Chapter 4
Criteria Derivation
Chlorpyrifos

4-1.0 Basic information

Chemical: Chlorpyrifos (Fig. 1.1); o,o-diethyl o-(3,5,6-trichloro-2-pyridinyl) phosphorothioate

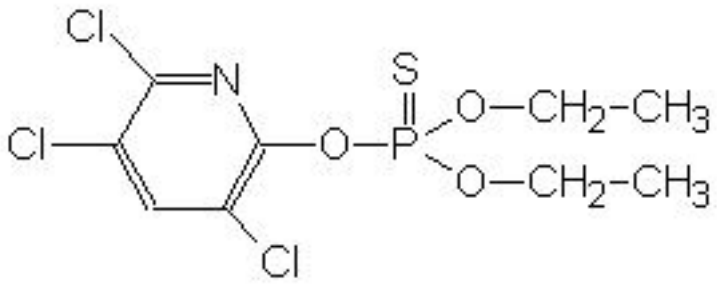

Figure 1.1. Structure of chlorpyrifos.

Trade names: Brodan, Chlorban Insect Granules, Detmol UA, Dowco 179, Dursban, Empire, Equity, Eradex, Killmaster, Lentrek, Lock-On, Lorsban, Pageant, Piridane, Pyrinex, Scout, Stipend (EXTOXNET 1996; Racke 1993)

CAS Number: 2921-88-2
USEPA PC Code: 059101 (PAN 2006)
CA DPR Chem Code: 253 (PAN 2006)

4-2.0 Physical-chemical data

Molecular Weight

350.6

Water Solubility

2 mg/L @ 23^{o}C (Hummel & Crummet 1964);
1.12 mg/L @ 24^{o}C (Felsot & Dahm 1979);
1.39 mg/L @ 25^{o}C (Drummond 1986);
Geometric mean: 1.46 mg/L

Melting Point

41.5-44^{o}C (Bowman & Sans 1983; Brust 1964; 1966; McDonald *et al.* 1985; Rigterink & Kenaga 1966);
Geometric mean of extremes: 42.73^{o}C

Density

1.44 g/mL @ 20^{o}C (Tomlin 2003, original reference not given)

Vapor Pressure

1.875 x 10 $^{-5}$ mm Hg (2.5 x 10^{-3} Pa) @ 25^{o}C (Brust 1964);
1.8 x 10^{-5} mm Hg (2.4 x 10^{-3} Pa) @ 25^{o}C (McDonald *et al.* 1985);
2.03 x 10^{-5} mm Hg (2.7 x 10^{-3} Pa) @ 25^{o}C (Chakrabarti & Gennrich 1987);
Geometric mean: 1.90 x 10^{-5} mm Hg (2.36 x 10^{-3} Pa)

Organic carbon-water partition coefficients

log K_{oc}: 3.93 (Racke 1993, mean of values ranging from 3.00-4.49)
log K_{oc}: 4.196 (Spieszalski *et al.* 1994)
Geometric mean: 4.06

Henry's constant (K_H)

0.897 Pa m^3/mol = 3.65 x 10^{-4} dimensionless (from Wu *et al.* 2002, original source not cited);
0.420 Pa m^3/mol = 1.7 x 10^{-4} dimensionless (Fendinger & Glotfelty 1990);
0.676 Pa m^3/mol = 2.76 x 10^{-4} dimensionless (Tomlin 2003, calculated from vapor pressure and solubility);
0.660 Pa m^3/mol = 2.7 x 10^{-4} dimensionless (Downey 1987)
Geometric mean: 0.640 Pa m^3/mol = 261 x 10^{-4} dimensionless

Log K_{ow}

4.96 (Sangster Research Laboratories 2004)

Bioconcentration Factor

2.1 x 10^4 L/kg in three-spined stickleback (lipid-based, Deneer 1994);
1,847 L/kg in guppies (Welling & Devries 1992);
1700 in fathead minnows (unitless, Jarvinen *et al.* 1983);
727-1143 in Japanese medaka (unitless, Rice *et al.* 1997);
1.0-5100 in yeast to gulf toadfish; many based on muscle tissue with equilibrium conditions not confirmed, some lipid-normalized (Racke 1993).

Biomagnification Factor

0.7, 0.5 and 0.3 after 9, 16, and 32 days, respectively, of bioaccumulation study; values are lipid-based (Varó *et al.* 2002).

Environmental Fate

Hydrolysis half-life @ 25°C: 22.8 d, 35.3 d, 62.7 d @ pH 8.1, 6.9 and 4.7, respectively (Meikle & Youngson 1978);
Hydrolysis half-life @ 35°C: 4.5 d, 11.5 d, 15.7 d @ pH 8.1, 6.9 and 4.7, respectively (Meikle & Youngson 1978);
Hydrolysis half-life @ 15°C: 54.2 d, 99.0 d, 210 d @ pH 8.1, 6.9 and 4.7, respectively (Meikle & Youngson 1978);
Hydrolysis half-life @ 25°C: 73 d, 72 d, 16 d at pH 5.0, 7.0 and 9.0, respectively (McCall 1986);
Hydrolysis half-life @ 25°C: 74 d at pH 7.0 (Batzer *et al.* 1990);
Hydrolysis half-life @ 20°C: 120 d, 53 d @ pH 6.1 and 7.4, respectively (Freed *et al.* 1979);
Hydrolysis half-life @ 25°C: 54 d, 142 d, 10 d at pH 5.9, 6.1 and 9.8, respectively (Macalady & Wolfe 1985);
Volatility from water half-life = 3.5-20d (McCall *et al.* 1984; Neely & Blau 1977);
Photolysis (aqueous) half-life: 13.9 d, 21.7 d, 13.1 d at pH 5.0, 6.9, 8.0, respectively @ 25°C (Meikle *et al.* 1983);
Photolysis (aqueous) half-life: 31 d in midsummer at 0.001 cm depth; 345 d in midwinter at 0.001 cm depth; 43 d in midsummer at 1 m depth (Dilling *et al.* 1984).

4-3.0 Human and wildlife dietary values

Food tolerances and FDA action levels not established (USEPA 2000a; 2002; USFDA 2000).

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

Mallard duck: 136 mg/kg (Stevenson 1965; cited in USEPA 2000c)
203 mg/kg (Roberts & Phillips 1987; cited in USEPA 2000c)

Wildlife dietary NOECs for animals with significant food sources in water

Mallard duck: 46 mg/kg (Fink & Beavers 1977; cited in USEPA 2000c)
30 mg/kg (Hakin 1990; cited inUSEPA 2000c)
25 mg/kg (Fink *et al.* 1978; cited in USEPA 2000c)

These wildlife values were cited in USEPA (2000c), but are in unpublished reports. Original references could not be found. No other dietary values were found for chlorpyrifos.

4-4.0 Ecotoxicity data

Using data sources in Tables 3.1 and 3.2 (Chapter 3, Appendix 3B), approximately 340 original studies of the effects of chlorpyrifos on aquatic life were identified. Most of the single-species effects studies identified for this criteria derivation

were summarized using the form shown in Figure 3.3 (Chapter 3, Appendix 3A). Information in these summaries was used to evaluate each study for relevance and reliability based using the rating systems described in the methodology (Chapter 3; section 3-2.3). Some chlorpyrifos studies were deemed irrelevant from an initial screening and were not summarized (e.g., studies not using whole-animal exposures). Ecosystem-level studies were not summarized due to their complexity. Many mosquito studies were conducted according to methods described by the World Health Organization (WHO 1963), but this methodology was judged unacceptable by more recent standards due to such things as allowing use of deionized water as a dilution water, using 4^{th} instar larvae rather than 2^{nd}-3^{rd} instars as required by ASTM (2005) and USEPA (2000b), 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). Therefore, studies citing WHO methods were not given credit for following an acceptable standard (or equivalent) method. Copies of completed summaries for all studies rated relevant and reliable (RR) for criteria derivation are included in Appendix 4B of this chapter.

Using the data evaluation criteria, 25 acute studies yielding 64 toxicity values were judged relevant and reliable for criteria derivation (Tables 4.1 and 4.2, Appendix 4A). The Chinook salmon study by Wheelock *et al*. (2005) did not calculate an LC50 value, but raw data were available and a value was calculated using the trimmed Spearman-Karber method (Hamilton *et al.* 1977; USEPA 2006). Similarly, 96-h raw data from a chronic *Ceriodaphnia dubia* study (CDFG 1999) were used to calculate an LC_{50} of 0.0396 μg/L. Four chronic studies yielding 19 toxicity values were both relevant and reliable (2 crustaceans, 1 insect, and 1 fish; Tables 4.3 and 4.4, Appendix 4A). Eighteen studies were rated RL, LL, or LR and may be used as supplemental information for evaluation of derived criteria (Table 4.5, Appendix 4A). Additional freshwater acute toxicity studies for bluegill sunfish, *Daphnia magna*, *Hyalella azteca*, and gulf killifish, as well as one chronic fathead minnow study were found in the USEPA Office of Pesticide Programs (OPP) Pesticide Ecotoxicity Database (PED; www.ipmcenters.org/pesticides.cfm). However, the original data were not available and not enough information was given in the database to thoroughly evaluate the studies. Original data that had been found for several studies found in the PED did not pass the data screening process, indicating that reliability and relevance of data are not ensured merely by inclusion in the PED. For this reason, and since toxicity values reported for these additional studies fell within the range of sensitivity of data already judged relevant and reliable, these additional studies were not added to the data set to be used for criteria derivation.

All of the freshwater plant studies that were found used formulations of chlorpyrifos and had other problems resulting in ratings of N for either relevance or reliability, or both (Birmingham & Colman 1977; Butcher *et al.* 1977; Samson & Popovic 1988; Van Donk *et al.* 1992), while all of the tests with chlopryrifos of $\geq$ 80% purity were for saltwater species (Borthwick & Walsh 1981; Walsh *et al.* 1988). Thus, no plant studies of chlorpyrifos were rated relevant and reliable for criteria derivation. Only the saltwater algal study by *Walsh et al*. (1988) was rated highly enough to be used as

supporting data. This study reported EC_{50}s of 240 and 640 μg/L for population density of *Minutocellus polymorphus* and *Skeletonema costata*, respectively. These values are orders of magnitude higher than chronic toxicity values for invertebrates and fish (Tables 4.3 and 4.5). This limited data set indicates that setting criteria without plant values should not lead to underprotective criteria.

Twenty-seven mesocosm, microcosm and ecosystem (field and laboratory) studies were found. Most of these studies used formulations, rather than chlorpyrifos of ≥ 80% purity. Also, for many of them, chorpyrifos levels were not measured, and other water quality parameters were not reported. Using the rating system described in section 3-2.3 of the methodology, 20 of these studies were rated R or L and may be used as supporting data (Table 4.6).

Two studies of chlorpyrifos effects on wildlife were found. Herin *et al*. (1978) studied the effects of dietary chlorpyrifos exposure in mallard ducks. No NOEC was determined because the study did not use low enough chlorpyrifos concentrations. Wilson *et al*. (1991) studied non-dietary chlorpyrifos exposure in red-tailed hawks. In this methodology wildlife data are used only to assess whether or not water quality criteria are set at levels that could cause harm to wildlife due to biaccumulation in food items. Since neither the Herin *et al*. (1978) nor Wilson *et al*. (1991) studies produced NOEC values, they are not useful for this assessment. Additional wildlife values were found in USEPA (2000c), but original studies could not be found for review (values are listed in section 4-3.0).

Raw data were available for two acute toxicity studies (CDFG 1992g; h) with the opossum shrimp *Neomysis mercedis*. These data were used with the USEPA ACE program v. 2.0 (USEPA 2003a) to estimate chronic toxicity values (to enhance the chronic data set). Tables 4.7 and 4.8 show the raw data used for the ACE analyses. The life-cycle of *N. mercedis* is 3-4 mo (Brandt *et al.* 1993), thus the ACE model was set to estimate chronic toxicity at 120 d. For both tests, the accelerated life testing (ALT) model was used. Both *N. mercedis* tests yielded the same chronic value of 0.001 μg/L (the 120-d, 1% mortality value), which were added to the chronic data set (Table4.3).

4-5.0 Data reduction

Chlorpyrifos data were reduced according to procedures in Chapter 3, section 3-2.4. Acceptable acute and chronic data that were excluded, and the reasons for their exclusion, are shown in Tables 4.2 and 4.4, respectively. The final acute and chronic data sets are shown in Tables 4.1 and 4.3, respectively. The final acute data set contains 17 species mean acute values; the final chronic set contains 3 species mean chronic values.

4-6.0 Acute criteria calculation

Since at least 5 acceptable acute toxicity values are available from 5 different families (as described in Chapter 3, section 3.1.1.), the SSD procedure was used to derive 5^{th} percentile values (median and 95% confidence limit), as well as 1^{st} percentile values

(median and 95% confidence limit). Using the BurrliOz v. 1.0.13 program (CSIRO 2001) a Reciprocal Weibull distribution (i.e., the limiting Burr Type III distribution when the *k* parameter is > 100) was fit and the following values were obtained.

Fit parameters: $\alpha = 0.697$; $\beta = 0.386$.

5^{th} percentile, 50% confidence limit: 0.023 μg/L (23 ng/L)
5^{th} percentile, 95% confidence limit: 0.018 μg/L (18 ng/L)
1^{st} percentile, 50% confidence limit: 0.008 μg/L (8 ng/L)
1^{st} percentile, 95% confidence limit: 0.004 μg/L (4 ng/L)

Recommended acute value = 0.023 μg/L (median 5^{th} percentile value)

Acute criterion = acute value ÷ 2 = 0.0115 μg/L = 11.5 ng/L

Note: by way of example only, the assessment factor (AF) method was applied to the chlorpyrifos data set to determine the range of acute criteria that would be obtained depending on whether the data set contained 1, 2, 3 or 4 values. The lowest value in the data set is 0.035 μg/L for *Daphnia ambigua* (Harmon et al. 2003). Since this species is in the family Daphniidae and the genus *Daphnia*, the AF method can be used. The following acute values were obtained and then divided by 2 to determine hypothetical acute criteria.

1 sample: 35 ng/L ÷ (57 x 10) = 0.06 ng/L ⇒ Acute criterion = 0.03 ng/L
2 samples: 35 ng/L ÷ 36 = 0.97 ng/L ⇒ Acute criterion = 0.49 ng/L
3 samples: 35 ng/L ÷ 7.8 = 4.5 ng/L ⇒ Acute criterion = 2.2 ng/L
4 samples: 35 ng/L ÷ 5.1 = 6.9 ng/L ⇒ Acute criterion = 3.4 ng/L

4-7.0 Chronic criteria calculation

Fewer than 5 chronic toxicity values from 5 different families are available, thus the acute-to-chronic ratio (ACR) method was used. Three chronic values in the accepted (RR) data set have corresponding acute values. Two are for *Ceriodaphnia dubia* (CDFG 1994), and one is for *Pimephales* promelas (Jarvinen & Tanner 1982). To avoid excessive layers of estimation, the estimated chronic values for *N. mercedis* were not used to calculate ACRs. Since not enough freshwater data were available for calculation of the ACR, saltwater data were used to meet minimum data requirements. Among saltwater studies reviewed, acute and corresponding chronic data were available for California grunion, *Leuresthes tenuis* (Borthwick *et al.* 1985; 1985). *Ceriodaphnia dubia*, *P. promelas* and *L. tenuis* are from three different families representing two fish and one invertebrate and so can be used to calculate an ACR for chlorpyrifos. The geometric mean of ACRs for *C. dubia* is 1.0, the value for *P. promelas* is 60.9, and the value for *L. tenuis* is 5.0. The ACRs increase with increasing species mean acute values (SMAVs) for this data set, so only those values within a factor of 10 of the ACR of the species with the SMAV nearest the 5^{th} percentile value were used to determine a final multi-species ACR of 2.2. Data used to determine the ACR are summarized in Table 4.4. The ACR of 2.2,

determined by this methodology is lower than the value of 4.1 determined by the USEPA (1986) or the value of 3.5 determined by the Siepmann & Finlayson (2000). The difference in values is due to different data sets resulting from new data and/or from different data acceptiblity standards in the different methodologies.

Chronic criterion = acute 5^{th} percentile value ÷ ACR = 0.023 µg/L ÷ 2.2 = 0.0105 µg/L
= 10.5 ng/L

4-8.0 Bioavailability

Few studies of the effects of suspended and dissolved solids on the bioavailability of chlorpyrifos are available. Phillips *et al.* (2003) found that fewer walleye survived exposure to chlorpyrifos-humic acid (HA) complexes than to either HA alone or chlorpyrifos alone, and no differences were seen in cholinesterase inhibition between chlorpyrifos-HA and aqueous chlorpyrifos exposures. In a study of chlorpyrifos binding to colloidal materials, Wu & Laird (2004) found that chlorpyrifos sorbed strongly to a calcium-humate and did not desorb, but moderately sorbed to, and desorbed from, a river sediment. They concluded that both the organic and inorganic materials in suspended sediment affect the adsorption and desorption of chlorpyrifos. These studies indicate that bioavailability of chlorpyrifos is not predictable without site-specific, species-specific data. Until such data are available, compliance with criteria should be determined on a total concentration basis.

4-9.0 Mixtures

Chlorpyrifos often occurs in the environment with other organophosphate pesticides (discussed in Phase I, TenBrook & Tjeerdema 2006). Since compounds in this class have a similar mode of action, either the toxic unit or the relative potency factor approach (Chapter 3, section 3-5.2.1) can be used to determine compliance in cases where organophosphate mixtures are present.

Several studies report greater than additive toxicity of chlorpyrifos in combination with triazine herbicides (Anderson & Lydy 2002; Belden & Lydy 2000; Jin-Clark *et al.* 2002; Lydy & Austin 2005). Chlorpyrifos synergized the action of esfenvalerate in fathead minnows, but the same response was not clear in the midge *Chironomus tentans* (Belden & Lydy 2006). Table 4.9 shows the synergistic ratios (SR) for these studies. The SR is obtained by dividing the EC_{50} or 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). SR values > 1 indicate synergistic interaction.

