected data selection was the reporting of or acceptability of control survival (see Part I). The UCD rating system was most stringent, favoring the use of complete study reports that contained control descriptions and responses, experimental concentrations, etc. The other agencies accepted studies because of the reputation of the laboratory or citation of ASTM methods, even if measured parameters were not reported. This factor had a noticeable effect, resulting in smaller data sets for UCD and CDFG.

Additionally, some of the lowest values in the UCD report were not in the EPA or CDFG report for various reasons (see Part III). These lower values contributed to decreasing the example acute criterion derived using the log-triangular distribution with the UCD data set.

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[1] The CDFG recommended criteria were recalculated (CVRWQCB 2005) after a problem with the value of 0.2 µg/L for *Gammarus fasciatus* was identified (Hall & Anderson 2005). In this review, that value was also omitted from the CDFG data set.

<u>Summary of the influence of the statistical distribution:</u> The Burr Type III distribution resulted in both higher and lower criteria in different instances. The log-triangular distribution gave more similar results to the Burr Type III distribution when the Burr Type III distribution was fit to a lower subset of the data.

PART I

Reasons studies were excluded by UCD, while the values were used by CDFG and/or EPA

UCD excluded some of the acute values that were used in CDFG and EPA diazinon criteria reports (Siepmann and Finlayson 2000, USEPA 2005). This section summarizes the main reasons those studies were excluded by UCD.

First, the number of acute studies used by agency was counted. In this count, if multiple species were tested in the same study, they were counted as separate studies. The EPA report used the most studies (36), while CDFG (29) and UCD (22) used less studies.

There were 29 values used by CDFG or EPA that were excluded by UCD. The reasons UCD did not use the values from those studies are listed bellow:

<u>Number of times a parameter was used to exclude a value, followed by the reason:</u>

- (19) control survival not reported or acceptable*
- (4) chemical grade was lower than 80% pure or not reported & control or control survival not reported or acceptable
- (1) no toxicity values calculated & chemical grade was lower than 80% pure
- (4) lack of other parameters that had less weight in rating system (control not described, water quality parameters not reported, concentrations used not reported, no standard method, temp not held to ± 1 ºC, organism source not reported)
- (1) was not obtained because it did not have a calculated value and the study was not in the peer reviewed literature, OPP or ECOTOX data bases. (Vial 1990, *Daphnia magna* LC_{50} > 2.6 µg/L)

Judging by the list above and comparing to criteria of the other agencies in Part II, UCD selection was more stringent on the chemical grade used and not using values reported as > or <. More importantly, there was some difference in evaluation of an acceptable description of controls as described below.

*These 19 values came from nine studies in which control survival was not reported or acceptable. Both CDFG and EPA also state that unreported or unacceptable control response was a reason for excluding studies (see Part II). However, these studies were used in their documents. EPA used all nine studies, while CDFG used only four of the nine. Of the studies CDFG used, two were Sanders and Cope (1966) and Keizer *et al.* (1991), which CDFG states had 100% control survival, but this information was not found in these studies. In the CDFG report, personal communication was also cited for Ankley *et al.* (1991). UCD contacted the author who said they may or may not still have this record. The information was not received then or after a later follow up. CDFG also used Mayer and Ellersieck (1986), for which they describe the reference and the reason they use the studies below.

Note about Mayer and Ellersieck (1986), Johnson and Finley (1980)
Description from CDFG (Siepmann & Finlayson 2000) criteria report:
"Mayer and Ellersieck (1986) - In 1986, a study was conducted by the Fish and Wildlife Service to generate static acute toxicity test data for 410 chemicals with 66 freshwater species. All tests were performed at the Columbia National Fisheries Research Laboratory and its field laboratories between 1965 to 1984. The studies on technical grade diazinon (97%) were conducted with eight species. The tests were generally in compliance with ASTM (1980) and EPA (1975) standards. At least five concentrations of diazinon were tested. Two replicates per concentration were tested. Depending on the species, water quality parameters during the tests were as follows: temperature of 2.0 ºC to 29 ºC; pH of 6.0 to 9.0; and hardness of 44 mg/L to 272 mg/L. Control survival, dissolved oxygen, and measurement of diazinon concentrations were not discussed…. Although information about some important test characteristics could not be obtained, most of these data were accepted because of the use of ASTM guidelines and the reputation of the laboratory…."

The Mayer & Ellersieck (1986) report contains most of the data reported in Johnson and Finley (1980). Mayer Ellersieck (1986) says to assume all tests meet cited ASTM and EPA methods. Johnson and Finley (1980) describe methods in detail, but not use of controls. Values from Sanders and Cope (1968), Sanders (1969), and Macek *et al.* (1969) are also repeated in these volumes. These references are also the source of the erroneous value of 0.2 µg/L for *Gammarus fasciatus.*

From the UCD methods perspective, to be fair and impartial in rating the quality of all studies, such assumptions should be avoided and evaluation should be based only on information reported. It was also preferable that original study reports be used. This helps to avoid errors, as in the value for *G. fasciatus*.

<u>PART II</u>

The data screening methods in the EPA and CDFG criteria reports were reviewed here to be able to compare them with UCD methods. Overall, the reasons EPA and CDFG provided for excluding studies were similar to those of UCD.

CDFG exclusion of studies
The CDFG diazinon and chlorpyrifos criteria document (Siepmann and Finlayson 2000) contains an appendix that summarizes and briefly discusses why studies were used or not used, including both saltwater and freshwater data. The 16 studies rejected often had more than one of the reasons below.