Since multiple SR (or K) values are available for atrazine over a range of concentrations, these values were used to derive a quantitative relationship. The JMP IN program v. 5.1.2 (JMP 2004) was used to do least squares regressions of the *C. tentans* and *Hyalella azteca* data together, which resulted in a significant relationship between

atrazine concentration and K values ($p < 0.05$). The relationship is described by the following equation:

$K = 0.008(\text{Conc. Atrazine}) + 1.27 \quad (r^2 = 0.52, p = 0.03)$ (4.2)

The r^2 value is not very high , so the species were considered indepently. For *C. tentans* the relationship between K and atrazine concentration was not significant ($p > 0.05$), but for *H. azteca* the following relationship was determined:

$K = 0.009(\text{Conc. Atrazine}) + 1.12 \quad (r^2 = 0.94, p = 0.03)$ (4.3)

This relationship should be used with caution due to the small data set (n = 4) and due the fact that three of the four values are from the same study. The lack of a significant relationship between atrazine concentration and K values for *C. tentans* may be due to differences between studies (there were not enough data to evaluate the experiment effect statistically).

Since *H. azteca* is among the most sensitive species in the data set, it is worthwhile to use equation 4.3 to estimate K values for various levels of atrazine co-occurring with chlorpyrifos. To determine compliance, or to assess potential for harm, equation 4.3 may be used to establish the effective concentration of chlorpyrifos in the presence of atrazine:

$$C_a = C_m(K) \quad (4.3)$$

where:

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

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

Ankley & Collyard (1995) reported reduced toxicity of chlropyrifos 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 inhibit organophosphates by inhibiting the P450 enzymes that activate the pesticides (Ankley *et al.* 1991; Hunt *et al.* 2003). Since no interaction coefficients (K) have been derived to describe antagonism between chlorpyrifos and piperonyl butoxide, it is not possible to quantify this non-additive toxicity. Consequently, there is no way to account for this interaction in compliance determination.

4-10.0 Temperature, pH, other water quality effects

Several studies have shown increased chlorpyrifos toxicity with increased temperature (Humphrey & Klumpp 2003; Johnson & Finley 1980; Macek *et al.* 1969; Mayer & Ellersieck 1986). However, none of these studies was rated RR, so they could not be used to quantify effects of temperature on chlorpyrifos toxicity. Among chlorpyrifos studies rated RR, there are no cases of chronic tests conducted at different temperatures for the same species. There are three acute *Pimephales promelas* studies conducted at 25^{o} C (Geiger *et al.* 1988; Holcombe *et al.* 1982; Jarvinen & Tanner 1982), one conducted at 16^{o} C (Geiger *et al.* 1988) and one at 17.3^{o} C (Phipps & Holcombe 1985). Least squares regression of these values shows a strong relationship of increasing chlorpyrifos toxicity with increasing temperature ($r^2 = 0.95$; $p < 0.01$). No invertebrate studies of temperature effects are in the data set.

Rainbow trout and bluegill studies (Mayer & Ellersieck 1986) included in the supplemental data table were rated highly enough to be used as supporting information, and can be used here for comparison to the derived criteria. For both species, the acute toxicity of chlorpyrifos increased with increasing temperature, but only for rainbow trout at 18^{o}C did the 96-h LC_{50} of < 1 μg/L approach the proposed criterion of 11.5 ng/L. A definitive LC_{50} value would be needed to make a reasonable assessment of potential risks to rainbow trout exposed to chlorpyrifos at 18^{o}C. At 13^{o}C the 96-h LC_{50} for rainbow trout was 7.1 μg/L, well above the proposed acute criterion. Bluegill sensitivity was highest at the highest temperature tested (29^{o}C), but the 96-h LC_{50} at 29^{o}C was 1.7 μg/L, well above the proposed acute criterion.

Although there is evidence of temperature effects on chlropyrifos toxicity, there are not data for enough species to adequately quantify the relationship at this time. Therefore, only results of tests conducted at standard temperatures (i.e., temperatures recommended in standard toxicity test methods) are included in the data set and equations are not needed for criteria expression.

4-11.0 Sensitive species

The calculated acute and chronic criteria (11.5 and 10.5 ng/L, respectively) are below the lowest acute and chronic values in the data set. The lowest acute value in either the data set rated RR, or those rated RL, LR, or LL is 35 ng/L for *Daphnia ambigua* (Harmon *et al.* 2003). The lowest measured chronic value in either data set is a maximum acceptable toxicant concentration (MATC) of 40 ng/L for *Ceriodaphnia dubia* (CDFG 1999). The estimated chronic value of 1 ng/L for *Neomysis mercedis* (CDFG 1992g; h) is below the calculated criterion, but the chronic criterion should not be adjusted until and unless that estimated value is supported by measured data. Both the acute and chronic criteria, as calculated, should be adequately protective based on currently available data from single-species toxicity tests.

4-12.0 Bioaccumulation

Bioaccumulation of chlorpyrifos has been measured in fish and plants (Karen *et al.* 1998; Rice *et al.* 1997; Welling & Devries 1992). It has a log K_{ow} of 4.96 (Sangster Research Laboratories 2004), and molecular weight of 350.6, which further indicate its bioaccumulative potential. There are no tolerance or FDA action levels for fish tissue (USEPA 2000a; 2002; USFDA 2000), but there are a few reported dietary NOEC values for mallard ducks. As noted in section 4-3.0, all of the available mallard duck LC_{50}s from USEPA (2000c) are from unpublished studies and cannot be reviewed for reliability. Herin *et al*. (1978) was reviewed and rated L, but no NOEC values were determined.

Varó *et al.* (2002) reported biomagnification factors (BMF) of 0.7-0.3 (decreasing with increasing time of exposure) for chlorpyrifos in a two-level food chain experiment with *Artemia* spp. and the fish *Aphanus iberius*. These BMF values of less than 1.0, and the fact that the BMFs decrease over time, indicate that chlorpyrifos does not biomagnify. Varó *et al.* (2002) suggest that this is due to the ability of fish to biotransform chlorpyrifos and to the log K_{OW} for chlorpyrifos being < 6. Berglund *et al.* (2000) reported no biomagnification over three trophic levels for polychlorinated biphenyls with log K_{OW} values < 6.

A BCF value of 1,847 L/kg was reported for guppies (Welling & Devries 1992), but that value was obtained under inappropriate exposure conditions (14-d static). A value of 1700 (unitless) was reported by Jarvinen *et al*. (1983) for fathead minnows. Rice *et al*. (1997) reported BCF values ranging from 727-1143 (unitless) in tests with Japanese medaka, but those values were reported after a 48-h exposure, with no confirmation of steady-state conditions. Karen *et al*. (1998) studied partitioning of chlorpyrifos between water and aquatic macrophytes, but did not determine steady-state BCF values. A lipid-based BCF value of 2.1×10^4 L/kg is provided by Deneer (1994). The highest of the non-lipid based values (1700) is used in this analysis to assess a worst-case bioaccumulation scenario.

It is interesting to note that the highest BMF of 0.7 reported by Varó *et al.* (2002) is in good agreement with the default value of 1.0 given in Table 3.18 (Chapter 3, Appendix 3B) for compounds with BCF < 2000.

The dietary LC_{50} of 136 mg/kg for mallards (Stevenson 1965) was translated to a water value using equation 3.17 (Chapter 3, section 3-6.2) along with a BMF value of 0.7, which represents the highest value measured by Varó *et al.* (2002), and will give a worst-case assessment :

$NOEC_{water}$ = 136 mg/kg ÷ 1700 * 0.7 = 0.114 mg/L = 114 μg/L

The proposed acute criterion is well below the $NOEC_{water}$ based on acute toxicity to mallards.

Although the original study could not be evaluated, the dietary NOEC of 25 mg/kg for mallard duck (Fink *et al.* 1978) was used to get a worst-case idea of potential chronic harm due to bioaccumulation.

$NOEC_{water}$ = 25 mg/kg ÷ (1700 * 0.7) = 2.1 x 10^{-2} mg/L = 21 μg/L

The proposed chronic criterion is below the estimated chronic $NOEC_{water}$ value for mallard ducks. Neither the acute nor chronic criteria are expected to cause unacceptable levels of bioaccumulation.

4-13.0 Ecosystem and other studies

Twenty studies of chlorpyrifos effects on microcosms, mesocosm and model ecosystems were rated acceptable (R or L rating; Table 4.6). Many studies involved one-time application of chlorpyrifos at levels well above the calculated criteria and so are not relevant for this analysis (Brock *et al.* 1992b; Brock *et al.* 1993; Cuppen *et al.* 1995; Kersting & Van Wijngaarden 1992; Rawn *et al.* 1978; Van Breukelen & Brock 1993; Van Donk *et al.* 1995; Van Wijngaarden & Leeuwangh 1989). Ward *et al*. (1995) observed reduced abundance of macroinvertebrates within 11 d, as well as secondary effects on biomass with continuous chlorpyrifos treatment every day for 21 d at 0.1 μg/L. In tests of chlorpyrifos effects on the mayfly *Cloeon dipterum*, Van Wijngaarden (1993) found that effects were no longer demonstrable when concentrations reached 0.16, 0.2 and 0.06 μg/L in laboratory microcosms, outdoor ponds and experimental ditches, respectively, based on 48-h laboratory exposures of *Cloeon dipterum* to samples from each experimental habitat. At a continuous concentration of 0.1 μg/L for 7 wk, chlorpyrifos caused primary effects on species in the order Cyclopoida and on *Daphnia galeata*, and caused secondary effects on the rotifer *Keratella quadrata* (Van Den Brink *et al.* 1995). Bluegill survival was reduced by 3%, and largemouth bass by 10%, 63 d after treatment of an outdoor pond with 0.97 μg/L chlorpyrifos, compared to 1% reduction in survival in control ponds (Macek *et al.* 1972). After exposure in outdoor pond microcosms Giddings *et al*. (1997) report 3-mo IC_{25} (25% inhibition) values for bluegill sunfish of 0.4 and 1.9 μg/L, based on survival and total biomass, respectively.

Van Wijngaarden *et al*. (1996) report 7-d mesocosm EC_{50} vlaues ranging from 0.1 μg/L for *Mystacides* spp. to 2.8 μg/L for *Ablabesmyia* spp. In the same study, 7-d EC_{10} values ranging from 0.01 μg/L for *Mystacides* spp. to 2.7 for *Ablabesmyia* spp. were reported. Van Wijngaarden *et al*. (2005) report community 4-5 wk NOECs of 0.1 μg/L in three separate laboratory microcosm experiments of chlorpyrifos exposure to plankton-dominated nutrient-rich microcosms. Similarly, species and community NOECs of 0.1 μg/L were reported from 0.1-55 wk post-treatment for macroinvertebrate and zooplankton communities exposed to chlopryifos in outdoor experimental ditches (Van Den Brink *et al.* 1996). Pusey *et al*. (1994) reported no effects on taxon richness for 80 d from one-time 6-h applications of chlopryrifos at 0.1 μg/L to an outdoor artificial stream. In various measures of ecosystem metabolism Kersting & Van Den Brink (1997) report a 20-wk NOEC of 0.9 μg/L chlorpyrifos based on system oxygen concentration, a 12-wk NOEC of 6 μg/L based on system pH, and a 24-wk NOEC of < 0.1 μg/L based on gross

production (mg O_2/L-d) and respiration (mg O_2/L-d). The authors acknowledge that the latter two significant findings may be due to a Type II error. Brock *et al*. (1992b) observed that model ecosystems were able to recover when concentrations of chlorpyrifos fell below 0.1-0.2 μg/L. In studies in experimental streams, Eaton *et al*. (1985) exposed macroinvertebrates, fathead minnows and bluegills to continuous concentrations of chlorpyrifos ranging from 0.12-0.83 μg/L, and pulsed concentrations ranging from 0.94 -7.0 μg/L-d (from area under time-concentration curves). Translating the time-concentration values to apply to the 1-h acute averaging period yields range of 1-h concentrations of 22.6-168 μg/L, and a range of 4-d concentrations of 0.24-1.8 μg/L. Differences in macroinverterbrate communities were observed in both the continuous and pulsed-treated streams compared to a control stream over the 100-d duration of the study. Deformities (19.4-23.6%) were observed in fathead minnows in two samplings from the pulse exposure experiment, but no other effects were observed in either bluegills or fathead minnows.

Werner *et al*. (2000) performed laboratory toxicity tests and toxicity identification evaluations on samples collected from the Sacramento-San Joaquin River Delta. Six filtered samples exhibiting acute toxicity (measured as significant mortality in $\leq$ 4 d) had chlorpyrifos concentrations ranging from 0.09-0.52 μg/L (with no other pesticides detected). Two filtered samples exhibiting chronic toxicity (significant mortality in > 4 d) had chlorpyrifos concentrations ranging from 0.058-0.068 μg/L (with no other pesticides). Hundreds of other samples did not exhibit toxicity, implying that they had chlorpyrifos levels below those found in the toxic samples.

Given the results of these studies, it appears that an acute criterion of 11.5 ng/L and a chronic criterion of 10.5 ng/L will be protective organisms in ecosystems. These results are not entirely conclusive because, as discussed in section 4-8.0, the potential effects of suspended and dissolved solids in natural waters on chlorpyrifos bioavailbility cannot be predicted.

4-14.0 Threatened and endangered species

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 web site (CDFG 2006a; b). The species *Oncorhynchus mykiss* (steelhead rainbow trout) is listed as federally threatened throughout California. The data set used to calculate the acute criterion includes a value for *O. mykiss* of 8.0 μg/L, indicating that the acute criterion of 11.5 ng/L should be protective of this species. *Oncorhynchus tshawytscha* (Chinook salmon) is listed as federally threatened or endangered, depending on season and location. The acute value for *O. tshawytscha* in the data set is 15.96 μg/L, so this species, too should be protected by the criterion. None of the other listed animals or plants is represented in the acute or chronic data set. However, some of the listed species are represented in the acute data set by members of the same family or genus and for these, the USEPA interspecies correlation estimation software (ICE v. 1.0, USEPA 2003b) was used to estimate toxicity values. Table 4.10 summarizes the results of the ICE analyses. The values in Table 4.10 range from 4.0 μg/L for *Oncorhynchus clarki*

henshawi (Lahontan cutthroat trout) to 171 μg/L for *Ptychocheilus lucius* (Colorado squawfish). The value of 9.2 μg/L estimated by ICE for *O. tshawytscha* is in good agreement with the measured value of 15.96 μg/L (calculated from data in Wheelock *et al.* 2005).

No plant data were rated relevant and reliable for criteria derivation, and none of the studies were of plants on the state or federal endangered, threatened or rare species lists. As discussed in section 4-4.0, plants are relatively insensitive to chlorpyrifos and 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 under-protective of threatened and endangered species. The caveat is that this assessment is lacking in that cladocerans and insects are the most sensitive species in the acute criterion data set, but no data were found for effects of chlorpyrifos on federally endangered cladocerans or insects, or acceptable surrogates (i.e., in the same family).

4-15.0 Harmonization/coherence across media

The MacKay (2001) fugacity-based environmental equilibrium partitioning model, Level I, was used to estimate equilibrium concentrations of chlorpyrifos expected in sediment, biota and air based on having 10.5 ng/L in water (i.e., the chronic criterion). To use this model, the organic carbon content of soil was set to zero so that no chlorpyrifos would partition into that compartment which is not in direct contact with water. Chlorpyrifos loading was adjusted by trial and error to a level that resulted in a final concentration in water of 10.5 ng/L. Default values were used for compartment volumes. The model was run several times over ranges of sediment and suspended sediment organic carbon content, and fish lipid content. Model inputs and outputs are summarized in Tables 4.12 and 4.13, respectively. The model used the K_{OW} to estimate a fish-water partition coefficient of 4,560, which is somewhat higher than the BCF of 1700 measured by Jarvinen *et al*. (1983). A log organic carbon-water partition coefficient (log K_{OC}) of 4.57 L/kg was also estimated. This log K_{OC} is within an order of magnitude of the geometric mean value of 4.06 determined in section 4-2.0. Since these estimated partition coefficients are somewhat higher than measured values, the model output will tend to overestimate the levels of chlorpyrifos in fish, sediment and suspended sediment.

The fish tissue concentration obtained from the worst case considered here (20% lipid content) was 191 ng/g. This fish tissue value, is well below the dietary NOEC values of 25-46 μg/g for wildlife (section 4-3.0). There are no federal or state air or sediment quality standards for chlorpyrifos, nor is chlorpyrifos mentioned in the NOAA sediment quality guidelines (California Air Resources Board 2005, USEPA 2006b,c, NOAA 1999). Based on this modeling and available guideline values, the chronic criterion of 10.5 ng/L should not cause problems in other environmental compartments.

4-16.0 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 chlorpyrifos does not exceed 10.5 ng/L more than once every three years on the average and if the one-hour average concentration does not exceed 11.5 ng/L more than once every three years on the average.

These criteria are lower than the USEPA chlorpyrifos acute and chronic freshwater criteria of 83 and 41 ng/L, respectively (USEPA 1986). They are also lower than current water quality objectives for the lower San Joaquin River (CVRWQCB 2005) and those proposed for the Sacramento and San Joaquin River Delta (CVRWQCB 2006). Acute and chronic objectives for both of these water bodies are 25 and 15 ng/L, respectively. These objectives are based on criteria derived by the California Department of Fish and Game (Siepmann & Finlayson 2000) using the USEPA (1985) methodology, but with a different data set than that used in USEPA (1986).