<u>Number of times a parameter was used to exclude a value, followed by the reason:</u>

- (8) active ingredient too low or not reported
- (6) control survival too low or not reported
- (5) mortality range inadequate or not reported
- a few studies also cited

-dissolved oxygen low or not reported
-no toxicity values calculated
-inadequate duration
-inappropriate dilution water
-hardness not reported

EPA exclusion of studies
EPA documents (USEPA 2000b, 2005) contain an unused data section in which a reason for exclusion of a study is followed by citations of studies omitted for that reason. Freshwater and saltwater data were mixed in this section that contains 158 excluded studies.

Number of times a parameter was used to exclude a value, followed by the reason:

- (43) conducted with species that are not resident in North America
- (16) data were compiled from other sources
- (42) diazinon was a component of a drilling mud, effluent, mixture, sediment or sludge
- (11) either the test procedures, test material, or dilution water was not adequately described
- (3) the tests were conducted in distilled or deionized water without addition of appropriate salts or were conducted in chlorinated or "tap" water,
- (1) concentration of a water-miscible solvent used to prepare the test solution exceeded 0.5 mL/L
- (10) results were not adequately described or could not be interpreted
- (4) tests conducted without controls, with unacceptable control survival, or with too few tests
- (1) organisms preconditioned to organophosphorus chemicals
- (27) experimental model was plasma, enzymes, tissue, or cell cultures

Additionally, examination of data tables and species mean acute values show that acceptable values from static tests with fish were not used if acceptable values were available from flow through tests.

PART III

Burr Type III and log-triangular criteria calculation with all three data sets

Methods
To examine how the different values selected may influence the final criteria calculation, the log-triangular and Burr Type III distributions were fit to each agency's data set to calculate criteria. To address the criticism that criteria by UCD method were lower simply because it excluded higher values contained mostly in Mayer & Ellersieck (1986), a hypothetical combination data set was created by adding excluded values back into the UCD data set. This was done by starting with the UCD data set (as it is in Table B-3 or B-4) and adding in any species values from EPA data where UCD had none, or from CFDG if EPA had none.

To fit the log-triangular distribution, Genus Mean Acute Values (GMAVs) were used following EPA (1985) methods. To fit the Burr Type III distribution, Species Mean Acute Values (SMAVs) were used, according to the UC-Davis methodology (TenBrook *et al.* 2009a). SMAVs were calculated as the geometric mean of all LC_{50} values for the same species. Then, GMAVs were calculated as the geometric mean of all species values in the same genus. The 5th percentile at 50% confidence estimates were calculated for the Burr Type III distribution, which is the same estimate used in UCD criteria reports. These results are presented in Tables B-3 and B-4. For the log-triangular calculation, the lowest 4 values are repeated at the bottom of the table for easy comparison, as those values are weighted heavily in this calculation.

Plots of the distributions fit to the UCD data set are included as Figure B-2. The EPA log-triangular plot was graphed following the procedure in USEPA (1985) and the Burr Type III distribution was constructed using the fit parameters obtained from the BurrliOZ software (CSIRO 2001).

For the Burr Type III distribution, the EPA, CDFG, and hypothetical data sets did not produce a 5th percentile value (values were calculated as 0.000000, 0.027 and 0.020 µg/L, respectively, and the fitted distribution did not pass the fit test). This was likely due to the multimodality of these data (Figure B-1 and B-2). Also included in Table B-4 is the calculation performed with the lower subset of values as suggested in the UCD methodology for data that is multimodal. The visual break was below 400 µg/L and separated the phyla Arthropoda from the other phyla. Chordates (fish) and a few other phyla had higher LC_{50} values. *Rana clamitans,* which did not have an explicit value and was reported as > 50 µg/L, was grouped with the other chordates for this calculation. Also, the CDFG values for *Lepomis macrochirus* (272 µg/L) and *Oncorhynchus mykiss* (90 µg/L) did not fit clearly into one subset and were grouped with the other chordates.

When the UCD and CDFG data sets were split, they contained less than eight values. Following the UCD methodology, data sets with eight or fewer values were fit to a Log-Logistic distribution. This was done using the ETX 1.3 software (Aldenberg 1993).

Results
Using these different data sets and methods, most of the resulting criteria equated to approximately 0.2 µg/L (Table B-2). Use of the log-triangular distribution with the UCD data set and the Burr Type III distribution with the CDFG data set resulted in lower criteria, closer to 0.1 µg/L. These lower criteria could have been caused by the lower values and a smaller number of values in these data sets.

<u>Influential values</u>
The UCD data set did contain some of the lowest values at the sensitive end, which seemed to be very influential in the log-triangular distribution. Sources of the low GMAVs not included in the EPA report included one study from CDFG (*Neomysis mercedis*, CDFG 1992c, d) and one published after the EPA 2005 criteria report (*Procloeon sp*., Anderson *et al.* 2006). For the genus *Daphnia (magna* and *pulex*) the GMAV used were higher in EPA and CDFG reports than in the UCD report, 1.06 and 0.902 µg/L vs. 0.52 µg/L, respectively. The values used by EPA and CDFG did not rate high enough to be used by UCD, while UCD used the value from Surprenant (1988a), which was not used by EPA (although it is an unpublished report, typical of data used to meet registration requirements) or CDFG, perhaps because the organisms were fed during the acute test. Also, UCD used a value for *Hyalella azteca* (Anderson and Lydy 2002) that was published after the CDFG 2000 report and that EPA did not use.