Table 2.4 of Chapter 2 of this report shows that when the same data set is used, the median 95th percentile acute values determined by the new methodology (23 ng/L) compares well with that determined by the USEPA methodology (32 ng/L). Therefore, the differences in the final acute criteria values are due to different data sets. The current data set includes values from 22 studies published after 1986, when the USEPA criteria were derived, and values from 9 studies published in or after 2000, when the Sacramento and San Joaquin River criteria were derived (Siepmann & Finlayson 2000). Chronic criteria in all three derivations were accomplished by applying an acute-to-chronic ratio (ACR) to the 5th percentile acute value. Thus, the differences in chronic criteria are due in part to the different acute data sets, and in part to the use of different ACRs. The USEPA (1986) derivation used an ACR of 4.064; Siepmann & Finlayson (2000) used 3.0, and this methodology used 2.2.

The USEPA (1986) acute criterion of 83 ng/L is higher than the lowest acute value of 35 ng/L for *Daphnia ambigua* in the current data set and is clearly not protective of the most senstivie spsecies. The Sacramento and San Joaquin River acute objective of 25 ng/L (CVRWQCB 2005; 2006) is lower than the lowest acute value, but provides a margin of safety of just 1.4. The criterion of 11.5 μg/L derived by this methodology provides a larger, but not excessive, margin of safety (3.0) for the most sensitive species. The USEPA (1986) chronic criterion of 41 ng/L is approximately equal to the lowest chronic value of 40 ng/L for *Ceriodaphni dubia* in the current data set. Clearly, there is potential for harm if the concentration of chlorpyrifos were at the level of the USEPA chronic criterion. The Sacramento and San Joaquin River chronic objective of 15 ng/L provides a margin of safety of 2.7, and the chronic criterion of 10.5 μg/L by this methodology provides a slightly larger margin of safety (3.8).

4-17.0 References

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Appendix 4A
Data Tables

Table 4.1. Final acute toxicity data set for chlorpyrifos. All studies were rated 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/EC50 (ug/L)	Reference
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Meas	99.0%	96 h	25	Mortality	< 24 h	0.053	Bailey *et al.* (1997)
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Meas	99.0%	96 h	25	Mortality	< 24 h	0.055	Bailey *et al.* (1997)
Ceriodaphnia dubia	Cladoceran	Daphniidae	SR	Meas	99.0%	96 h	24.6	Mortality	< 24 h	0.13	CDFG (1992f)
Ceriodaphnia dubia	Cladoceran	Daphniidae	SR	Meas	99.0%	96 h	24.3	Mortality	< 24 h	0.08	CDFG (1992c)
Ceriodaphnia dubia	Cladoceran	Daphniidae	SR	Meas	99.8%	96 h	24.6	Survival	< 24 h	0.0396	CDFG (1999)
Ceriodaphnia dubia	Cladoceran	Daphniidae						Geometric Mean		**0.0654**	
Chironomus tentans	Insect	Chironomidae	S	Meas	98.0%	96 h	21	Immobility	3-4th instar	0.16	Belden & Lydy (2006)
Chironomus tentans	Insect	Chironomidae	S	Meas	90.0%	96 h	21	Immobility	4th instar	0.17	Lydy & Austin (2005)
Chironomus tentans	Insect	Chironomidae	S	Meas	98.0%	96 h	20	Immobility + Mortality	4th instar	0.39	Belden & Lydy (2000)
Chironomus tentans	Insect	Chironomidae						Geometric Mean		**0.220**	
Daphnia ambigua	Cladoceran	Daphniidae	S	Meas	99.0%	48 h	21	Immobility	Neonates	**0.035**	Harmon *et al.* (2003)

Table 4.1. Final acute toxicity data set for chlorpyrifos. All studies were rated 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 (^{o}C)	Endpoint	Age/size	LC/EC50 (ug/L)	Reference
Daphnia magna	Cladoceran	Daphniidae	S	Meas	99.0%	48 h	19.5	Mortality	< 24 h	**1.0**	Kersting & Van Wijngaarden (1992)
Daphnia pulex	Cladoceran	Daphniidae	S	Meas	Technical	48 h	20	Immobility	< 24 h	**0.25**	Van Der Hoeven & Gerritsen (1997)
Hyalella azteca	Amphipod	Hyalellidae	S	Meas	90.0%	96 h	20	Mortality	14-21 d	**0.0427**	Anderson & Lydy (2002)
Ictalurus punctatus	Channel catfish	Ictaluridae	FT	Meas	99.9%	96 h	17.3	Mortality	7.9 g	**806**	Phipps & Holcombe (1985)
Lepomis macrochirus	Blugill	Centrarchidae	FT	Meas	99.9%	96 h	17.3	Mortality	0.8 g	**10**	Phipps & Holcombe (1985)
Neomysis mercedis	Opossum shrimp	Mysidae	SR	Meas	99.0%	96 h	17.4	Mortality	< 5 d	0.15	CDFG (1992e)
Neomysis mercedis	Opossum shrimp	Mysidae	SR	Meas	99.0%	96 h	17.2	Mortality	< 5 d	0.16	CDFG (1992a)
Neomysis mercedis	Opossum shrimp	Mysidae	SR	Meas	99.0%	96 h	17.1	Mortalit	< 5 d	0.14	CDFG (1992d)
Neomysis mercedis	Opossum shrimp	Mysidae						Geometric Mean		**0.150**	
Oncorhynhus mykiss	Rainbow trout	Salmonidae	FT	Meas	99.9%	96 h	12	Mortality	Juvenile	**8.0**	Holcombe *et al*. (1982)

Table 4.1. Final acute toxicity data set for chlorpyrifos. All studies were rated 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 (^{o}C)	Endpoint	Age/size	LC/EC50 (ug/L)	Reference
Oncorhynchus tshawytscha	Chinook salmon	Salmonidae	SR	Meas	99.5%	96 h	14.8	Mortality	Juvenile	**15.96**	Wheelock *et al.* (2005)
Orconectes immunis	Crayfish	Cambaridae	FT	Meas	99.9%	96 h	17.3	Mortality	1.8 g	**6**	Phipps & Holcombe (1985)
Pimephales promelas	Fathead minnow	Cyprinidae	FT	Meas	99.9%	96 h	25	Mortality	32 d	200	Geiger *et al.* (1988)
Pimephales promelas	Fathead minnow	Cyprinidae	FT	Meas	99.9%	96 h	25	Mortality	31-32 d	203	Holcombe *et al.* (1982)
Pimephales promelas	Fathead minnow	Cyprinidae	FT	Meas	98.7%	96 h	25	Mortality	Newly hatched	140	Jarvinen & Tanner (1982)
Pimephales promelas	Fathead minnow	Cyprinidae						Geometric Mean		**178**	
Procloeon sp.	Insect	Baetidae	SR	Meas	99%	48 h	21.3^{o}C	Mortality	0.5-1.0 cm	0.1791	Anderson *et al.* (2006)
Procloeon sp.	Insect	Baetidae	SR	Meas	99%	48 h	21.3^{o}C	Mortality	0.5-1.0 cm	0.0704	Anderson *et al.* (2006)
Procloeon sp.	Insect	Baetidae	SR	Meas	99%	48 h	21.3^{o}C	Mortality	0.5-1.0 cm	0.0798	Anderson *et al.* (2006)
								Geometric Mean		**0.100**	
Pungitius pungitius	Stickleback	Gasterosteidae	FT	Meas	99.8%	96 h	19	Mortality	Adult	**4.7**	Van Wijngaarden *et al.* (1993)

Table 4.1. Final acute toxicity data set for chlorpyrifos. All studies were rated 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 (^{o}C)	Endpoint	Age/size	LC/EC50 (ug/L)	Reference
Simulium vitatum IS-7	Insect	Simuliidae	S	Meas	98.0%	24 h	19	Mortality	2nd & 3rd instar	**0.06**	Hyder *et al*. (2004)
Xenopus lavis	African clawed frog	Pipidae	SR	Nom	99.80%	96 h	24.7	Mortality	< 24 h	**2410**	El-Merhibi *et al*. (2004)

Table 4.2. Acceptable acute data (rated RR) excluded in data reduction process.

Species	Common identifier	Family	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC50 (ug/L)	Reference	Reason for exclusion
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Meas	99.0%	24 h	25 C	Mortality	< 24 h	0.101	Bailey *et al*. (1997)	1
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Meas	99.0%	48 h	25	Mortality	< 24 h	0.079	Bailey *et al*. (1997)	1
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Meas	99.0%	72 h	25	Mortality	< 24 h	0.078	Bailey *et al*. (1997)	1
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Meas	99.0%	24 h	25	Mortality	< 24 h	0.063	Bailey *et al*. (1997)	1
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Meas	99.0%	48 h	25	Mortality	< 24 h	0.058	Bailey *et al*. (1997)	1
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Meas	99.0%	72 h	25	Mortality	< 24 h	0.058	Bailey *et al*. (1997)	1
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Meas	99.0%	24 h	25	Mortality	< 24 h	0.095	Bailey *et al*. (1997)	1
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Meas	99.0%	48 h	25	Mortality	< 24 h	0.066	Bailey *et al*. (1997)	1
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Meas	99.0%	24 h	25	Mortality	< 24 h	0.086	Bailey *et al*. (1997)	1
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Meas	99.0%	48 h	25	Mortality	< 24 h	0.064	Bailey *et al*. (1997)	1
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Nom	99.8%	48 h	25.2	Mortality	< 24 h	0.05	El-Merhibi *et al*. (2004)	1,2

Table 4.2. Acceptable acute data (rated RR) excluded in data reduction process.

Species	Common identifier	Family	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC50 (ug/L)	Reference	Reason for exclusion
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Meas	99.0%	48 h	25	Immobility	Neonates	0.056	Harmon *et al*. (2003)	1
Chironomus tentans	Insect	Chironomidae	S	Nom	95.0%	96 h	23	Mortality/ Immobility	3rd instar	0.47	Ankley & Collyard (1995)	2
Chironomus tentans	Insect	Chironomidae	S	Nom	99.0%	96 h	20	Immobility	4th instar	0.58	Pape-Lindstrom & Lydy (1997)	2
Chironomus tentans	Insect	Chironomidae	S	Nom	99.0%	96 h	20	Immobility	4th instar	0.75	Pape-Lindstrom & Lydy (1997)	2
Chironomus tentans	Insect	Chironomidae	S	Nom	99.0%	96 h	20	Immobility	4th instar	0.51	Pape-Lindstrom & Lydy (1997)	2
Daphnia magna	Cladoceran	Daphniidae	S	Meas	99.0%	24 h	19.5	Mortality	< 24 h	3.7	Kersting & Van Wijngaarden (1992)	3
Daphnia pulex	Cladoceran	Daphniidae	S	Meas	Technical	48 h	19.5	Mortality	< 24 h	0.3	Van Der Hoeven & Gerritsen (1997)	4
Daphnia pulex	Cladoceran	Daphniidae	S	Meas	Technical	24 h	20	Immobility	< 24 h	0.42	Van Der Hoeven & Gerritsen (1997)	3
Hyalella azteca	Amphipod	S	S	Nom	95.0%	96 h	23	Mortality/ Immobility	7-14 d	0.04	Ankley & Collyard (1995)	2

Table 4.2. Acceptable acute data (rated RR) excluded in data reduction process.

Species	Common identifier	Family	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC50 (ug/L)	Reference	Reason for exclusion
Oncorhynchus mykiss	Rainbow trout	Salmonidae	FT	Meas	99.9%	48 h	25	Mortality	Juvenile	11.4	Holcombe *et al.* (1982)	1
Oncorhynchus mykiss	Rainbow trout	Salmonidae	FT	Meas	99.9%	72 h	25	Mortality	Juvenile	8.0	Holcombe *et al.* (1982)	1
Oncorhynchus mykiss	Rainbow trout	Salmonidae	FT	Meas	99.9%	96 h	17.3	Mortality	3.0 g	9	Phipps & Holcombe (1985)	5
Pungitius pungitius	Stickleback	Gasterosteidae	FT	Meas	99.8%	48 h	19	Mortality	Adult	5.7	Van Wijngaarden *et al.* (1993)	1
Simulium vitatum IS-7	Insect	Simuliidae	S	Meas	98.0%	24 h	19	Mortality	4th & 5th instar	0.11	Hyder *et al.* (2004)	6
Simulium vitatum IS-7	Insect	Simuliidae	S	Meas	98.0%	24 h	19	Mortality	6th & 7th instar	0.68	Hyder *et al.* (2004)	6
Simulium vittatum III-1	Insect	Simuliidae	S	Meas	98.0%	24 h	19	Mortality	6th & 7th instar	0.91	Hyder *et al.* (200)	6
Simulium vittatum III-1	Insect	Simuliidae	S	Meas	98.0%	24 h	19	Mortality	4th & 5th instar	0.13	Hyder *et al.* (2004)	6
Pimephales promelas	Fathead minnow	Cyprinidae	SR	Meas	98.0%	48 h	21	Mobility	< 24 h	200	Belden & Lydy (2006)	1, 7
Pimephales promelas	Fathead minnow	Cyprinidae	FT	Meas	99.9%	24 h	25	Mortality	31-32 d	320	Holcombe *et al.* (1982)	1
Pimephales promelas	Fathead minnow	Cyprinidae	FT	Meas	99.9%	48 h	25	Mortality	31-32 d	248	Holcombe *et al.* (1982)	1

Table 4.2. Acceptable acute data (rated RR) excluded in data reduction process.

Species	Common identifier	Family	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC50 (ug/L)	Reference	Reason for exclusion
Pimephales promelas	Fathead minnow	Cyprinidae	FT	Meas	99.9%	72 h	25	Mortality	31-32 d	220	Holcombe *et al*. (1982)	1
Pimephales promelas	Fathead minnow	Cyprinidae	S	Meas	98.7%	96 h	25	Mortality	Newly hatched	150-170	Jarvinen & Tanner (1982)	7
Pimephales promelas	Fathead minnow	Cyprinidae	FT	Meas	99.9%	96 h	16	Mortality	44 d	506	Geiger *et al*. (1988)	5
Pimephales promelas	Fathead minnow	Cyprinidae	FT	Meas	99.9%	96 h	17.3	Mortality	0.5 g	542	Phipps & Holcombe (1985)	5

1. 96-h result available
2. Test with measured concentrations available
3. 48-h result available
4. More sensitive endpoint available
5. Non-standard temperature
6. More sensitive lifestage available
7. Flow-through test available

Table 4.3. Final chronic toxicity data set for chlorpyrifos. All studies were rated RR and were conducted at standard temperature. Chronic values for *Neomysis mercedis* were estimated from acute data. Values in bold are species mean chronic values. SR: static renewal; FT: flow-through.

Species	Common identifier	Test type	Meas/ Nom	Chemical	Duration	Temp (°C)	Endpoint	Age/size	NOEC (ug/L)	LOEC (ug/L)	MATC (ug/L)	Reference
Ceriodaphnia dubia	Cladoceran	SR	Meas	99.8%	7 d	24.6	Mortality	< 24 h	0.029	0.054	0.0396	CDFG (1999)
Ceriodaphnia dubia	Cladoceran	SR	Meas	99.8%	7 d	24.6	Reproduction	< 24 h	0.029	0.054	0.0396	CDFG (1999)
Ceriodaphnia dubia	Cladoceran						Geometric Mean		0.029	0.054	**0.0396**	
Pimephales promelas	Fathead minnow	FT	Meas	98.7%	60 d	24.3-25.9	Growth	< 24 h	0.63	1.21	0.87	Jarvinen *et al.* (1983)
Pimephales promelas	Fathead minnow	FT	Meas	98.7%	32 d	23.5-26.0	Weight	Newly hatched	1.6	3.2	2.3	Jarvinen & Tanner (1982)
Pimephales promelas	Fathead minnow						Geometric Mean		1.0	1.97	**1.4**	
Neomysis mercedis	Opossum shrimp	SR	Meas	99.0%	96 h	17	Mortality	< 5 d	0.001			CDFG (1992a)
Neomysis mercedis	Opossum shrimp	SR	Meas	99.0%	96 h	17	Mortality	< 5 d	0.001			CDFG (1992e)
							Geometric Mean		**0.001**			

Table 4.4. Calculation of the final acute-to-chronic ratio. Values in bold were used in the calculation.

Species	Common identifier	LC50 (μg/L)	Reference	Chronic Endpoint	MATC (μg/L)	Reference	ACR (LC50/MATC)
Ceriodaphnia dubia	Cladoceran	0.0396	CDFG (1999)	Mortality	0.04	CDFG (1999)	1.0
Ceriodaphnia dubia	Cladoceran	0.0396	CDFG (1999)	Reproduction	0.04	CDFG (1999)	1.0
Ceriodaphnia dubia	Cladoceran					**Species Mean ACR**	**1.0**
Pimephales promelas	Fathead minnow	140	Jarvinen & Tanner (1982)	Weight	2.3	Jarvinen & Tanner (1982)	60.9[a]
Leuresthes tenuis[b]	California grunion	1.0	Borthwick *et al*. (1985)	Growth	0.2	Goodman *et al*. (1985)	**5.0**
						Final ACR	**2.2**

[a] Excluded; > 10x the ACR for cladocerons whose species mean acute value is nearest the 5th percentile value of 0.026 μg/L.
[b] Saltwater species included in ACR calculation; study rated relevant and reliable in every other respect (see Table 4.6).

Table 4.5. Acceptable chronic data excluded in data reduction process.