<u>Log-Triangular Distribution, Table B-3</u>
Criteria resulting from the log triangular calculation for the UCD data set were lower than those resulting from the EPA, CDFG, or hypothetical data sets, which were more similar. When the

excluded values were added back to the UCD data set (exemplified in the hypothetical data set) the criteria doubles, from 0.083 to 0.20 µg/L. Two reasons were found to explain the lower criterion from the UCD data set: 1) the lower values in the data sets, and 2) there were fewer values in the data set. However, the criterion from the CDFG data set, which had only one more value (14 values), was closer to the EPA criterion (derived from 20 values). The two lowest values in the UCD data set may be driving the difference, setting the resulting criterion apart from the others.

<u>Burr Type III Distribution, Table B-4</u>
The bimodal data distribution makes it difficult to derive a number with the whole EPA, hypothetical, and CDFG data sets using the Burr Type III distribution. Surprisingly, the criterion derived from the lower EPA subset (0.21 µg/L) using the Burr Type III distribution was close to the criterion reported by EPA (0.17 µg/L). The criterion derived using the entire UCD data set (0.18 µg/L) was similar to that of the EPA (0.20 µg/L). The criteria results of the Burr Type III distribution approach (including the log-logistic distribution) were higher compared to the log-triangular results for the same data set in two of four cases, particularly for the UCD data set (0.18 vs. 0.083 µg/L). For the hypothetical data set, the criteria were equivalent (0.20 µg/L), and for the CDFG data set it was lower with the log-triangular than Burr Type III (0.11 and 0.16 µg/L, respectively).

The purpose of the hypothetical data set was to examine the effect of the exclusion of values from Mayer and Ellersieck (1986) by UCD. The values were added back to the hypothetical data set to see if they would alter the criteria significantly. Using the Burr Type III distribution the criterion from the UCD dataset (0.18 µg/L) was close to that from hypothetical data set (0.20 µg/L), suggesting these values were not very influential. This comparison could not be made exactly because the Burr Type III distribution could only be used with the lower subset of the values in the hypothetical data set. However, the criteria from the log-triangular distribution were the same for both data sets (0.20 µg/L.)

The Burr Type III distribution fit the entire UCD data set, but this data set was also split based on the bimodal distribution for the purpose of comparison. Fitting the log-logistic distribution to the lower subset provided similar results to the log-triangular analysis (0.1 and 0.083 µg/L, respectively).

Summary
Overall, criteria from different agencies did not vary widely and were comparable, especially those of EPA and UCD. This comparison demonstrates that the UCD data set yielded a lower criterion using the log-triangular distribution, but the Burr Type III distribution yielded a nearly equivalent criterion (0.18 µg/L) to the EPA criterion (0.17 µg/L). The Burr Type III distribution does not always provide higher criteria, as this was not the case in the CDFG data set or the chlorpyrifos report.

The main factors altering criteria:

1) inclusion of lower data, by UCD for various reasons;
2) the use of less data by UCD (and CDFG), see part I for details;
3) the distribution, with the Burr Type III distribution resulting in both higher and lower criteria in different instances.

As a final point of interest for the diazinon data set, the log-triangular distribution gave more similar results to the Burr Type III distribution when it was fit to only the lower subset of the data.

Table B-1. Comparison of Acceptable Acute Values for Diazinon Criteria by Agency.
Y- indicates agency used that value. Where disputed, the value used is shown. Only studies that at least one agency used are included. Please refer to an appropriate criteria document for full citations

Species, Common identifier	LC/EC_{50} (µg/L)	EPA 2005	CDFG 2000	UCD 2010	Reference	UCD Rating: Reason for Exclusion (see end of table for key)	Comments
Brachionus calyciflorus, Rotifer	29,220		Y		Fernandez-Casalderrey *et al.* 1992a	29,220 was a preliminary LC_{50}, w/o test details (Rating for other values in study - RL: SM, Conc NR, DO, C, % Solvent NR)	
Carassius auratus, Goldfish	9,000	Y			Beliles 1965	RL: 7, SM, Conc NM, % solvent NR, Temp not held ± 1 ºC, H, A, DO, C, pH, P,	
Ceriodaphnia dubia, Cladoceran	0.5	Y	Y		Ankley *et al.* 1991	RN: 4, 7, 8 Conc NR, H, A, DO, C, Ph, P, >0.05% solvent	CDFG: also cited pers comm
	0.58	Y			Bailey *et al.* 1997		EPA used 48h values (there were 4) WB and CDFG used 96h values (only 2)
	0.48	Y					
	0.26	Y					
	0.29	Y					
	0.32		Y	Y			
	0.35		Y	Y			
	0.33			Y	Bailey *et al.* 2000		
	0.38			Y	Bailey *et al.* 2001		
	0.33			Y			
	0.21			Y	Banks *et al.* 2005		
	0.45			Y	Banks *et al.* 2003		
	0.436		Y	Y	CDFG 1998a, Test 122		
	0.47		Y	Y	CDFG 1992a, Test 157		
	0.507		Y	Y	CDFG 1992b, Test 163		
	0.57		Y		Norberg-King 1987	(Tests 1 & 3) LL: 8, SM, Conc NR, Fed, A, H, P	EPA: Acceptable: h Memorandum, Not in OPP data base or Diazinon IRED
	0.35	Y				(Tests 4, 5, 8-14) LL: 8 SM, Conc NR, Fed, DO, Inappropriate dilution water, A, C, H, pH, P	