Species	Common identifier	Test type	Meas /Nom	Chemical purity	Duration	Temp (oC)	Endpoint	Age/size	NOEC (ug/L)	LOEC (ug/L)	MATC (ug/L)	Reference	Reason for exclusion
Chironomus tentans	Midge	FT	Meas	99.0%	10 d	20	Mortality	3rd instar	0.070 (10-d LC50)	---	---	Ankley *et al*. (1994)	1
Pimephales promelas	Fathead minnow	FT	Meas	98.7%	32 d	23.5-26.0	Mortality	Newly hatched	3.2	5.7	4.3	Jarvinen & Tanner (1982)	2
Pimephales promelas	Fathead minnow	FT	Meas	98.7%	30 d	24.3-25.9	Growth	< 24 h	1.21	2.68	1.8	Jarvinen *et al.* (1983)	2
Pimephales promelas	Fathead minnow	FT	Meas	98.7%	136 d	24.3-25.9	Growth	< 24 h	1.21	2.68	1.8	Jarvinen *et al*. 1983	2
Pimephales promelas	Fathead minnow	FT	Meas	98.7%	200 d	24.3-25.9	Growth	< 24 h	2.68	> 2.68	---	Jarvinen *et al*. 1983	2
Pimephales promelas	Fathead minnow	FT	Meas	98.7%	136 d	24.3-25.9	Total egg production	< 24 h	**0.27**	0.63	0.41	Jarvinen *et al*. 1983	3
Pimephales promelas	Fathead minnow	FT	Meas	98.7%	136 d	24.3-25.9	Maturation	< 24 h	< 1.21	0.12	---	Jarvinen *et al*. 1983	2
Pimephales promelas	Fathead minnow	FT	Meas	98.7%	136 d	24.3-25.9	Mean spawns per spawning pair	< 24 h	1.21	2.68	1.8	Jarvinen *et al*. 1983	2
Pimephales promelas	Fathead minnow	FT	Meas	98.7%	136 d	24.3-25.9	Embryo hatchability	< 24 h	1.21	2.68	1.8	Jarvinen *et al*. 1983	2
Pimephales promelas	Fathead minnow	FT	Meas	98.7%	30 d	24.3-25.9	2nd generation survival	< 24 h	2.68	> 2.68	---	Jarvinen *et al*. 1983	2
Pimephales promelas	Fathead minnow	FT	Meas	98.7%	30 d	24.3-25.9	2nd generation normal	< 24 h	1.21	2.68	1.8	Jarvinen *et al*. 1983	2
Pimephales promelas	Fathead minnow	FT	Meas	98.7%	30 d	24.3-25.9	2nd generation weight	< 24 h	0.63	1.21	0.87	Jarvinen *et al*. 1983	2

Table 4.5. Acceptable chronic data excluded in data reduction process.

Species	Common identifier	Test type	Meas /Nom	Chemical purity	Duration	Temp (oC)	Endpoint	Age/size	NOEC (ug/L)	LOEC (ug/L)	MATC (ug/L)	Reference	Reason for exclusion
Pimephales promelas	Fathead minnow	FT	Meas	98.7%	30 d	24.3-25.9	2nd generation length	< 24 h	0.63	1.21	0.87	Jarvinen *et al*. 1983	2
Pimephales promelas	Fathead minnow	FT	Meas	98.7%	30 d	24.3-25.9	2nd generation biomass	< 24 h	< 0.12	0.12	---------	Jarvinen *et al*. 1983	2
Pimephales promelas	Fathead minnow	FT	Meas	98.7%	32 d	24.3-25.9	Weight	Newly hatched	1.6	3.2	2.3	Jarvinen & Tanner (1982)	2
Pimephales promelas	Fathead minnow	FT	Meas	98.7%	30 d	24.3-25.9	Mortality	< 24 h	1.21	2.68	1.8	Jarvinen *et al*. 1983	2

1. No NOEC, LOEC or MATC determined

2. More sensitive endpoint available from same test

3. Large response at NOEC

Table 4.6. Studies excluded from criteria derivation (rated RL, LR, or LL). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC50 (ug/L)	MATC (ug/L)	Reference	Rating/ Reason for rating
Anguilla anguilla	European eel	S	Nom	97.0%	24 h @ 20°C	Mortality	20-30 g	1290	--------	Ferrando *et al*. (1991)	LL/ 4,7
Anguilla anguilla	European eel	S	Nom	97.0%	48 h @ 20°C	Mortality	20-30 g	690	--------	Ferrando et al. 1991	LL/ 4,7
Anguilla anguilla	European eel	S	Nom	97.0%	72 h @ 20°C	Mortality	20-30 g	590	--------	Ferrando et al. 1991	LL/ 4,7
Anguilla anguilla	European eel	S	Nom	97.0%	96 h @ 20°C	Mortality	20-30 g	540	--------	Ferrando et al. 1991	LL/ 4,7
Anisus vortex	Gastropod	FT	Meas	99.8%	96 h @ 20°C	Mortality	7.2 mm	> 94	--------	Van Wijngaarden *et al*. (1993)	LL/ 6,7
Anisus vortex	Gastropod	FT	Meas	99.8%	96 h @ 20°C	Immobility	7.2 mm	> 94	--------	Van Wijngaarden *et al*. (1993)	LL/ 6,7
Aplexa hypnorum	Snail	FT	Meas	98.7%	96 h @ 17.3°C	Mortality	Adutl	> 806	---------	Phipps & Holcombe (1985)	LR/ 6
Bithynia tentaculata	Gastropod	FT	Meas	99.8%	96 h @ 20°C	Mortality	10.5 mm	> 94	---------	Van Wijngaarden *et al*. (1993)	LL/ 6,7
Bithynia tentaculata	Gastropod	FT	Meas	99.8%	96 h @ 20°C	Immobility	10.5 mm	> 94	---------	Van Wijngaarden *et al*. (1993)	LL/ 6,7

Table 4.6. Studies excluded from criteria derivation (rated RL, LR, or LL). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC50 (ug/L)	MATC (ug/L)	Reference	Rating/ Reason for rating
Brachionus calyciflorus	Rotifer	S	Nom	NR	48 h @ 25°C	Intrinsic rate of increase (r)	< 2 h	0.36	0.27	Snell & Moffat (1992)	LL/ 1,7
Brachionus calyciflorus	Rotifer	S	Nom	NR	24 h @ 25°C	Mortality	0-2 h	12,000	--------	Snell *et al.* (1991)	LL/ 1,7
Carassius auratus	Goldfish	FT	Meas	99.9%	96 h @ 17.3°C	Mortality	10.7 g	> 806	--------	Phipps & Holcombe (1985)	LR/ 6
Ceridaphnia dubia	Cladoceran	SR	Meas	99.0%	96 h @ 24.5°C	Mortality	< 24 h	0.118	0.118	CDFG (1992b)	LR/ 4
Chironomus tentans	Insect	S	Nom	99.5%	48 h @ 25°C	Immobility	4th instar	0.49	-------	Jin-Clark et al. (2002)	RL/ 7
Chironomus tentans	Insect	SR	Nom	99.5%	29 d @ 25°C	Mortality	Newly hatched	-------	-------	Rakotondravelo *et al.* (2006)	LL/ 6,7
Chironomus tentans	Insect	SR	Nom	99.5%	29 d @ 25°C	Growth	Newly hatched	-------	-------	Rakotondravelo *et al.* (2006)	LL/ 6,7
Classeenia sabulosa	Insect	S	Nom	97%	24 h @ 15°C	Mortality	2nd year class	8.2	--------	Mayer & Ellersieck (1986)	LL/ 4,7
Classeenia sabulosa	Insect	S	Nom	97%	96 h @ 15°C	Mortality	2nd year class	0.57	--------	Mayer & Ellersieck (1986)	LL/ 4,7

Table 4.6. Studies excluded from criteria derivation (rated RL, LR, or LL). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC50 (ug/L)	MATC (ug/L)	Reference	Rating/ Reason for rating
Cloeon dipterum	Insect	FT	Meas	48%	48 h @ 18°C	Mortality	Naiads	1.0	--------	Van Wijngaarden *et al.* (1993)	LL/ 1,7
Cloeon dipterum	Insect	FT	Meas	48%	96 h @ 18°C	Mortality	Naiads	0.3	--------	Van Wijngaarden *et al.* (1993)	LL/ 1,7
Cyprinidon variegatus	Sheepshead minnow	FT	Meas	92%	28 d @ 30°C	Mortality	Embryo	------	--------	Cripe *et al.* (1986)	LR/ 5,6
Cyprinidon variegatus	Sheepshead minnow	FT	Meas	92%	28 d @ 30°C	Growth, wet weight	Embryo	------	2.26	Cripe *et al.* (1986)	LR/ 5
Cyprinidon variegatus	Sheepshead minnow	FT	Meas	92%	28 d @ 30°C	Growth, dry weight	Embryo	------	4.72	Cripe *et al.* (1986)	LR/ 5
Cyprinidon variegatus	Sheepshead minnow	FT	Meas	92%	96 h @ 31.4°C	Mortality	Not Reported	136	--------	Schimmel *et al.* (1983)	LL/ 5
Daphnia magna	Cladoceran	S	Meas	99%	24 h @ temperature not reported	AChE inhibition (50% at LC50)	Juvenile	0.42 (IC50)	--------	Barata *et al.* (2004)	LL/ 4,7
Daphnia magna	Cladoceran	SR	Nom	99.0%	21 d @ 19.5°C	Survival	< 24 h	------	0.17	Kersting & Van Wijngaarden (1992)	RL/ 7
Daphnia magna	Cladoceran	SR	Nom	99.0%	21 d @ 19.5°C	Reproduction	< 24 h	------	0.17	Kersting & Van Wijngaarden (1992)	RL/ 7

Table 4.6. Studies excluded from criteria derivation (rated RL, LR, or LL). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC50 (ug/L)	MATC (ug/L)	Reference	Rating/ Reason for rating
Daphnia magna	Cladoceran	S	Nom	Analytical	48 h @ 21°C	Immobility	< 24 h	0.19	---------	Kikuchi *et al.* (2000)	RL/ 7
Daphnia magna	Cladoceran	S	Meas	44.9%	48 h @ 20°C	Immobility	< 24 h	0.6	---------	Moore *et al.* (1998)	LR/ 1
Daphnia pulex	Cladoceran	S	Meas	45.0%	48 h @ 20°C	Mortality/ Immobility	< 24 h	0.21	-------	Van Der Hoeven & Gerritsen (1997)	LR/ 1
Daphnia pulex	Cladoceran	SR	Meas	45.0%	10 d @ 20°C	Mortality/ Immobility	< 24 h	0.19	-------	Van Der Hoeven & Gerritsen (1997)	LR/ 1
Daphnia pulex	Cladoceran	SR	Meas	45.0%	17 d @ 20°C	Reproduction	< 24 h	-------	0.14	Van Der Hoeven & Gerritsen (1997)	LR/ 1
Daphnia pulex	Cladoceran	SR	Meas	45.0%	6 d @ 20°C	Mortality/ Immobility	< 24 h	0.39	--------	Van Der Hoeven & Gerritsen (1997)	LR/ 1
Daphnia pulex	Cladoceran	SR	Meas	45.0%	6 d @ 20°C	Length	< 24 h	-------	0.48	Van Der Hoeven & Gerritsen (1997)	LR/ 1
Daphnia pulex	Cladoceran	SR	Meas	45.0%	8 d @ 20°C	Mortality/ Immobility	7-8 d	0.28	-------	Van Der Hoeven & Gerritsen (1997)	LR/ 1

Table 4.6. Studies excluded from criteria derivation (rated RL, LR, or LL). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC50 (ug/L)	MATC (ug/L)	Reference	Rating/ Reason for rating
Daphnia pulex	Cladoceran	SR	Meas	45.0%	8 d @ 20°C	Reproduction	7-8 d	--------	0.28	Van Der Hoeven & Gerritsen (1997)	LR/ 1
Daphnia pulex	Cladoceran	SR	Meas	45.0%	6 d @ 20°C	Mortality/ Immobility	9-10 d	0.42	--------	Van Der Hoeven & Gerritsen (1997)	LR/ 1
Daphnia pulex	Cladoceran	SR	Meas	45.0%	6 d @ 20°C	Reproduction	9-10 d		--------	Van Der Hoeven & Gerritsen (1997)	LR/ 1,6
Daphnia pulex	Cladoceran	SR	Meas	45.0%	28 d @ 20°C	Population size	Mixed ages	--------	0.116	Van Der Hoeven & Gerritsen (1997)	LR/ 1
Daphnia pulex	Cladoceran	SR	Meas	45.0%	28 d @ 12-23°C	Population size	Mixed ages	--------	0.202	Van Der Hoeven & Gerritsen (1997)	LR/ 1
Fundulus similis	Longnose killifish	FT	Meas	92.0%	96 h @ 30°C	Mortality	Not Reported	4.1	--------	Schimmel *et al*. (1983)	LL/ 5,7
Gammarus fasciatus	Amphipod	S	Nom	Technical	96 h @ 21°C	Mortality	30-50 mg; 7-11 mg	0.32	--------	Sanders (1972)	LL/ 4,7
Gasterosteus aculeatus	Stickleback	FT	Meas	48.0%	48 h @ 21°C	Mortality	1-2 yr	13.4	--------	Van Wijngaarden *et al*. (1993)	LL/ 1,7

Table 4.6. Studies excluded from criteria derivation (rated RL, LR, or LL). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC50 (ug/L)	MATC (ug/L)	Reference	Rating/ Reason for rating
Gasterosteus aculeatus	Stickleback	FT	Meas	48.0%	96 h @ 21°C	Mortality	1-2 yr	8.5	--------	Van Wijngaarden *et al.* (1993)	LL/ 1,7
Hyalella azteca	Amphipod	S	Meas	44.9%	48 h @ 20°C	Immobility	2-3 wk	0.1	---------	Moore *et al.* (1998)	LR/ 1
Lepomis macrochirus	Bluegill	S	Nom	97%	24 h @ 18°C	Mortality	0.6 g	> 10	-------	Mayer & Ellersieck (1986)	LL/ 4,7
Lepomis macrochirus	Bluegill	S	Nom	97%	96 h @ 18°C	Mortality	0.6 g	2.4	-------	Mayer & Ellersieck (1986)	LL/ 4,7
Lepomis macrochirus	Bluegill	S	Nom	97%	96 h @ 13°C	Mortality	0.5 g	4.2	-------	Mayer & Ellersieck (1986)	LL/ 4,7
Lepomis macrochirus	Bluegill	S	Nom	97%	96 h @ 18°C	Mortality	0.5 g	1.8	-------	Mayer & Ellersieck (1986)	LL/ 4,7
Lepomis macrochirus	Bluegill	S	Nom	97%	96 h @ 24°C	Mortality	0.5 g	2.5	-------	Mayer & Ellersieck (1986)	LL/ 4,7
Lepomis macrochirus	Bluegill	S	Nom	97%	96 h @ 29°C	Mortality	0.5 g	1.7	-------	Mayer & Ellersieck (1986)	LL/ 4,7
Leuresthes tenuis	California grunion	FT	Meas	92%	96 h @ 25°C	Mortality	7 d	1.0	-------	Borthwick *et al.* (1985)	LR/ 5

Table 4.6. Studies excluded from criteria derivation (rated RL, LR, or LL). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC50 (ug/L)	MATC (ug/L)	Reference	Rating/ Reason for rating
Leuresthes tenuis	California grunion	FT	Meas	92%	35 d @ 23-26°C	Embryo survival	Embryo	-------	--------	Goodman *et al.* (1985)	LR/ 5
Leuresthes tenuis	California grunion	FT	Meas	92%	35 d @ 23-26°C	Fry survival	Embryo	-------	0.43	Goodman *et al.* (1985)	LR/ 5
Leuresthes tenuis	California grunion	FT	Meas	92%	35 d @ 23-26°C	Embryo + fry survival	Embryo	-------	0.94	Goodman *et al.* (1985)	LR/ 5
Leuresthes tenuis	California grunion	FT	Meas	92%	35 d @ 23-26°C	Embryo growth	Embryo	-------	0.2	Goodman *et al.* (1985)	LR/ 5
Leuresthes tenuis	California grunion	FT	Meas	92%	26 d @ 23-26°C	Fry survival	Fry	-------	0.9	Goodman *et al.* (1985)	LR/ 5
Leuresthes tenuis	California grunion	FT	Meas	92%	26 d @ 23-26°C	Fry growth	Fry	-------	0.42	Goodman *et al.* (1985)	LR/ 5
Lumbriculus variegatus	Oligochaete	S	Nom	$\geq$ 95%	96 h @ 23°C	Mortality/ Immobility	Mixed ages	--------	-------	Ankley & Collyard (1995)	LL/ 6,7
Lymnaea stagnalis	Gastropod	FT	Meas	99.8%	96 h @ 20°C	Mortality/ Immobility	22.4 mm	> 94	-------	Van Wijngaarden *et al.* (1993)	LR/ 6
Menidia menidia	Atlantic silverside	FT	Meas	92.0%	96 h @ 25°C	Mortality	0 d	0.5	-------	Borthwick *et al.* (1985)	LR/ 5

Table 4.6. Studies excluded from criteria derivation (rated RL, LR, or LL). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC50 (ug/L)	MATC (ug/L)	Reference	Rating/ Reason for rating
Menidia menidia	Atlantic silverside	FT	Meas	92.0%	96 h @ 27.5°C	Mortality	Not Reported	1.7	-------	Schimmel *et al.* (1983)	LL/ 5,7
Menidia peninsulae	Gulf silverside	FT	Meas	92.0%	96 h @ 25°C	Mortality	14 d	0.4	-------	Borthwick *et al.* (1985)	LR/ 5
Minutocellus polymorphus	Marine diatom	S	Meas	97%	48 h @ 20°C	Population density	Not Reported	240	-------	Walsh *et al.* (1988)	
Mugil cephalus	Striped mullet	FT	Meas	92.0%	96 h @ 24.8°C	Mortality	Not Reported	5.4	-------	Schimmel *et al.* (1983)	LL/ 5,7
Oncorhynchus kisutch	Coho salmon	SR	Meas	99.3%	96 h @ 11-13°C	Enzyme activity	4-5 mo	-------	-------	Sandahl *et al.* (2005)	LR/ 2
Oncorhynchus kisutch	Coho salmon	SR	Meas	99.3%	96 h @ 11-13°C	Spontaneous swimming rate	4-5 mo	-------	-------	Sandahl *et al.* (2005)	LR/ 2
Oncorhynchus kisutch	Coho salmon	SR	Meas	99.3%	96 h @ 11-13°C	Feeding swimming rate	4-5 mo	-------	0.85	Sandahl *et al.* (2005)	LR/ 2
Oncorhynchus kisutch	Coho salmon	SR	Meas	99.3%	96 h @ 11-13°C	First feeding strike	4-5 mo	-------	2.1	Sandahl *et al.* (2005)	LR/ 2
Oncorhynchus kisutch	Coho salmon	SR	Meas	99.3%	96 h @ 11-13°C	Total feeding strikes	4-5 mo	-------	2.1	Sandahl *et al.* (2005)	LR/ 2

Table 4.6. Studies excluded from criteria derivation (rated RL, LR, or LL). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC50 (ug/L)	MATC (ug/L)	Reference	Rating/ Reason for rating
Oncorhynchus mykiss	Rainbow trout	S	Meas	97.0%	24 h @ 2.0°C	Mortality	1.4 g	550	-------	Mayer & Ellersieck (1986)	LL/ 4,7
Oncorhynchus mykiss	Rainbow trout	S	Meas	97.0%	96 h @ 2.0°C	Mortality	1.4 g	51	-------	Mayer & Ellersieck (1986)	LL/ 4,7
Oncorhynchus mykiss	Rainbow trout	S	Meas	97.0%	24 h @ 7.0°C	Mortality	1.4 g	110	-------	Mayer & Ellersieck (1986)	LL/ 4,7
Oncorhynchus mykiss	Rainbow trout	S	Meas	97.0%	96 h @ 7.0°C	Mortality	1.4 g	15	-------	Mayer & Ellersieck (1986)	LL/ 4,7
Oncorhynchus mykiss	Rainbow trout	S	Meas	97.0%	96 h @ 13°C	Mortality	1.4 g	7.1	-------	Mayer & Ellersieck (1986)	LL/ 4,7
Oncorhynchus mykiss	Rainbow trout	S	Meas	97.0%	24 h @ 18°C	Mortality	1.4 g	15	-------	Mayer & Ellersieck (1986)	LL/ 4,7
Oncorhynhus mykiss	Rainbow trout	S	Meas	97.0%	24 h @ 13°C	Mortality	1.4 g	53	-------	Mayer & Ellersieck (1986)	LL/ 4,7
Oryzias latipes	Medaka	SR	Meas	99.0%	24 h @ 25°C	Mortality	30 d	300	-------	Rice *et al.* (1997)	LR/ 3
Oryzias latipes	Medaka	SR	Meas	99.0%	48 h @ 25°C	Mortality	30 d	250	--------	Rice et al. (1997)	LR/ 3

Table 4.6. Studies excluded from criteria derivation (rated RL, LR, or LL). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC50 (ug/L)	MATC (ug/L)	Reference	Rating/ Reason for rating
Pimephales promelas	Fathead minnow	S	Meas	10.6%	96 h @ 23.5-26.0°C	Mortality	Newly hatched	130-280	------	Jarvinen & Tanner (1982)	LR/ 1
Pimephales promelas	Fathead minnow	FT	Meas	10.6%	96 h @ 23.5-26.0°C	Mortality	Newly hatched	120.0	-------	Jarvinen & Tanner (1982)	LR/ 1
Pimephales promelas	Fathead minnow	FT	Meas	10.6%	32 d @ 23.5-26.0°C	Mortality	Newly hatched	------	3.2	Jarvinen & Tanner (1982)	LR/ 1
Pimephales promelas	Fathead minnow	FT	Meas	10.6%	32 d @ 23.5-26.0°C	Weight	Newly hatched	---------	3.2	Jarvinen & Tanner (1982)	LR/ 1
Pimephales promelas	Fathead minnow	FT	Meas	98.70%	30 d @ 24.3-25.9°C	Mortality	< 24 h	--------	0.87	Jarvinen *et al.* (1983)	LR/ 4
Pimephales promelas	Fathead minnow	FT	Meas	98.7%	60 d @ 24.3-25.9°C	AChE inhibition (21-41% at LOEC)	< 24 h	-------	-------	Jarvinen *et al.* (1983)	LR/ 2,6
Pimephales promelas	Fathead minnow	FT	Meas	98.7%	136 d @ 24.3-25.9°C	Mean eggs per spawn	< 24 h	-------	0.87	Jarvinen *et al.* (1983)	LR/ 6
Pimephales promelas	Fathead minnow	S	Meas	10.6%	96 h @ 24.6-25.4°C	Mortality	< 24 h	122.2	--------	Jarvinen *et al.* (1988)	LR/ 1,4,7
Pimephales promelas	Fathead minnow	S	Meas	10.6%	28-30 d @ 24.6-25.4°C	Deformities	< 24 h	--------	1.65	Jarvinen *et al.* (1988)	LR/ 1

Table 4.6. Studies excluded from criteria derivation (rated RL, LR, or LL). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC50 (ug/L)	MATC (ug/L)	Reference	Rating/ Reason for rating
Pimephales promelas	Fathead minnow	S	Meas	44.9%	48 h @ 20°C	Immobility	< 24 h	162.7	--------	Moore *et al.* (1998)	LR/ 1
Pimephales promelas	Fathead minnow	SR	Meas	NR	7 d @ 25°C	Growth	< 24 h	-------	5.2	Norberg & Mount (1985)	LL/ 1,7
Pimephales promelas	Fathead minnow	SR	Meas	24.7%	96 h @ 25°C	Mortality	< 24 h	381	-------	Sherrard *et al.* (2002)	LL/ 1,4,7
Pimephales promelas	Fathead minnow	SR	Meas	24.7%	10 d @ 25°C	Mortality	< 24 h	150	-------	Sherrard *et al.* (2002)	LL/ 1,4,7
Pimephales promelas	Fathead minnow	SR	Meas	24.7%	96 h @ 25°C	Growth	< 24 h	-------	112	Sherrard *et al.* (2002)	LL/ 1,4,7
Pimephales promelas	Fathead minnow	SR	Meas	24.7%	10 d @ 25°C	Growth	< 24 h	-------	61	Sherrard *et al.* (2002)	LL/ 1,4,7
Procambarus clarkii	Crayfish	S	Nom	99.8%	24 h @ 22°C	Mortality	15-30 g	37	--------	Cebrián *et al.* (1992)	RL/ 7
Procambarus clarkii	Crayfish	S	Nom	99.8%	48 h @ 22°C	Mortality	15-30 g	23	--------	Cebrián *et al.* (1992)	RL/ 7
Procambarus clarkii	Crayfish	S	Nom	99.8%	72 h @ 22°C	Mortality	15-30 g	22	--------	Cebrián *et al.* (1992)	RL/ 7

Table 4.6. Studies excluded from criteria derivation (rated RL, LR, or LL). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC50 (ug/L)	MATC (ug/L)	Reference	Rating/ Reason for rating
Procambarus clarkii	Crayfish	S	Nom	99.8%	96 h @ 22°C	Mortality	15-30 g	21	--------	Cebrián *et al.* (1992)	RL/ 7
Pteronarcys californica	Insect	S	Nom	97%	24 h @ 15°C	Mortality	2nd year class	50	-------	Mayer & Ellersieck (1986)	RL/ 4,7
Simocephalus vetulus	Cladoceran	SR	Meas	48.0%	48 h @ 18°C	Mortality	Juvenile-adult	0.8	-------	Van Wijngaarden *et al.* (1993)	LL/ 1,7
Simocephalus vetulus	Cladoceran	SR	Meas	48.0%	96 h @ 18°C	Mortality	Juvenile-adult	0.5	-------	Van Wijngaarden *et al.* (1993)	LL/ 1,7
Skeletonema costatum	Marine diatom	S	Meas	97%	72 h @ 20°C	Population density	Not Reported	640	-------	Walsh *et al.* (1988)	
Stizostedion vitreum	Walleye	S	Meas	99.6%	48 h @ 13.9-22.2°C	Mortality	Various	12-225	-------	Phillips *et al.* 2002	LL/ 4,7
Xenopus laevis	African clawed frog	SR	Nom	99.8%	10 d @ 24.7°C	Mortality	< 24 h	-------	28	El-Merhibi *et al.* (2004)	RL/ 7
Xenopus laevis	African clawed frog	SR	Nom	99.8%	10 d @ 24.7°C	Malformation	< 24 h	-------	28	El-Merhibi *et al.* (2004)	RL/ 7
Xenopus laevis	African clawed frog	SR	Nom	99.8%	10 d @ 24.7°C	AChE inhibition	< 24 h	-------	7.1	El-Merhibi *et al.* (2004)	RL/ 7

1. Chemical grade

Table 4.6. Studies excluded from criteria derivation (rated RL, LR, or LL). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC50 (ug/L)	MATC (ug/L)	Reference	Rating/ Reason for rating
2. Endpoint not linked to population effects											
3. Family not in N. America											
4. Control description/response											
5. Not freshwater											
6. No toxicity value calculated											
7. Low reliability score											

Table 4.7. Acceptable multispecies field, semi-field, laboratory, microcosm, mesocosm studies; R = reliable; L = less reliable.

Reference	Habitat	Rating
Brock *et al*. (1992a)	Laboratory model ecosystem	L
Brock *et al*. (1992b)	Laboratory model ecosystem	L
Brock *et al*. (1993)	Laboratory model ecosystem	R
Cuppen *et al*. (1995)	Laboratory microcosm	L
Eaton *et al*. (1985)	Outdoor stream	L
Giddings *et al*. (1997)	Outdoor pond	R
Kersting & Van Den Brink (1997)	Outdoor ditch	L
Kersting & Van Wijngaarden (1992)	Laboratory microcosm	L
Macek *et al*. (1972)	Outdoor pond	R
Pusey *et al*. (1994)	Outdoor stream	L
Rawn *et al*. (1978)	Outdoor pond	R
Van Breukelen & Brock (1993)	Laboratory microcosm	L
Van Den Brink *et al*. (1995)	Laboratory microcosm	L
Van Den Brink *et al*. (1996)	Outdoor ditch	L
Van Donk *et al*. (1995)	Laboratory microcosm	L
Van Wijngaarden & Leeuwangh (1989)	Outdoor pond	L
Van Wijngaarden (1993)	Laboratory microcosm	R
	Outdoor pond	R
	Outdoor ditch	R
Van Wijngaarden *et al*. (1996)	Outdoor ditch	R
Van Wijngaarden *et al*. (2005)	Laboratory microcosm	L
Ward *et al*. (1995)	Artificial stream	L

Table 4.8. *Neomysis mercedis* raw acute data from CDFG (1992a) used for estimation of chronic toxicity using ACE (v. 2.0).

Chlorpyrifos (µ/L)	**Time (h)**	**Total exposed**	**Total responding**
0	24	20	1
0.06	24	20	0
0.14	24	20	0
0.30	24	20	1
0.61	24	20	7
1.30	24	20	20
0	48	20	1
0.06	48	20	0
0.14	48	20	0
0.30	48	20	11
0.61	48	20	19
1.30	48	20	20
0	72	20	1
0.06	72	20	0
0.14	72	20	2
0.30	72	20	19
0.61	72	20	20
1.30	72	20	20
0	96	20	1
0.06	96	20	0
0.14	96	20	7
0.30	96	20	20
0.61	96	20	20
1.30	96	20	20

Table 4.9. *Neomysis mercedis* raw acute data from CDFG (1992e) used for estimation of chronic toxicity using ACE (v. 2.0).

Chlorpyrifos (µ/L)	**Time (h)**	**Total exposed**	**Total responding**
0	24	10	0
0.04	24	10	0
0.09	24	10	0
0.18	24	10	0
0.36	24	10	0
0.75	24	10	3
0	48	10	0
0.04	48	10	0
0.09	48	10	0
0.18	48	10	0
0.36	48	10	8
0.75	48	10	10
0	72	10	0
0.04	72	10	0
0.09	72	10	0
0.18	72	10	5
0.36	72	10	10
0.75	72	10	10
0	96	10	0
0.04	96	10	0
0.09	96	10	0
0.18	96	10	7
0.36	96	10	10
0.75	96	10	10

Table 4.10. Synergistic interactions between chlorpyrifos and other pesticides.

Species	**Pesticide 1**	**Synergist (concentration)**	**SR (K)[1]**	**Reference**
Pimephales promelas	Esfenvalerate	Chlorpyrifos (7μ/L)	1.29	Belden & Lydy 2006
Chironomus tentans	Chlorpyrifos	Atrazine (200 μ/L)	1.75	Jin-Clark et al. 2002
Chironomus tentans	Chlorpyrifos	Cyanazine (200 μ/L)	2.23	Jin-Clark et al. 2002
Chironomus tentans	Chlorpyrifos	Cyanazine (200 μ/L)	1.7	Lydy & Austin 2004
Chironomus tentans	Chlorpyrifos	Simazine (200 μ/L)	1.8	Lydy & Austin 2004
Chironomus tentans	Chlorpyrifos	Hexazione (200 μ/L)	1.6	Lydy & Austin 2004
Chironomus tentans	Chlorpyrifos	Diuron (200 μ/L)	1.5	Lydy & Austin 2004
Hyalella azteca	Chlorpyrifos	Atrazine (10 μ/L)	1.0	Anderson & Lydy 2002
Hyalella azteca	Chlorpyrifos	Atrazine (40 μ/L)	1.6	Anderson & Lydy 2002
Hyalella azteca	Chlorpyrifos	Atrazine (80 μ/L)	2.0	Anderson & Lydy 2002
Hyalella azteca	Chlorpyrifos	Atrazine (200 μ/L)	2.8	Anderson & Lydy 2002
Chironomus tentans	Chlorpyrifos	Atrazine (10 μ/L)	1.0	Belden & Lydy 2000
Chironomus tentans	Chlorpyrifos	Atrazine (40 μ/L)	1.83	Belden & Lydy 2000
Chironomus tentans	Chlorpyrifos	Atrazine (80 μ/L)	2.75	Belden & Lydy 2000
Chironomus tentans	Chlorpyrifos	Atrazine (200 μ/L))	4.00	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 4.11. Predicted LC_{50} values for threatened or endangered species; ICE v. 1.0.

Species	**Common Name**	**Family**	**LC_{50} (µg/L)**	**Surrogate**
Oncorhynchus tshawytscha	Chinook Salmon	Salmonidae	9.2	*Oncorhynchus mykiss*
Oncorhynchus kisutch	Coho Salmon	Salmonidae	7.3	*Oncorhynchus mykiss*
Oncorhynchus clarki henshawi	Lahontan cutthroat trout	Salmonidae	4.0	*Oncorhynchus mykiss*
Gila elegans	Bonytail chub	Cyprinidae	186	*Pimephales promelas*
Ptychocheilus lucius	Colorado squawfish	Cyprinidae	171	*Pimephales promelas*

Table 4.12. Level I fugacity model inputs.

Inputs	Value
Molecular weight	350.6
Temperature (^oC)	25
log K_{OW}	4.96
Water Solubility (mg/L)	1.46
Vapor Pressure (Pa)	2.36×10^{-3}
Melting Point (^oC)	42.73
Henry's Constant ($Pa*m^3/mol$)[1]	0.567
Partition coefficients[1]	
Organic carbon-water (L/kg)	37,392
Air-water (dimensionless)	2.29×10^{-4}
Suspended particles-water (dimensionless)	3,590
Fish-water	4,560
Compartment volumes (m^3)	
Air	10^{14}
Aerosol	2000
Water	2×10^{11}
Suspended particles	10^6
Fish	2×10^5
Sediment	10^8
Chlorpyrifos concentration in water (ng/L)	10.5
Fish lipid levels (%)	0.5-20%
Suspended sediment organic carbon content (%)	0.5-20%
Sediment (%)	0.5-20%

[1] Calculated/estimated by model based on log K_{OW}.

Table 4.13. Level I fugacity model outputs; chlorpyrifos concentrations in non-water environmental compartments with varying levels of fish lipids, suspended sediment organic carbon and sediment organic carbon; water concentration is 10.5 ng/L in all cases.

			Chlorpyrifos concentrations					
Lipid (%)	Suspended Sediment Organic Carbon (%)	Sediment Organic Carbon (%)	Fish (ng/g)	Suspended sediment (ng/g)	Sediment (ng/g)	Air (ng/m^3)	Aerosol (ng/m^3 air)	Mass (kg)
0.5	0.5	0.5	4.8	2.0	2.0	2.4	0.08	2820
1	0.5	0.5	4.8	2.0	2.0	2.4	0.08	2820
5	0.5	0.5	48	2.0	2.0	2.4	0.08	2820
10	0.5	0.5	96	2.0	2.0	2.4	0.08	2850
15	0.5	0.5	144	2.0	2.0	2.4	0.08	2850
20	0.5	0.5	191	2.0	2.0	2.4	0.08	2850
0.5	1	0.5	4.8	3.9	2.0	2.4	0.08	2830
0.5	5	0.5	4.8	20	2.0	2.4	0.08	2860
0.5	10	0.5	4.8	39	2.0	2.4	0.08	2880
0.5	15	0.5	4.8	59	2.0	2.4	0.08	2900
0.5	20	0.5	4.8	79	2.0	2.4	0.08	2950
0.5	0.5	1	4.8	2.0	3.9	2.4	0.08	3300
0.5	0.5	5	4.8	2.0	20	2.4	0.08	7050
0.5	0.5	10	4.8	2.0	39	2.4	0.08	11800
0.5	0.5	15	4.8	2.0	59	2.4	0.08	16500
0.5	0.5	20	4.8	2.0	78	2.4	0.08	21100

Appendix 4B
Data summary sheets for data rated relevant and reliable

Abbreviations used in this appendix:

NA = Not Applicable; for example, in a study where concentrations were not measured, NA is entered for items related to chemical method; a score of 0 is assigned for NA entries;
NC = Non Calculable; for example, if a NOEC was determined, but no LOEC, then the MATC is not calculable;
NR = Not Reported
RR = Relevant, Reliable study

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Ceriodaphia dubia

Toxicity Data Summary

Study: Bailey HC, Miller JL, Miller MJ, Wiborg LC, Deanovic L, Shed T. 1997. Joint acute toxicity of diazinon and chlropyrifos to *Ceriodaphnia dubia.* Environ Toxicol Chem 16: 2304-2308.