Species, Common identifier	LC/EC$_{50}$ (µg/L)	EPA 2005	CDFG 2000	UCD 2010	Reference	UCD Rating: Reason for Exclusion (see end of table for key)	Comments
	0.35	Y				See above	
	0.25	Y				See above	
	0.33	Y				See above	
	0.35	Y				See above	
	0.59	Y				See above	
	0.43	Y				See above	
	0.35	Y				See above	
	0.36	Y				See above	
Chironomus tentans, Insect	10.7	Y		Y	Ankley and Collyard 1995		
Danio rerio, Zebrafish	8,000	Y	Y		Keizer *et al.* 1991	LN: 4, 7, 8, Conc. NR, fed NR, DO, A, C, H, # per replicate NR	
Daphnia magna, Cladoceran	0.8	Y	Y		Ankley *et al.* 1991	RN: 4, 7, 8 Conc NR, H, A, DO, C, Ph, P, >0.05% solvent	CDFG: also cited pers comm.
	1.5	Y			Dortland 1980	LN: 4, 7, SM Conc NR, H, A, DO, C, pH,	
	0.52			Y	Surprenant 1988a		
	>2.6		Y		Vial 1990	No value calculated, Not obtained	Not in OPP data base
	0.96	Y			Vilkas 1976	LL: 4, 7, 8, Conc NR,	
Daphnia pulex, Cladoceran	0.65	Y	Y		Ankley *et al.* 1991	RN: 4, 7, 8 Conc NR, H, A, DO, C, Ph, P, >0.05% solvent	CDFG: also cited pers comm.
	0.9	Y	Y		Cope 1965; Sanders and Cope 1966	N: 1,4, 8, SM	CDFG: Sanders and Cope 1966 " control survival was 100%'
	0.8	Y	Y		Johnson and Finley 1980; Mayer and Ellersieck 1986	LL: 4, 7*	CDFG: "control survival acceptable in all tests", also cited pers. comm.
Dugesia tigrina, Planaria	11,640	Y			Phipps 1988	N: 1,7,8	Not in OPP data base or Diazinon IRED
Gammarus fasciatus, Amphipod	2.04	Y			Johnson and Finley 1980; Mayer and Ellersieck 1986	LL: 4,7 *	CDFG originally use the value of 0.204. See footnote 1, p C2
Gammarus pseudolimnaeus, Amphipod	16.82	Y		Y	Hall and Anderson 2005		

Species, Common identifier	LC/EC_{50} (µg/L)	EPA 2005	CDFG 2000	UCD 2010	Reference	UCD Rating: Reason for Exclusion (see end of table for key)	Comments
Gillia altilis, Snail	11,000	Y			Robertson and Mazzella 1989	LL: 4,7, SM, Conc NM, DO, C, P, Fed NR, % solvent too high, Temp not held ± 1 ºC, Org. possibly prior contaminant exposure	
Hyalella azteca, Amphipod	6.51	Y			Ankley and Collyard 1995	LR: 4	
	4.3			Y	Anderson & Lydy 2002		
Jordanella floridae, Flagfish	1,500	Y	Y	Y	Allison and Hermanutz 1977		CDFG: also cited pers comm.
	1,800	Y	Y	Y			
Lepomis macrochirus, Bluegill	480	Y		Y	Allison and Hermanutz 1977		CDFG: insufficient number of test organisms used
	440	Y	Y	Y			CDFG: also cited pers comm
	168		Y		Johnson and Finley 1980; Mayer and Ellersieck 1986	LL:4, 7*	CDFG: "control survival acceptable in all tests", also cited pers. comm EPA: Acceptable:h
Lumbriculus variegatus, Oligochaete worm	6,160	Y			Ankley and Collyard 1995	LL: 4,7, SM, Conc NR, % solvent too high	
	9,980	Y			Phipps 1988	N: 1,7,8	Not in OPP data base or Diazinon IRED
Neomysis mercedis, Mysid	3.57		Y	Y	CDFG 1992c, Test 162		
	4.82		Y	Y	CDFG 1992d, Test 168		
Oncorhynchus clarki, Cutthroat trout	1,700	Y	Y		Johnson and Finley 1980; Mayer and Ellersieck 1986	LL: 4,7*	CDFG: "control survival acceptable in all tests", also cited pers. comm
	2,760	Y	Y		Mayer and Ellersieck 1986	LL: 4,7*	CDFG: "control survival acceptable in all tests", also cited pers. comm
Oncorhynchus mykiss, Rainbow trout	400	Y			Beliles 1965	RL: 7, SM, Conc NM, Temp not ± 1 ºC, H , A, DO, C, pH, P,	
	3,200	Y			Bathe *et al.* 1975a	N: 1,4, 8 SM	

Species, Common identifier	LC/EC50 (µg/L)	EPA 2005	CDFG 2000	UCD 2010	Reference	UCD Rating: Reason for Exclusion (see end of table for key)	Comments
	90	Y	Y		Cope 1965a; Johnson and Finley 1980; Mayer and Ellersieck 1986, Ciba-Geigy 1976	LL: 4,7 for Johnson and Finley 1980*, Cope 1965 LN: 4	CDFG: "control survival acceptable in all tests", also cited pers. comm
	1,350	Y			Meier *et al.* 1979; Dennis *et al.* 1980	LN: 4, SM, solvent % NR, Org. stage + source, Conc NR, DO, T pH	
Physa sp. Pond snail	4,441		4.41	Y	CDFG 1998b, Test 132		report in mg/L. CDFG mistake
Pimephales promelas, Fathead minnow	6,600	Y	Y	Y	Allison and Hermanutz 1977		CDFG: also cited pers comm
	6,800	Y	Y	Y			
	10,000	Y	Y	Y			
	9,350	Y	Y	Y	Geiger/University of Wisconsin-Superior 1988		
	6,900	Y	Y	Y	Jarvinen and Tanner 1982		
Poecilia reticulata, Guppy	800	Y	Y		Keizer *et al.* 1991	LL: 4, 7 ,8, Conc. NR, fed NR, DO, A, C, H, # per replicate NR	CDFG: Control survival was 100%, but article only states 'meets EEC guidelines'
Pomacea paludosa, Apple snail	2,950	Y		Y	Call 1993		
	3,270	Y		Y			
	3,390	Y		Y			
Procloeon sp., Insect	1.53			Y	Anderson et al. 2006		
	2.11			Y			
	1.77			Y			
Pteronarcys californica, Insect	25	Y	Y		Cope 1965a; Sanders and Cope 1968; Johnson and Finley 1980; Mayer and Ellersieck 1986	LL: 4,7 for Johnson and Finley 1980*; LL 4,7 for Sanders and Cope 1968	CDFG: "control survival acceptable in all tests", also cited pers. comm
Rana clamitans, Frog	>50	Y			Harris *et al.* 1998	LL: 1,6,7	
Salvelinus fontinalis, Brook trout	800	Y	Y	Y	Allison and Hermanutz 1977		CDFG: also cited pers comm.
	450	Y	Y	Y			

Species, Common identifier	LC/EC50 (μg/L)	EPA 2005	CDFG 2000	UCD 2010	Reference	UCD Rating: Reason for Exclusion (see end of table for key)	Comments
	1,050	Y	Y	Y			
Salvelinus namaycush, Lake trout	602	Y	Y		Johnson and Finley 1980; Mayer and Ellersieck 1986	LL: 4,7 for Johnson and Finley 1980*	CDFG:"control survival acceptable in all tests", also cited pers. comm
Simocephalus serrulatus, Cladoceran	1.8	Y	Y		Cope 1965a; Sanders and Cope 1966; Mayer and Ellersieck 1986	LL: 4,7 for Johnson and Finley 1980*; N: 4,1 for Sanders and Cope 1966	CDFG: Sanders and Cope 1966 " control survival was 100%'
	1.4	Y	Y		Sanders and Cope 1966; Johnson and Finley 1980; Mayer and Ellersieck 1986	LL: 4,7 for Johnson and Finley 1980*; N: 4,1 for Sanders and Cope 1966	CDFG: Sanders and Cope 1966 " control survival was 100%'
Total individual values (total number of 'Y's)	58	37	35				
Studies used (values for different species in the same reference counted separately)	36	29	23				

* See text in Part I for discussion of why UCD did not use values in Johnson and Finley 1980 and Mayer and Ellersieck 1986

Codes for reasons for exclusion in the Table B-1.

This table includes all values used by any of the three agencies. Reports from all agencies mention many studies that were judged unacceptable that were not included in the reports. Because of the large number of these studies, they were not included in this table.

Y- indicates value was USED by agency

Acceptable: indicated values were ACCEPTABLE, BUT NOT USED by specified agency because more preferable data were available. Details are in the following list:

a. 96-h result available
b. Test with measured concentrations available
c. 48-h result available
d. More sensitive endpoint available
e. Non-standard temperature
f. More sensitive lifestage available
g. Flow-through test available
h. EPA 2005: a more sensitive study was available

Major reasons for studies rated UNACCEPTABLE by UCD only.
These studies were rated LR, RL, LL, RN, LN, N according to UCD methods (see Chapter 3 of TenBrook *et al.* 2009a for details):

1. Chemical grade was lower than 80% pure
2. Endpoint not linked to population effects
3. Family not in North America
4. Control response was not acceptable or not reported
5. Not a freshwater test
6. No toxicity value calculated
7. Low reliability score- based on reporting of many parameters including those listed just below
8. Control not described or not reported (i.e., solvent or water only)

For studies excluded only because of low reliability score (#7 from table above) more information was given with the following abbreviations:

NR- not reported
SM- no standard method
Conc NR- concentrations not reported
Conc NM- concentrations not measured (nominal)
Org- organism
Control desc. -control not described at all
DO - dissolved oxygen NR
H-hardness NR
A- alkalinity NR
C-conductivity NR
pH- pH NR
T- temperature NR
P-photoperiod NR
% solvent -carrier solvent percent not reported or too high, as indicated
Control Type NR- not reported whether control was solvent control or water only
Fed- organisms fed in acute test

Table B-2. Acute criteria comparison by data set and calculation methods.

Method of calculation	Acute criteria (μg/L) from each data set			
	EPA 2005	CDFG 2000	UCD 2010	Hypothetical Combination
Log-Triangular	0.17	0.16	0.083	0.20
Burr Type III/Log-logistic	0.21 [a,b]	0.11 [a,b]	0.18 [a]	0.20 [a,b]
Criterion from agency report	0.17	0.16	0.18 [a]	-

[a] Values would be rounded to 1 significant figure by UCD methods, but left here with 2 significant figures to show slight difference in calculation.
[b] Based on lower subset of invertebrates, because the entire data set could not be fit to a Burr Type III distribution.

Table B-3. Log-Triangular Calculation for Diazinon Genus Mean Acute Values.