Rating: RR

Notes: Summary of data for chlorpyrifos only exposures.

Bailey et al. 1997		
Parameter	**Value**	**Comment**
Test method cited	USEPA 1991	EPA 600/4-90/027
Phylum/subphylum	Arthropoda/Crustacea	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	*Ceriodaphnia*	
Species	*dubia*	
Family resides in	North America	
Age/size at start of test/growth phase	< 24 h	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	NR	
Test duration	24, 48, 72, 96 h	
Data for multiple times?	Yes	
Effect 1	Mortality	
Control response 1	< 10%	
Temperature	25 $\pm$ 1 ^{o}C	
Test type	Static	
Photoperiod	16L:8D	
Dilution water	Moderatelyhard synthetic water	
pH	7.40-8.23	Water quality
Hardness	80-100 mg/L as $CaCO_3$	within guidelines
Alkalinity	100-120 mg/L as $CaCO_3$	in USEPA 1991

Bailey et al. 1997		
Parameter	**Value**	**Comment**
Conductivity	290-300 umhos/cm	
Dissolved Oxygen	NR	
Feeding	None	
Purity of test substance	99%	
Concentrations measured?	Yes; 81.4% of nominal	
Measured is what % of nominal?	81.4%	
Chemical method documented?	Yes	
Concentration of carrier in test solutions	< 0.1%	
Concentration 1 Nom (µg/L)	0.008	Reps: 4 w/5 per
Concentration 2 Nom (µg/L)	0.016	Reps: 4 w/5 per
Concentration 3 Nom (µg/L)	0.033	Reps: 4 w/5 per
Concentration 4 Nom (µg/L)	0.066	Reps: 4 w/5 per
Concentration 5 Nom (µg/L)	0.132	Reps: 4 w/5 per
Control	Methanol at < 0.1%	Reps: 4 w/5 per
LC50 µg/L (95% ci)	Test 1 24-h: 0.101 (0.079-0.130); Test 1 48-h: 0.079 (0.073-0.086); Test 1 72-h: 0.078 (0.043-0.143); Test 1 96-h: 0.053 (0.040-0.071); Test 2 24-h: 0.063 (0.056-0.072); Test 2 48-h: 0.058 (0.027-0.124); Test 2 72-h: 0.058 (0.027-0.124); Test 2 96-h: 0.055 (0.049-0.061); Test 3 24-h: 0.095 (0.083-0.109); Test 3 48-h: 0.066 (0.055-0.078); Test 4 24-h: 0.086 (0.074-0.101); Test 4 48-h: 0.064 (0.055-0.073)	Trimmed Spearman-Karber or binomial; based on measured values

Toxicity Data Summary

Ceriodaphnia dubia

Study: CDFG. 1999. Test 61: 7-day chronic *Ceriodaphnia dubia* test for chlorpyrifos. Aquatic Toxicology Laboratory, Elk Grove, California.

Rating: RR for acute and chronic

CDFG 1999		
Parameter	**Value**	**Comment**
Test method cited	USEPA 1993 and ASTM 1988 (E729-88, E1192-88)	
Phylum/subphylum	Arthropoda/crustacea	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	*Ceriodaphnia*	
Species	*dubia*	
Found in	N. Amer.	
Age/size at start of test/growth phase	< 24 h	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	7 d	
Data for multiple times?	Yes	
Effect 1	Mortality	
Control response 1	Dilution water: 0% Solvent: 20%	20% control mortality is limit
Effect 2	Reproduction	
Control response 2	Dilution water: 27.4 Solvent: 15.9 neonates/female	NOEC was determined by comparison to solvent control
Temperature; mean (range); ^{o}C	Control: 24.6 (24.0-25.1) Test: 24.6 (24.0-25.1)	Measured in highest test concentration
Test type	Static; daily renewal	
Photoperiod	16L:8D	

CDFG 1999		
Parameter	**Value**	**Comment**
Dilution water	CDFG Aquatic Tox Lab well water	Measured in highest test concentration
pH; mean (range)	Control: 8.18 (7.97-8.47) Test: 8.32 (7.91-8.58)	Measured in highest test concentration
Hardness; mean (range); mg/L as $CaCO_3$	Control: 175 (168-178) Test: 171 (168-176)	Measured in highest test concentration
Alkalinity; mean (range); mg/L as $CaCO_3$	Control: 188 (184-192) Test: 186 (184-190)	Measured in highest test concentration
Conductivity; mean (range); uS/cm	Control: 381 (337-419) Test: 379 (316-407)	Measured in highest test concentration
Dissolved Oxygen; mean (range); mg/L	Control: 7.59 (5.75-9.1) Test: 7.50 (3.85-9.78)	Measured in highest test concentration
Feeding	1:1 YCT:*Selenastrum* after loading and after daily renewal	
Purity of test substance	99.8% (Dursban R)	
Concentrations measured?	Yes	
Measured is what % of nominal?	82-300%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	$\leq$ 0.125 mL/L	
Concentration 1 Nom/Meas (µg/L)	0.004/0.012	Reps: 10 w/1 per
Concentration 2 Nom/Meas (µg/L)	0.008/0.022	Reps: 10 w/1 per
Concentration 3 Nom/Meas (µg/L)	0.016/0.015	Reps: 10 w/1 per
Concentration 4 Nom/Meas (µg/L)	0.033/0.029	Reps: 10 w/1 per
Concentration 5 Nom/Meas (µg/L)	0.066/0.054	Reps: 10 w/1 per
Control	Dilution water; solvent (methanol $\leq$ 0.125 mL/L	Reps: 10 w/1 per
LC50 (95% ci); ug/L	7-d: 0.039 (0.038-0.040); Data are available to calculate LC50 24, 48, 72, etc up to 7 d	Trimmed Spearman-Karber
ECx; indicate calculation method	NC, but it may be possible to calculate from raw data	
NOEC; ug/L	Survival: 0.029 Reproduction: 0.029 (MSD = 4.9)	Survival:Fisher's exact Reproduction: Dunnett's
LOEC; indicate calculation method	Survival: 0.054 Reproduction: 0.054	
MATC (GeoMean NOEC,LOEC)	Survival: 0.0396 Reproduction: 0.0396	
% of control at NOEC	Survival: 100%	Compared to

CDFG 1999		
Parameter	**Value**	**Comment**
	Reproduction: 134%	solvent control
% of control at LOEC	Survival: 10% Reproduction: 13.2%	Compared to solvent control

Application factors or ACRs: Determine 96-h LC50, then calculated ACR for this test:

96-h LC50 by Trimmed Spearman Karber = 0.0396 ug/L.

MATC = 0.0396

ACR = 0.0396/0.0396 = 1.0

Toxicity Data Summary

Ceriodaphnia dubia

Study: CDFG. 1992c. Test No. 139. 96-h acute toxicity of chlorpyrifos to *Ceriodaphnia dubia*.

Rating: RR

CDFG 1992c		
Parameter	**Value**	**Comment**
Test method cited	ASTM 1988; USEPA 1993	
Phylum/subphylum	Arthropoda/crustacea	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	*Ceriodaphnia*	
Species	*dubia*	
Found in	N. Amer.	
Age/size at start of test/growth phase	< 24 h	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	Yes; see study	
Effect 1	Mortality	
Control response 1	10%	
Temperature; mean (range); ^{o}C	24.3 (23.7-24.8)	
Test type	Static renewal; daily renewal	
Photoperiod	16L:8D	
Dilution water	Aquat Tox Lab well water	
pH; mean (range)	8.2 (8.0-8.6)	
Hardness; mean (range); mg/L as $CaCO_3$	122 (120-123)	
Alkalinity; mean (range); mg/L as $CaCO_3$	105 (104-106)	
Conductivity; mean (range); uS/cm	334 (320-350)	

Dissolved Oxygen; mean (range); mg/L	7.7 (6.9-8.1)	
Feeding	YCT:*Selenastrum* 2 h prior to test and 2 hr prior to each renewal	
Purity of test substance	99%	
Concentrations measured?	Yes	
Measured is what % of nominal?	92.5%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	$\leq$ 0.00787 mL/L	
Concentration 1 Meas (µg/L)	0.02	Reps: 4 w/5 per
Concentration 2 Meas (µg/L)	0.03	Reps: 4 w/5 per
Concentration 3 Meas (µg/L)	0.07	Reps: 4 w/5 per
Concentration 4 Meas (µg/L)	0.135	Reps: 4 w/5 per
Concentration 5 Meas (µg/L)	0.285	Reps: 4 w/5 per
Control	Dilution water; solvent (triethylene glycol dimethyl ether, triethylene glycol, $\leq$ 0.00787 mL/L)	Reps: 4 w/5 per
LC50 (95% ci); ug/L	0.08 (0.06-0.11)	Moving average
NOEC; ug/L	0.07	Chi square (no MSD reported)
LOEC; ug/L	0.135	
MATC (GeoMean NOEC,LOEC)	0.097	
% of control at NOEC	100%	
% of control at LOEC	11%	

Toxicity Data Summary

Ceriodaphnia dubia

Study: CDFG. 1992. Test No. 150. 96-h acute toxicity of chlorpyrifos to *Ceriodaphnia dubia*.

Rating: RR

CDFG 1992f		
Parameter	**Value**	**Comment**
Test method cited	ASTM 1988; USEPA 1993	
Phylum/subphylum	Arthropoda/crustacea	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	*Ceriodaphnia*	
Species	*dubia*	
Found in	N. Amer.	
Age/size at start of test/growth phase	< 24 h	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	Yes; see study	
Effect 1	Mortality	
Control response 1	0%	
Temperature; mean (range); ^{o}C	24.6 (24.3-25.1)	
Test type	Static renewal; daily renewal	
Photoperiod	16L:8D	
Dilution water	Aquat Tox Lab well water	
pH; mean (range)	8.3 (8.0-8.5)	
Hardness; mean (range); mg/L as $CaCO_3$	120	
Alkalinity; mean (range); mg/L as $CaCO_3$	107 (106-108)	
Conductivity; mean (range); uS/cm	326 (290-350)	

CDFG 1992f		
Parameter	**Value**	**Comment**
Dissolved Oxygen; mean (range); mg/L	7.7 (7.3-8.0)	
Feeding	YCT:*Selenastrum* 2 h prior to test and 2 hr prior to each renewal	
Purity of test substance	99%	
Concentrations measured?	Yes	
Measured is what % of nominal?	97%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	$\leq$ 0.00787 mL/L	
Concentration 1 Meas (µg/L)	0.02	Reps: 4 w/5 per
Concentration 2 Meas (µg/L)	0.03	Reps: 4 w/5 per
Concentration 3 Meas (µg/L)	0.08	Reps: 4 w/5 per
Concentration 4 Meas (µg/L)	0.155	Reps: 4 w/5 per
Concentration 5 Meas (µg/L)	0.36	Reps: 4 w/5 per
Control	Dilution water; solvent (triethylene glycol dimethyl ether, triethylene glycol, $\leq$ 0.00787 mL/L)	Reps: 4 w/5 per
LC50 (95% ci); ug/L	0.13 (0.1-0.19)	binomial
NOEC; ug/L	0.08	Chi square (no MSD reported)
LOEC; ug/L	0.155	
MATC (GeoMean NOEC,LOEC)	0.11	
% of control at NOEC	100%	
% of control at LOEC	20%	

Toxicity Data Summary

Ceriodaphnia dubia

Study: Harmon SM, Specht WL, Chandler GT. 2003. A comparison of the daphnids *Ceriodaphnia dubia* and *Daphnia ambigua* for their utilization in routine toxicity testing in the Southeastern United States. Arch Environ Contamin Toxicol 45: 79-85.

Rating: RR

Harmon et al. 2003		
Parameter	**Value**	**Comment**
Test method cited	ASTM E729-88a	
Phylum/sub-phylum	Arthropoda/Crustacea	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	*Ceriodaphnia*	
Species	*dubia*	
Found in	North America	
Age/size at start of test/growth phase	Neonates	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	NR	
Test duration	48 h	
Data for multiple times?	No	
Effect 1	Immobilization	
Control response 1	Dil water = 50/50; Solvent = 50/50	
Temperature	25 $\pm$ 2 ^{o}C	
Test type	Static	glass beakers
Photoperiod	16L:8D	
Dilution water	Moderately Hard Reconstituted Water	
pH	8.11-8.66	
Hardness	54-72 mg/L as $CaCO_3$	
Alkalinity	57-76 mg/L as $CaCO_3$	
Conductivity	NR	
Dissolved Oxygen	7.46-9.14 mg/L	
Feeding	No	

Harmon et al. 2003		
Parameter	**Value**	**Comment**
Purity of test substance	Not stated; used research grade Dursban XP	
Concentrations measured?	Yes	
Measured is what % of nominal?	NR	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	NR, but ASTM method	
Concentration Meas (µg/L)	0.03	Reps: 5 w/10 per
Concentration Meas (µg/L)	0.04	Reps: 5 w/10 per
Concentration Meas (µg/L)	0.07	Reps: 5 w/10 per
Concentration Meas (µg/L)	0.09	Reps: 5 w/10 per
Concentration Meas (µg/L)	0.19	Reps: 5 w/10 per
Control?	Yes; control 1 = dilution water; control 2 = solvent control	Reps: 5 w/10 per; methanol carrier @ 37.5 ul/L
LC50; indicate calculation method	0.056 ug/L (0.054-0.059)	Trimmed Spearman-Karber (95% ci)

Toxicity Data Summary

Chironimus tentans

Study: Ankley GT, Call DJ, Cox JS, Kahl MD, Hoke RA, Kosian PA. 1994. Organic carbon partitioning as a basis for predicting the toxicity of chlorpyrifos in sediments. Environ Toxicol Chem 13: 621-626.

Rating: RR

Notes: This study includes a water-only exposure as well as sediment exposures; only water exposures are described below.

Ankley et al. 1994		
Parameter	**Value**	**Comment**
Test method cited	No standard method cited	
Phylum	Arthropoda	
Class	Insecta	
Order	Diptera	
Family	Chironomidae	
Genus	*Chironomus*	
Species	*tentans*	
Family resides in	N. Amer.	
Age/size at start of test/growth phase	3rd instar larvae	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	10 d	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	5%	
Temperature	20 ± 1^{o} C	
Test type	Flow-through	
Photoperiod	16L:8D	
Dilution water	Dechlorinated tapwater	
pH	NR	
Hardness	NR	
Alkalinity	NR	

Ankley et al. 1994		
Parameter	**Value**	**Comment**
Conductivity	NR	
Dissolved Oxygen	NR	
Feeding	daily	
Purity of test substance	99%	
Concentrations measured?	Yes, but NR	Results based on measurements corrected for recovery
Measured is what % of nominal?	NR	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	None used	
Concentration 1 Nom/Meas (μg/L)	5 nominal concentrations ranging from 15-828 ng/L	Reps: 2 w/10 per
Control	Dechlorinated tapwater	Reps: 2 w/10 per
LC50; **n**g/L	70 (40-130)	Trimmed Spearman-Karber

Toxicity Data Summary

Chironomus tentans

Study: Ankley GT, Collyard SA. 1995. Influence of piperonyl butoxide on the toxicity of organophosphate insecticides to three species of freshwater benthic invertebrates. Comp Biochem Physiol 110C: 149-155.

Rating: RR

Notes: Using only data for chlorpyrifos only exposures; water quality information, test substance purity, replication, other information given as ranges for all tests and compounds; not possible to match specific data with each test.

Ankley & Collyard 1995		
Parameter	**Value**	**Comment**
Test method cited	None cited, but appears to follow EPA acute methods	Study by EPA staff
Phylum	Arthropoda	
Class	Insecta	
Order	Diptera	
Family	Chironomidae	
Genus	*Chironomus*	
Species	*tentans*	
Family resides in	North America	
Age/size at start of test/growth phase	Third instar	
Test duration	96 h	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Data for multiple times?	No	
Effect 1	Mortality/immobility	
Control response 1	NR	
Temperature	$23 \pm 1\ ^{o}C$	
Test type	Static	
Photoperiod	16L:8D	
Dilution water	Lake Superior water; as is, or with added hardness	

pH	7.4-8.5	
Hardness	42-47 mg/L as $CaCO_3$	Hardness adjusted to 105 mg/L as $CaCO_3$, but not clear for which species in the study
Alkalinity	39-46 mg/L as $CaCO_3$	
Conductivity	NR	
Dissolved Oxygen	5.2-8.1 mg/L	
Feeding	None	
Purity of test substance	$\geq$ 95% pure	
Concentrations measured?	No	
Measured is what % of nominal?	NA	
Chemical method documented?	NA	
Concentration of carrier (if any) in test solutions	$\leq$ 0.15 mL/L	
Concentration 1 Nom/Meas (µg/L)	NR	Reps: 2-4 w/5-10 per
Concentration 2 Nom/Meas (µg/L)	NR	Reps: 2-4 w/5-10 per
Concentration 3 Nom/Meas (µg/L)	NR	Reps: 2-4 w/5-10 per
Concentration 4 Nom/Meas (µg/L)	NR	Reps: 2-4 w/5-10 per
Control?	Methanol carrier at $\leq$ 1.5%	Reps: 2-4 w/5-10 per
LC50; indicate calculation method	0.47 ug/L (0.39-0.56, 95% ci)	Trimmed Spearman-Karber

Toxicity Data Summary

Chironomus tentans

Study: Belden JB, Lydy MJ. 2000. Impact of atrazine on organophosphate insecticide toxicity. Environ Toxicol Chem 19: 2266-2274.

Rating: RR

Notes: Study showed significant synergism between chlorpyrifos and atrazine. Only data for chlorpyrifos alone is shown here for use in criteria derivation, but synergism data is useful for consideration of mixtures.