	Diazinon Genus Mean Acute Values (µg/L)			
Genus species	**EPA 2005**	**CDFG 2000**	**UCD 2010**	**Hypothetical Combination**
Brachionus calyciflorus		29220		29220
Dugesia tigrina	11640			11640
Gillia altilis	11000			11000
Carassius auratus	9000			9000
Danio rerio	8000	8000		8000
Lumbriculus variegatus	7841			7841
Pimephales promelas	7804	7804	7804	7804
Pomacea paludosa	3198		3198	3198
Jordanella floridae	1643	1643	1643	1643
Oncorhynchus clarki, mykiss	960.4	441		960.4
Poecilia reticulata	800	800		800
Salvelinus fontinalis, namaycush	659.7	660	723	723
Lepomis macrochirus	459.6	272	459.6	459.6
Rana clamitans	>50			50
Pteronarcys californica	25	25		25
Chironomus tentans	10.7		10.7	10.7
Hyalella azteca	6.51		4.3	4.3
Gammarus fasciatus, pseudolimnaeus	5.858		16.82	16.82
Physa sp.		4.41	4441	4441
Neomysis mercedis		4.15	4.15	4.15
Procloeon sp.			1.79	1.79
Simocephalus serrulatus	1.587	1.59		1.587
Daphnia magna, pulex	0.902	1.06	0.52	0.52
Ceriodaphnia dubia	0.3773	0.44	0.34	0.34
Lowest 4 values	5.858	4.15	4.15	1.79
	1.587	1.59	1.79	1.587
	0.9020	1.06	0.52	0.52
	0.3773	0.44	0.34	0.34
Log-triangular results				
Number of values	20	14	13	24
FAV/ 5th percentile*	0.3397	0.3105	0.1738	0.3971
Acute Criterion	**0.17**	**0.16**	**0.083**	**0.20**
Acute Criterion from agency report	0.17	0.16		

*The calculation yields a 5th percentile value (or the final acute value, FAV). This value is divided by 2 to obtain the criterion in both methods.

Table B-4. Burr Type III Calculation for Diazinon Species Mean Acute Values.

	Diazinon Species Mean Acute Values (µg/L)			
Genus species	**EPA 2005**	**CDFG 2000**	**UCD 2010**	**Hypothetical Combination**
Brachionus calyciflorus		29220		29220
Dugesia tigrina	11640			11640
Gillia altilis	11000			11000
Carassius auratus	9000			9000
Danio rerio	8000	8000		8000
Lumbriculus variegatus	7841			7841
Pimephales promelas	7804	7804	7804	7804
Physa sp.		**4.41**	4441	4441
Pomacea paludosa	3198		3198	3198
Oncorhynchus clarki	2166	2166		2166
Jordanella floridae	1643	1643	1643	1643
Poecilia reticulata	800	800		800
Salvelinus fontinalis	723	723	723	723
Salvelinus namaycush	602	602		602
Lepomis macrochirus	459.6	272	460	460
Oncorhynchus mykiss	426	90		425.8
Rana clamitans	>50			50
Pteronarcys californica	**25**	**25**		**25**
Gammarus pseudolimnaeus	**16.82**		**16.82**	**16.82**
Chironomus tentans	**10.7**		**10.7**	**10.7**
Hyalella azteca	**6.51**		**4.3**	**4.3**
Neomysis mercedis		**4.15**	**4.15**	**4.15**
Procloeon sp.			**1.79**	**1.79**
Simocephalus serrulatus	**1.587**	**1.59**		**1.587**
Daphnia magna	**1.048**	**1.44**	**0.52**	**0.52**
Daphnia pulex	**0.7764**	**0.78**		**0.7764**
Ceriodaphnia dubia	**0.3773**	**0.44**	**0.34**	**0.34**
Gammarus fasciatus	**2.04**			**2.04**
Burr III results, using entire data set				
Number of values	24	17	13	28
5th percentile*	No result	Failed fit test	0.349	Failed fit test
Criterion			**0.18**	
Burr III results, calculated for Arthropoda subset, indicated by bold values				
Number of values	9	7	7	11
5th percentile*	0.41	0.21	0.22	0.40
Criterion	**0.21**	0.11**	0.11**	**0.20**
Criterion from agency report	0.17	0.16		

*The calculation yields a 5th percentile value (or the final acute value, FAV). This value is divided by 2 to obtain the criterion in both methods.

**Log-Logistic distribution used for 8 or fewer data, according to UCD methods

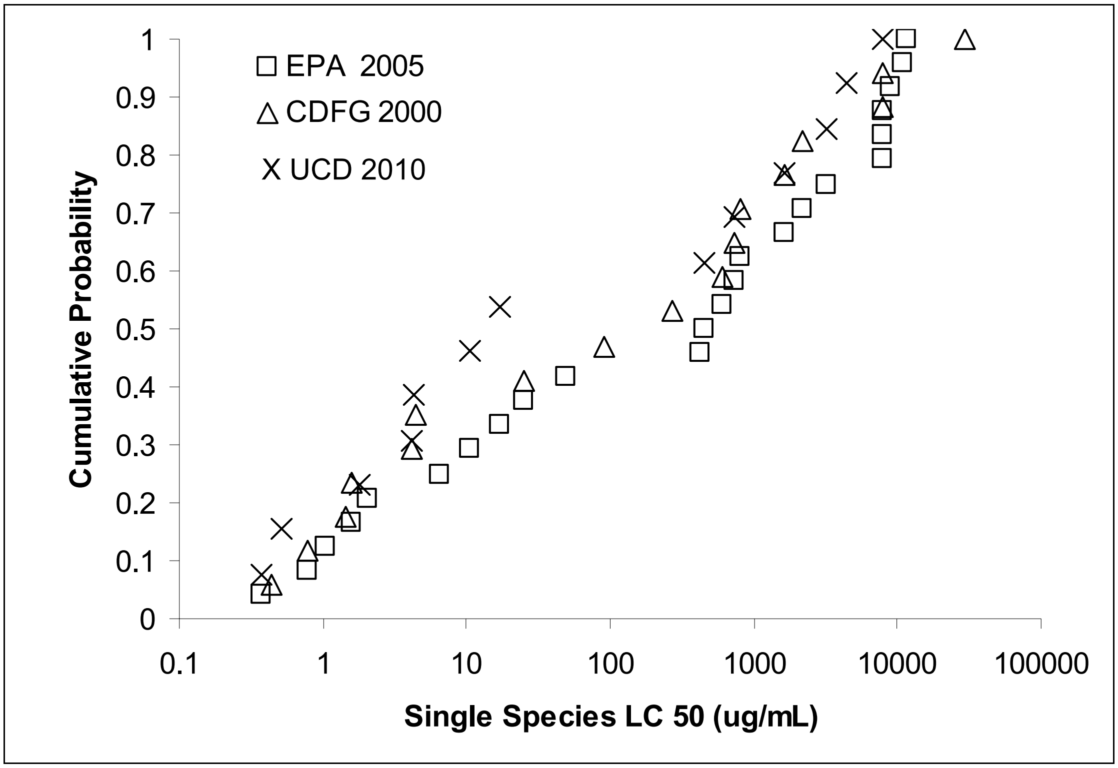

Figure B-1. Diazinon Acute Toxicity Data Distribution.

Note: Equivalent LC_{50} values will not overlap because probability (on y-axis) is relative to other values in the data set. Equivalent LC_{50} values will be vertically in line with each other (according to concentration on x-axis).

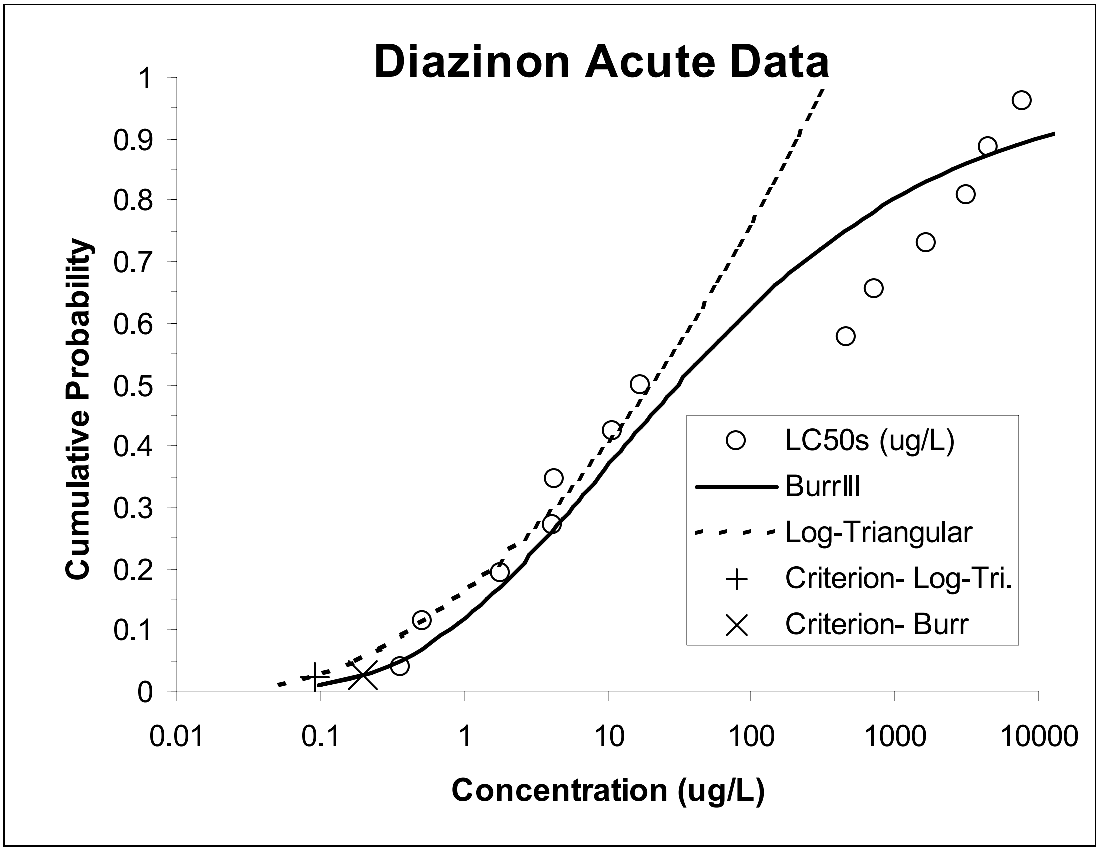

Figure B-2. The fit of the Burr Type III and Log-triangular distributions to the UCD diazinon acute data set

PART IV

Table B-5. Comparison of studies with acute and chronic toxicity data for diazinon used in different criteria reports.

Gray shading indicates that values from that study were not considered for ACR. Please refer to an appropriate criteria document for full citations.