Belden & Lydy 2000		
Parameter	**Value**	**Comment**
Test method cited	USEPA 1994	See full reference below
Phylum	Arthropoda	
Class	Insecta	
Order	Diptera	
Family	Chironomidae	
Genus	*Chironomus*	
Species	*tentans*	
Family resides in	North America	
Age/size at start of test/growth phase	4^{th} instar; 0.63-0.71 mm wide; $\geq$ 1.0 cm long	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	NR	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Immobility + Mortality	
Control response 1	NR	
Temperature	20 ± 1^{o} C	
Test type	Static	
Photoperiod	16L:8D	
Dilution water	MHSFW	
pH	7.3-7.8	
Hardness	NR	
Alkalinity	NR	

Belden & Lydy 2000		
Parameter	**Value**	**Comment**
Conductivity	320-350 uS/cm	
Dissolved Oxygen	> 70%	
Feeding	NR	
Purity of test substance	> 98%	
Concentrations measured?	Yes	Nominal values used in calcs since measured values were w/in 10%
Measured is what % of nominal?	90%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	NR	
Concentration 1 Nom/Meas (μg/L)	NR; initial measured conc. w/in 10% of nominal; post-test values were 76-85% of initial values	Reps: 3 w/10 per
Concentration 2 Nom/Meas (μg/L)	NR; initial measured conc. w/in 10% of nominal; post-test values were 76-85% of initial values	Reps: 3 w/10 per
Concentration 3 Nom/Meas (μg/L)	NR; initial measured conc. w/in 10% of nominal; post-test values were 76-85% of initial values	Reps: 3 w/10 per
Concentration 4 Nom/Meas (μg/L)	NR; initial measured conc. w/in 10% of nominal; post-test values were 76-85% of initial values	Reps: 3 w/10 per
Concentration 5 Nom/Meas (μg/L)	NR; initial measured conc. w/in 10% of nominal; post-test values were 76-85% of initial values	Reps: 3 w/10 per
Control	Dilution water; solvent (acetone, 50 uL/L)	Reps: 3 w/10 per
ECx (95% ci); ug/L	EC1: 0.12 (0.08-0.17) EC5: 0.17 (0.12-0.22) EC15: 0.23 (0.18-0.28) EC50: 0.39 (0.33-0.45)	probit

USEPA. 1994. Methods for measuring the toxicity and bioaccumulation of sediment-associated contaminant with freshwater invertebrates. EPA/600/R-94/024. US Environmental Protection Agency, Washington, DC.

Toxicity Data Summary

Chironomus tentans

Study: Belden JB, Lydy MJ. 2006. Joint toxicity of chlorpyrifos and esfenvalerate to fathead minnows and midge larvae. Environ Toxicol Chem 25: 623-629.

Rating: RR

Belden & Lydy 2006		
Parameter	**Value**	**Comment**
Test method cited	USEPA 1994	Reference below
Phylum	Arthropoda	
Class	Insecta	
Order	Diptera	
Family	Chironomidae	
Genus	*Chironomus*	
Species	*tentans*	
Family resides in	North America	
Age/size at start of test/growth phase	3^{rd}-4^{th} instar larvae	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	NR	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Mobility	
Control response 1	< 10% mortality	
Temperature	21 ± 2^{o} C	
Test type	Static	
Photoperiod/light intensity	NR	
Dilution water	Moderately hard synthetic (MHSFW)	
pH	7.8-8.3	
Hardness	MHSFW	
Alkalinity	MHSFW	
Conductivity	MHSFW	
Dissolved Oxygen	> 70%	
Feeding	NR	

Belden & Lydy 2006		
Parameter	**Value**	**Comment**
Purity of test substance	> 98%	
Concentrations measured?	No, but stability confirmed in separate study	
Measured is what % of nominal?	90% pre-test; 85% post-test	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	None	
Concentration 1 Nom/Meas (μg/L)	NR	Reps and #: 3 w 10 per
Concentration 2 Nom/Meas (μg/L)	NR	Reps and #: 3 w 10 per
Concentration 3 Nom/Meas (μg/L)	NR	Reps and #: 3 w 10 per
Concentration 4 Nom/Meas (μg/L)	NR	Reps and #: 3 w 10 per
Concentration 5 Nom/Meas (μg/L)	NR	Reps and #: 3 w 10 per
Control	Not described; presumably dilution water	Reps and #: 3 w 10 per
ECx (95% ci)	EC10: 0.084 (0.052-0.108) ug/L EC50: 0.16 (0.13-0.19) ug/L	Log-probit

USEPA. 1994. Methods for measuring the toxicity and bioaccumulation of sediment-associated contaminant with freshwater invertebrates. EPA/600/R-94/024. US Environmental Protection Agency, Washington, DC.

Toxicity Data Summary

Chironomus tentans

Study: Lydy MJ, Austin KR. 2004. Toxicity assessment of pesticide mixtures typical of the Sacramento-San Joaquin Delta using *Chironomus tentans*. Arch Environ Contam Toxicol 48: 49-55.

Rating: RR

Lydy & Austin 2004		
Parameter	**Value**	**Comment**
Test method cited	EPA/600/R-94/024	USEPA 1994
Phylum	Arthropoda	
Class	Insecta	
Order	Diptera	
Family	Chironomidae	
Genus	*Chironomus*	
Species	*tentans*	
Family resides in	North America	
Age/size at start of test/growth phase	4^{th} instar	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Unable to perform figure 8 when prodded	
Control response 1	< 10%	
Temperature	$21 \pm 2^{o}C$	
Test type	Static	
Photoperiod/light intensity	16:8	
Dilution water	MHSFW	
pH	7.8-8.2	
Hardness	MH water	
Alkalinity	MH water	
Conductivity	320-360 uS/cm	
Dissolved Oxygen	> 75%	
Feeding	None	
Purity of test substance	99.9%	

Lydy & Austin 2004		
Parameter	**Value**	**Comment**
Concentrations measured?	Yes	
Measured is what % of nominal?	> 90%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	100 uL/L	
Concentration 1 Nom/Meas (μg/L)	NR	Reps: 3 w 10 per
Concentration 2 Nom/Meas (μg/L)	NR	Reps: 3 w 10 per
Concentration 3 Nom/Meas (μg/L)	NR	Reps: 3 w 10 per
Concentration 4 Nom/Meas (μg/L)	NR	Reps: 3 w 10 per
Concentration 5 Nom/Meas (μg/L)	NR	Reps: 3 w 10 per
Control	Solvent	Reps: 3 w 10 per
EC50 (95% ci); ug/L	0.17 (0.15-0.21)	Method NR

Toxicity Data Summary

Chironomus tentans

Study: Pape-Lindstrom PA, Lydy MJ. 1997. Synergistic toxicity of atrazine and organophosphate insecticides contravenes the response addition mixture model. Environ Toxicol Chem 16: 2415-2420.

Rating: RR

Notes: Exposure is in water with silica sand substrate; this type of sand has been shown not to affect bioavailability of Ops.

Pape-Lindstrom & Lydy 1997		
Parameter	**Value**	**Comment**
Test method cited	None cited for entire test, but parts of USEPA1991 (EPA-600-4-90-027) cited	
Phylum	Arthropoda	
Class	Insecta	
Order	Diptera	
Family	Chironomidae	
Genus	*Chironomus*	
Species	*tentans*	
Family resides in	North America	
Age/size at start of test/growth phase	Fourth instar	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Failure to execute 3 figure-8 motions when prodded	Effect linked to mortality
Control response 1	< 5% mortality	
Temperature	20 $\pm$ 1 ^{o}C	Mean $\pm$ sd
Test type	Static	
Photoperiod	16L:8D	
Dilution water	Moderately hard standard referenc water (EPA)	

Pape-Lindstrom & Lydy 1997		
Parameter	**Value**	**Comment**
pH	7.95 ± 0.19	Mean ± sd
Hardness	NR; but meets EPA MHSFW specs	
Alkalinity	NR; but meets EPA MHSFW specs	
Conductivity	361 ± 10.3 uS/cm	Mean ± sd
Dissolved Oxygen	88.8 ± 7.1%	Mean ± sd
Feeding	None	
Purity of test substance	99%	
Concentrations measured?	No	
Measured is what % of nominal?	NA	
Chemical method documented?	NA	
Concentration of carrier (if any) in test solutions	0.5 mL/L	
Concentration 1 Nom/Meas (µg/L)	NR	Reps: 3 w/10 per
Concentration 2 Nom/Meas (µg/L)	NR	Reps: 3 w/10 per
Concentration 3 Nom/Meas (µg/L)	NR	Reps: 3 w/10 per
Concentration 4 Nom/Meas (µg/L)	NR	Reps: 3 w/10 per
Concentration 5 Nom/Meas (µg/L)	NR	Reps: 3 w/10 per
Control	Dilution water and solvent (acetone @ 0.5 ml/L	Reps: 3 w/10 per
LC50 (95% ci)	Test 1: 0.58 ug/L (0.43-0.68); Test 2: 0.75 (0.58-0.99); Test 3: 0.51 (0.42-0.63)	probit

Toxicity Data Summary

Daphnia ambigua

Study: Harmon SM, Specht WL, Chandler GT. 2003. A comparison of the daphnids *Ceriodaphnia dubia* and *Daphnia ambigua* for their utilization in routine toxicity testing in the Southeastern United States. Arch Environ Contamin Toxicol 45: 79-85.

Rating: RR

Harmon et al. 2003		
Parameter	**Value**	**Comment**
Test method cited	ASTM E-729-88a	
Phylum/sub-phylum	Arthropoda/Crustacea	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	*Daphnia*	
Species	*ambigua*	
Family resides in	North America	
Age/size at start of test/growth phase	Neonates	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	48 h	
Data for multiple times?	No	
Effect 1	Immobilization	
Control survival	Dilution water = 49/50 Solvent control = 50/50	
Temperature	21 $\pm$ 2 ^{o}C	
Test type	Static	
Photoperiod	16L:8L	
Dilution water	Moderately hard reconstituted water	
pH	8.11-8.66	
Hardness	54-72 mg/L as $CaCO_3$	
Alkalinity	57-76 mg/L as $CaCO_3$	
Conductivity	NR	
Dissolved Oxygen	7.46-9.14 mg/L	
Feeding	No	

Harmon et al. 2003		
Parameter	**Value**	**Comment**
Purity of test substance	Not stated; used research grade Dursban XP	
Concentrations measured?	Yes	
Measured is what % of nominal?	NR	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	37.5 uL/L	
Concentration 1 Meas (µg/L)	0.02	Reps: 5 w/10 per
Concentration 2 Meas (µg/L)	0.03	Reps: 5 w/10 per
Concentration 3 Meas (µg/L)	0.04	Reps: 5 w/10 per
Concentration 4 Meas (µg/L)	0.06	Reps: 5 w/10 per
Concentration 5 Meas (µg/L)	0.08	Reps: 5 w/10 per
Control?	Dilution water and solvent	Reps: 5 w/10 per; 37.5 ul/L methanol
LC50; indicate calculation method	0.035 ug/L (0.032-0.037)	Trimmed Spearman-Karber; (95% ci)

Toxicity Data Summary

Daphnia magna

Study: Kersting K, Van Wijngaarden R. 1992. Effects of chlorpyrifos on a microecosystem. Environ Toxicol Chem 11: 365-372.

Rating: RR

Notes: This study includes a microecosystem component that did not produce any LC, EC or NOEC values. The information summarized here is only for the single-species components of this study.

Kersting & Van Wijngaarden 1992		
Parameter	**Value**	**Comment**
Test method cited	No standard method cited	
Phylum/subphylum	Arthropoda/Crustacea	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphnidae	
Genus	*Daphnia*	
Species	*magna*	
Family resides in	North America	
Age/size at start of test/growth phase	Neonates < 24 h	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	Acute: 48 h Chronic: 21 d	
Data for multiple times?	Yes, for acute test	
Effect 1	Acute: Mortality Chronic: Mortality	
Control response 1	Acute: 0% Chronic: 0%	
Effect 2	Chronic: Reproduction	
Control response 2	51-58 neonates per female	
Temperature	NR for single-species tests,	

Kersting & Van Wijngaarden 1992		
Parameter	**Value**	**Comment**
	but 18 ^{o}C for microecosystem	
Test type	Acute: static; Chronic: static-renewal (48-72-h renewal)	
Photoperiod	NR	
Dilution water	0.5 strength medium 63	From Taub & Dollar (1968)
pH	Acute: 6.8-7.0 Chronic: 7.0-8.1	
Hardness	NR	
Alkalinity	NR	
Conductivity	NR	
Dissolved Oxygen	Acute: 7.7-8.8 mg/L Chronic: 8.8-9.9 mg/L	
Feeding	Acute: None Chronic: Yes	
Purity of test substance	NR	
Concentrations measured?	Acute: Yes, highest 3 doses; reported as mean of concentration at 0 and 48 h; values of lower concentrations calculated assuming similar degradation; Chronic: apparently not measured; NOEC calculations based on nominal	
Measured is what % of nominal?	80-140%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	NR	
Concentration 1 Nom/Meas (µg/L)	0.01	Reps: NR w/25 per
Concentration 2 Nom/Meas (µg/L)	0.03	Reps: NR w/25 per
Concentration 3 Nom/Meas (µg/L)	0.1	Reps: NR w/25 per
Concentration 4 Nom/Meas (µg/L)	0.3	Reps: NR w/25 per
Concentration 5 Nom/Meas (µg/L)	1/0.8-1.4 (48 & 0 h in acute)	Reps: NR w/25 per
Concentration 6 Nom/Meas (µg/L)	3/2.4-3.1 (48 & 0 h in acute)	Reps: NR w/25 per
Concentration 7 Nom/Meas (µg/L)	10/8.0-10.4 (48 & 0 h in acute)	Reps: NR w/25 per
Control	Dilution water; solvent	Reps: NR w/25 per

Kersting & Van Wijngaarden 1992		
Parameter	**Value**	**Comment**
	(actone; amount not given)	
LCx (95% ci); ug/L	24-h LC50: 3.7 (2.5-5.9); 48-h LC50: 1.0 (1.0-1.1); 48-h LC25: 0.4	LC50: logit; LC25: graphical; Both based on mean of measured concentrations at 0 and 48 h.
NOEC; ug/L	Acute: 0.1; Chronic Survival: 0.1; Chronic Repr.: 0.1	Significant difference from control; method not stated; based on nominal
LOEC; indicate calculation method	Acute: 0.3 Chronic Survival: 0.3 Chronic Repr.: 0.3	
MATC (GeoMean NOEC,LOEC)	0.17 for all	
Difference from control at NOEC	Not calculable; data not given	
Difference from control at LOEC	Not calculable; data not given	

Taub FB, Dollar AM. 1968. The nutritional inadequacy of *Chlorella* and *Chlamydomonas* as food for *Daphnia pulex*. Linmol Oceanogr 13: 607-618.

Medium 63:
1.5 mM NaCl
1 mM $CaCl_2$
0.5 mM $NaNO_3$
0.42 mM $NaHCO_3$
0.1mM $MgSO_4$
0.08 mM $Na_2(SiO_4)_3$
0.04mM KH_2PO_4

Toxicity Data Summary

Daphnia pulex

Study: Van Der Hoeven N, Gerritsen AAM. 1997. Effects of chlorpyrifos on individuals and populations of *Daphnia pulex* in the laboratory and field. Environ Toxicol Chem 16: 2438-2447.