Reference	Organism	Used by EPA 2005			Used by CDFG 2000			UCD 2010			Comment
Freshwater species		LC_{50} µg/L	MATC µg/L	ACR	LC_{50} µg/L	MATC µg/L	ACR	LC_{50} µg/L	MATC µg/L	ACR	
Allison (1977)	*Jordanella floridae*	1643	68.93	23.8							Rejected by CDFG because it did not generate a NOEC. Rejected by UCD because control not described, no standard method, purity not reported.
Allison and Hermanutz (1977)	*Salvelinus fontinalis*	723	<0.8	904				723	6.8	106	Rejected by CDFG because it did not generate a NOEC (for growth rate of progeny- the most sensitive endpoint). However that endpoint had interrupted dose repose. UCD used data for the survival endpoint.
Allison and Hermanutz (1977)	*Pimephales promelas*							7800	41	190	Chronic data not included in EPA and CDFG. Study abstract reports no NOEC (for incidence of scoliosis-most sensitive endpoint, but it is not linked to survival, growth, reproduction). UCD used data for the survival endpoint.
Jarvinen and Tanner (1982)	*Pimephales promelas*	6900	67.08	103	6900	67	103	6900	67	103	
Norberg-King (1989)	*Pimephales promelas*	9350	24.97	374	9350	25	374				Study did not rate as high quality be UCD because control response not reported and low reliability score
Norberg-King (1987)	*Ceriodaphnia dubia*	0.376	0.3382	**1.1**	0.57	0.34	**1.7**				CDFG states it is unavailable yet did include values. Report is a memorandum to USEPA. Study did not rate as high quality by UCD.
Surprenant (1988a)	*Daphnia magna*				1.44	0.23	**6.3**	0.52	0.23	**2.3**	Not referenced at all by USEPA (EPA 1985 guidelines advised against using confidential studies and acute tests with feeding). CDFG used a geometric mean from multiple endpoints.
Saltwater species											
Goodman et al. (1979)	*Cyprinodon variegatus*	1400	<0.47	2979							Rejected by CDFG and UCD because it did not generate a NOEC.
Nimmo et al. (1981)	*Mysidopsis bahia*	4.82	3.04	**1.6**	4.82	1.9	**2.5**				Rejected by UCD because diazinon purity was <80%, control description & response not reported. EPA used original data to recalculate values. CDFG used value calculated by authors.
Final ACR (species values included in bold)				2*			3			2.3	All three agencies used the geometric mean of ACRs of species whose acute values were close to the FAV.

*EPA used 1985 Guidelines stipulation that if the most appropriate SMACRs < 2.0, the FACR should be assumed to be 2.0

Appendix C

Fit test calculations

Raw data and calculations for fit test for diazinon acute data

LC50	Omit one 1	2	3	4	5	6	7	8	9	10	11	12	13
0.340		0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340
0.52	0.52		0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
1.79	1.79	1.79		1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79
4.15	4.15	4.15	4.15		4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15
4.30	4.30	4.30	4.30	4.30		4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30
10.70	10.70	10.70	10.70	10.70	10.70		10.70	10.70	10.70	10.70	10.70	10.70	10.70
16.82	16.82	16.82	16.82	16.82	16.82	16.82		16.82	16.82	16.82	16.82	16.82	16.82
459.6	459.6	459.6	459.6	459.6	459.6	459.6	459.6		459.6	459.6	459.6	459.6	459.6
723.0	723.0	723.0	723.0	723.0	723.0	723.0	723.0	723.0		723.0	723.0	723.0	723.0
1643	1643	1643	1643	1643	1643	1643	1643	1643	1643		1643	1643	1643
3198	3198	3198	3198	3198	3198	3198	3198	3198	3198	3198		3198	3198
4441	4441	4441	4441	4441	4441	4441	4441	4441	4441	4441	4441		4441
7804	7804	7804	7804	7804	7804	7804	7804	7804	7804	7804	7804	7804	

Omitted point, xi:	0.34	0.52	1.79	4.15	4.30	10.70	16.82	460	723	1643	3198	4441	7804
Median 5th perc.	0.67	0.55	0.39	0.00	0.00	0.31	0.31	0.30	0.30	0.31	0.32	0.32	0.33
F-i(xi)	97.69	95.27	84.43	79.72	79.54	63.19	57.55	23.21	19.94	14.93	11.65	10.27	8.23
	0.9769	0.9527	0.8443	0.7972	0.7954	0.6319	0.5755	0.2321	0.1994	0.1493	0.1165	0.1027	0.0823
1-F(xi)	0.0231	0.0473	0.1557	0.2028	0.2046	0.3681	0.4245						
min of F-i(xi) or 1 -F(xi)	0.0231	0.0473	0.1557	0.2028	0.2046	0.3681	0.4245	0.2321	0.1994	0.1493	0.1165	0.1027	0.0823
p_i =2(min)	0.0462	0.0946	0.3114	0.4056	0.4092	0.7362	0.849	0.4642	0.3988	0.2986	0.233	0.2054	0.1646

		Fisher test statistic	
p_i	$\ln(p_i)$	-2*Sum of $\ln(p_i)$	X^2_{2n}
0.0462	-3.0748	33.20915	0.156116
0.0946	-2.3581		
0.3114	-1.1667		
0.4056	-0.9024		
0.4092	-0.8936		
0	-0.3063		

0.1561 is > 0.05; the distribution fits the diazinon acute data set

	if $X^2_{2n} < 0.05$	significant lack of fit
***	if $X^2_{2n} > 0.05$	fit (no significant lack of fit)

.7362	
0.849	-0.1637
0.4642	-0.7674
0.3988	-0.9193
0.2986	-1.2087
0.233	-1.4567
0.20	-1.5828

5	
4	
0	
.	
1	
6	
4	
6	-1.8042