Rating: RR (only applies to study #2)

Notes: Study includes 8 different experiments including acute, chronic, recovery scenarios, and population studies. Tests were as follows;

1) 2-d exposure, starting with neonates, using Dursban (45.3% active ingredient)
2) 2-d exposure, starting with neonates, using technical grade chorpyrifos
3) 17-d exposure, starting with neonates, using Dursban
4) 6-d exposure, starting with neonates, using Dursban, with recovery period
5) 8-d exposure, starting with adults, using Dursban
6) 6-d exposure, starting with adults, using Dursban, with recovery period
7) 28-d field exposure of populations of mixed life stages
8) 28-d laboratory exposure of populations of mixed life stages

Van Der Hoeven & Gerritsen 1997		
Parameter	**Value**	**Comment**
Test method cited	No standard method cited	
Phylum	Arthropoda	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	*Daphnia*	
Species	*pulex*	
Family resides in	North America	
Age/size at start of test/growth phase	1) < 24 h 2) < 24 h 3) < 24 h 4) < 24 h 5) 7-8 d 6) 9-10 d 7) mixed 8) mixed	
Source of organisms	Lab culture	

Van Der Hoeven & Gerritsen 1997		
Parameter	**Value**	**Comment**
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	1) 2 d 2) 2 d 3) 17 d 4) 1,2 or 3 d exposure; recovery through 6 d; 5) 8 d 6) 1,2 or 3 d exposure; recovery through 6 d 7) 28 d 8) 28 d	
Data for multiple times?	Yes	
Effect 1	Mortality	
Control response 1	NR; 100% (from figure)	
Effect 2	Immobility	
Control response 2	NR	
Effect 3	Reproduction	
Control response 3	NR	
Effect 4	Population size	
Control response 4	NR	
Temperature	1-6,7) 20 $\pm$ 1 ^{o}C 8) 12-23 ^{o}C	
Test type	1) static 2) static 3) static-renewal; 3x per wk 4) static-renewal; 3x per wk 5) static-renewal; on days 1,2,3 6) static-renewal; on days 1,2,3 7,8) static-renewal; daily	
Photoperiod	Lab studies: 7 h D:1 h twilight; 15 h L: 1 h twilight; Field study: natural	
Dilution water	Lab studies: modified ground water	
pH	Lab: 8.0-8.2	

Van Der Hoeven & Gerritsen 1997		
Parameter	**Value**	**Comment**
	Field: 7.5-9.5	
Hardness	Lab: 220 mg/L as $CaCO_3$; Field: NR	
Alkalinity	NR	
Conductivity	NR	
Dissolved Oxygen	NR	
Feeding	For tests $\leq$ 2d: none; For longer tests: daily	
Purity of test substance	45.% in tests with Dursban; NR for test (2) with technical grade	Technical compound accepted as being $\geq$ 80% pure based on other reports of technical chrorpyrifos indicating that it is always $\geq$ 80% pure.
Concentrations measured?	Yes	
Measured is what % of nominal?	33-99% laboratory; 30-52% field	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	None used with technical grade tests; NR in formultaion tests	
Concentration range (µg/L); these are nominals; authors feel they are more reliable than the measured values; measured values as percentage of nominal ranged from 33-99% in laboratory studies; 30-52% in field.	1) 0.2-6.4; factor of 2; 2) 0.2-6.4; factor of 2; 3) 0.0125-0.4; factor of 2; 4) 0.05-1.6; factor of 2; 5) 0.2-0.64; factor of 1.8; 6) 0.4-1.6; factor of 2; 7) 0.1 and 0.7 ug/L; 8) 0.11, 0.17, 0.24, 0.33, 0.47, 0.66 ug/L	Reps: 1) 13-18 w/1 per 2) 13-19 w/1 per 3) 17-19 w/1 per 4) 19-20 w/1 per 5) 2 w/20 per 6) 2 w/14 per 7) 2 w/ 2 populations per 8) 2 w/1 per
Control	Dilution water and emulsifier controls	Reps: 1) 20 w/1 per 2) 20 w/1 per 3) 17 w/1 per 4) 20 w/1 per 5) 4 w/20 per 6) 4 w/14 per 7) 4 w/2 populations per 8) 4 w/1 per

Van Der Hoeven & Gerritsen 1997		
Parameter	**Value**	**Comment**
LC50; indicate calculation method	Tech grade test: 24 h: 4.9 ug/L 48 h: 0.42 ug/L	Maximum likelihood
ECx; indicate calculation method	Tech grade test: 24 h: 0.3 ug/L 48 h: 0.25 ug/L tables	Maxiimum likelihood
NOEC; indicate calculation method	1) < 0.2 ug/L 2) < 0.2 ug/L 3) 0.1 ug/L 4) 0.36 ug/L 5) 0.2 ug/L 6) < 0.4 ug/L 7) 0.052 ug/L 8) 0.17 ug/L	Dunnett's; 1,2) mortality, mobility; 3) mortality, mobility, reproduction; 4) mortality, mobility, length; 5,6) mortality, mobility, reproduction 7,8) population size
LOEC; indicate calculation method	1) 0.2 ug/L 2) 0.2 ug/L 3) 0.2 ug/L 4) 0.64 ug/L 5) 0.4 ug/L 6) 0.46ug/L 7) 0.26 ug/L 8) 0.24 ug/L	Dunnett's
MATC (GeoMean NOEC,LOEC)	1) NC 2) NC 3) 0.14 ug/L 4) 0.48 ug/L 5) 0.28 ug/L 6) NC 7) 0.12 ug/L 8) 0.20 ug/L	
Difference from control at NOEC	NC	
Difference from control at LOEC	NC	

Only test 2 was done with technical grade chlorpyrifos; it is the only test that can be used for criteria derivation.

Toxicity Data Summary

Hyalella azteca

Study: Anderson TD, Lydy MJ. 2002. Increased toxicity to invertebrates associated with a mixture of atrazine and organophosphate insecticides. Environ Toxicol Chem 21: 1507-1514.

Rating: RR

Anderson & Lydy 2002		
Parameter	**Value**	**Comment**
Test method cited	EPA -600-R-94-024	USEPA 1994
Phylum	Arthropoda	
Class	Malacostraca	
Order	Amphipoda	
Family	Hyalellidae	
Genus	*Hyalella*	
Species	*azteca*	
Family resides in	N. America	
Age/size at start of test/growth phase	14-21 d	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	NR	
Temperature	20 $\pm$ 1^{o}C	
Test type	Static	
Photoperiod/light intensity	16:8	
Dilution water	NR	
pH	7.3-7.5	
Hardness	NR	
Alkalinity	NR	
Conductivity	331-359 uS/cm	
Dissolved Oxygen	$\geq$ 81%	
Feeding	None	

Anderson & Lydy 2002		
Parameter	**Value**	**Comment**
Purity of test substance	$\geq$ 98%	
Concentrations measured?	Yes	
Measured is what % of nominal?	$\geq$ 90%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	100 uL per test vessel; size of vessel NR	
Concentration 1 Nom/Meas (µg/L)	NR	Reps: 3 w/10 per
Concentration 2 Nom/Meas (µg/L)	NR	Reps: 3 w/10 per
Concentration 3 Nom/Meas (µg/L)	NR	Reps: 3 w/10 per
Concentration 4 Nom/Meas (µg/L)	NR	Reps: 3 w/10 per
Concentration 5 Nom/Meas (µg/L)	NR	Reps: 3 w/10 per
Control	Solvent	Reps: 3 w/10 per
LC50 (95% ci)	0.0427 (0.0333-0..0492)	Log-probit

Toxicity Data Summary

Hyalella azteca

Study: Ankley GT, Collyard SA. 1995. Influence of piperonyl butoxide on the toxicity of organophosphate insecticides to three species of freshwater benthic invertebrates. Comp Biochem Physiol 110C: 149-155.

Rating: RR

Notes: Using only data for chlorpyrifos only exposures; water quality information, test substance purity, replication, other information given as ranges for all tests and compounds; not possible to match specific data with each test.

Ankley & Collyard 1995		
Parameter	**Value**	**Comment**
Test method cited	None cited, but appears to follow EPA acute methods	Study by EPA staff
Phylum	Arthropoda	
Class	Malacostraca	
Order	Amphipoda	
Family	Hyalellidae	
Genus	*Hyalella*	
Species	*azteca*	
Family resides in	North America	
Age/size at start of test/growth phase	7-14 d juveniles	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Mortality/immobility	
Control response 1	NR	
Temperature	$23 \pm 1\ ^{o}C$	
Test type	Static	
Photoperiod	16L:8D	
Dilution water	Lake Superior water; as is, or with added hardness	

pH	7.4-8.5	
Hardness	42-47 mg/L as $CaCO_3$	Hardness adjusted to 105 mg/L as $CaCO_3$, but not clear for which species in the study
Alkalinity	39-46 mg/L as $CaCO_3$	
Conductivity	NR	
Dissolved Oxygen	5.2-8.1 mg/L	
Feeding	Yeast-Cerophyll-Trout Chow at test start	
Purity of test substance	$\geq$ 95% pure	
Concentrations measured?	No	
Measured is what % of nominal?	NA	
Chemical method documented?	NA	
Concentration of carrier (if any) in test solutions	$\leq$ 0.15 mL/L	
Concentration 1 Nom/Meas (µg/L)	NR	Reps: 2-4 w/5-10 per
Concentration 2 Nom/Meas (µg/L)	NR	Reps: 2-4 w/5-10 per
Concentration 3 Nom/Meas (µg/L)	NR	Reps: 2-4 w/5-10 per
Concentration 4 Nom/Meas (µg/L)	NR	Reps: 2-4 w/5-10 per
Control?	Methanol carrier at $\leq$ 1.5%	Reps: 2-4 w/5-10 per
LC50; indicate calculation method	0.04 ug/L (0.03-0.05, 95% ci)	Trimmed Spearman-Karber

Toxicity Data Summary

Ictalurus punctatus

Study: Phipps G L, Holcombe GW. 1985. A method for acute multiple species toxicant testing: acute toxicity of 10 chemicals to 5 vertebrates and 2 invertebrates. Environ Poll (Series A) 38: 141-157.

Rating: RR

Notes: Multispecies exposure generating LC50s for each species. Not a multispecies test that is environmentally realistic because species were isolated from each other. Doesn't count as a mesocosm study due to lack of interaction.

Phipps & Holcombe 1985		
Parameter	**Value**	**Comment**
Test method cited	New multispecies method based on ASTM, EPA methods	
Phylum	Chordata	
Class	Actinopterygii	
Order	Siluriformes	
Family	Ictaluridae	
Genus	*Ictalurus*	
Species	*punctatus*	
Family resides in	North America	
Age/size at start of test/growth phase	7.9 g	
Source of organisms	Fish hatchery	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	0 in a separate test of 3680 mg/L dimethylformamide; NR in tests	
Temperature	17.3 $\pm$ 0.6 ^{o}C	
Test type	Flow-through	90% replacement in

Phipps & Holcombe 1985		
Parameter	**Value**	**Comment**
		8 h; 130 ml/min
Photoperiod	16L:8D	
Dilution water	Lake Superior	
pH	7.1-7.8	
Hardness	44.4 (range 40.7-46.6) mg/L as $CaCO_3$	
Alkalinity	45.4 (range 42.3-57.0) mg/L as $CaCO_3$	
Conductivity	NR	
Dissolved Oxygen	7.5 $\pm$ 1.6 mg/L (range 4.7-10.0); $\geq$ 50% saturation	mean $\pm$ sd
Feeding	None	
Purity of test substance	NR	
Concentrations measured?	Yes; average 99.5% of nominal; Measured concentrations ranged from 0.004-0.806 mg/L	Table 1 lists 3 different sets of Dursban measured concentrations, but only one Dursban test was done
Measured is what % of nominal?	99.5%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	108 mg/L dimethylformamide	
Concentration 1 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 2 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 3 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 4 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 5 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Control?	Solvent control; 108 mg/L dimethylformamide	Reps: 2 w 20 per
L50 (95% ci)	96-h: 0.806 (0.434-1.088) mg/L 72-h: 0.806 mg/L	Trimmed Spearman-Karber

Toxicity Data Summary

Lepomis macrochirus

Study: Phipps G L, Holcombe GW. 1985. A method for acute multiple species toxicant testing: acute toxicity of 10 chemicals to 5 vertebrates and 2 invertebrates. Environ Poll (Series A) 38: 141-157.

Rating: RR

Notes: Multispecies exposure generating LC50s for each species. Not a multispecies test that is environmentally realistic because species were isolated from each other. Doesn't count as a mesocosm study due to lack of interaction.

Phipps & Holcombe 1985		
Parameter	**Value**	**Comment**
Test method cited	New multispecies method based on ASTM, EPA methods	
Phylum	Chrodata	
Class	Actinopterygii	
Order	Perciformes	
Family	Centrarchidae	
Genus	*Lepomis*	
Species	*macrochirus*	
Family resides in	North America	
Age/size at start of test/growth phase	0.8 g	
Source of organisms	Fish hatchery	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	0 in a separate test of 3680 mg/L dimethylformamide; NR in tests	
Temperature	17.3 $\pm$ 0.6 ^{o}C	
Test type	Flow-through	90% replacement in

Phipps & Holcombe 1985		
Parameter	**Value**	**Comment**
		8 h; 130 ml/min
Photoperiod	16L:8D	
Dilution water	Lake Superior	
pH	7.1-7.8	
Hardness	44.4 (range 40.7-46.6) mg/L as $CaCO_3$	
Alkalinity	45.4 (range 42.3-57.0) mg/L as $CaCO_3$	
Conductivity	NR	
Dissolved Oxygen	7.5 $\pm$ 1.6 mg/L (range 4.7-10.0); $\geq$ 50% saturation	mean $\pm$ sd
Feeding	None	
Purity of test substance	NR	
Concentrations measured?	Yes; average 99.5% of nominal; Measured concentrations ranged from 0.004-0.806 mg/L	Table 1 lists 3 different sets of Dursban measured concentrations, but only one Dursban test was done
Measured is what % of nominal?	99.5%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	108 mg/L dimethylformamide	
Concentration 1 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 2 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 3 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 4 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 5 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Control	Solvent control; 108 mg/L dimethylformamide	Reps: 2 w 20 per
LC50 (95% ci)	96-h: 0.010 (0.006-0.014) mg/L	Trimmed Spearman-Karber

Toxicity Data Summary

Neomysis mercedis

Study: CDFG. 1992a. Test No. 133. 96-h acute toxicity of chlorpyrifos to *Neomysis mercedis*, Aquatic Toxicity Laboratory, Elk Grove, CA.

Rating: RR

CDFG 1992a		
Parameter	**Value**	**Comment**
Test method cited	ASTM 1988 (E729-88)	
Phylum/subphylum	Arthropoda/crustacea	
Class	Malacostraca	
Order	Mysidacea	
Family	Mysidae	
Genus	*Neomysis*	
Species	*mercedis*	
Family resides in	N. Amer.	
Age/size at start of test/growth phase	< 5 d post-release	
Source of organisms	Lab cultures	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	Yes; see study	
Effect 1	Mortality	
Control response 1	Dilution water: 0% Solvent: 5% Total: 2.5%	
Temperature; mean	17.2^{o} C	
Test type	Static renewal; daily renewal	
Photoperiod	16L:8D	
Dilution water	Aquat Tox Lab well water plus 2 g/kg artificial sea salt	
pH; mean	8.39	
Hardness; mean	499 mg/L as $CaCO_3$	

CDFG 1992a		
Parameter	**Value**	**Comment**
Alkalinity; mean	154 mg/L as $CaCO_3$	
Conductivity; mean	3076 uS/cm	
Dissolved Oxygen; mean	8.41 mg/L	
Feeding	Artemia nauplii; frequency NR	
Purity of test substance	99%	
Concentrations measured?	Yes	
Measured is what % of nominal?	124%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	0.026 mL/L	
Concentration 1 Meas (µg/L)	0.065	Reps: 20 w/1 per
Concentration 2 Meas (µg/L)	0.14	Reps: 20 w/1 per
Concentration 3 Meas (µg/L)	0.305	Reps: 20 w/1 per
Concentration 4 Meas (µg/L)	0.61	Reps: 20 w/1 per
Concentration 5 Meas (µg/L)	1.3	Reps: 20 w/1 per
Control	< 0.03 ug/L chlorpyrifos; dilution water; solvent (triethylene glycol, triethylene glycol dimethyl ether, $\leq$ 0.026 mL/L)	Reps: 20 w/1 per
LC50 (95% ci); ug/L	0.16 (0.14-0.30)	Non-linear interpolation
NOEC; ug/L	0.065	Chi squared
LOEC; ug/L	0.14	
MATC (GeoMean NOEC,LOEC)	0.095	
% of control at NOEC	105%	Based on solvent control
% of control at LOEC	68%	Based on solvent control

Toxicity Data Summary

Neomysis mercedis

Study: CDFG. 1992d. Test No. 142. 96-h acute toxicity of chlorpyrifos to *Neomysis mercedis*, Aquatic Toxicity Laboratory, Elk Grove, CA.

Rating: RR

CDFG 1992d		
Parameter	**Value**	**Comment**
Test method cited	ASTM 1988 (E729-88)	
Phylum/subphylum	Arthropoda/crustacea	
Class	Malacostraca	
Order	Mysidacea	
Family	Mysidae	
Genus	*Neomysis*	
Species	*mercedis*	
Family resides in	N. Amer.	
Age/size at start of test/growth phase	< 5 d post-release	
Source of organisms	Lab cultures	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	Yes; see study	
Effect 1	Mortality	
Control response 1	0%	
Temperature; mean	17.1^{o} C	
Test type	Static renewal; daily renewal	
Photoperiod	16L:8D	
Dilution water	Aquat Tox Lab well water plus 2 g/kg artificial sea salt	
pH; mean	8.36	
Hardness; mean	509 mg/L as $CaCO_3$	
Alkalinity; mean	151 mg/L as $CaCO_3$	
Conductivity; mean	3151 uS/cm	
Dissolved Oxygen; mean	9.26 mg/L	

CDFG 1992d		
Parameter	**Value**	**Comment**
Feeding	Artemia nauplii; frequency NR	
Purity of test substance	99%	
Concentrations measured?	Yes	
Concentration 1 Meas (µg/L)	0.045	Reps: 20 w/1 per
Concentration 2 Meas (µg/L)	0.09	Reps: 20 w/1 per
Concentration 3 Meas (µg/L)	0.18	Reps: 20 w/1 per
Concentration 4 Meas (µg/L)	0.365	Reps: 20 w/1 per
Concentration 5 Meas (µg/L)	0.77	Reps: 20 w/1 per
Control	< 0.03 ug/L chlorpyrifos; dilution water; solvent (triethylene glycol, triethylene glycol dimethyl ether, $\leq$ 0.026 mL/L)	Reps: 20 w/1 per
Measured is what % of nominal?	73%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	0.026 mL/L	
LC50 (95% ci); ug/L	0.14 (0.09-0.18)	Non-linear interpolation
NOEC; ug/L	0.09	Chi squared
LOEC; ug/L	0.18	
MATC (GeoMean NOEC,LOEC)	0.13	
% of control at NOEC	100%	
% of control at LOEC	15%	

Toxicity Data Summary

Neomysis mercedis

Study: CDFG. 1992e. Test No. 143. 96-h acute toxicity of chlorpyrifos to *Neomysis mercedis*, Aquatic Toxicity Laboratory, Elk Grove, CA.

Rating: RR

CDFG 1992e		
Parameter	**Value**	**Comment**
Test method cited	ASTM 1988 (E729-88)	
Phylum/subphylum	Arthropoda/crustacea	
Class	Malacostraca	
Order	Mysidacea	
Family	Mysidae	
Genus	*Neomysis*	
Species	*mercedis*	
Family resides in	N. Amer.	
Age/size at start of test/growth phase	< 5 d post-release	
Source of organisms	Lab cultures	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	Yes; see study	
Effect 1	Mortality	
Control response 1	0%	
Temperature; mean	17.4^{o} C	
Test type	Static renewal; daily renewal	
Photoperiod	16L:8D	
Dilution water	Aquat Tox Lab well water plus 2 g/kg artificial sea salt	
pH; mean	8.21	
Hardness; mean	515 mg/L as $CaCO_3$	
Alkalinity; mean	152 mg/L as $CaCO_3$	
Conductivity; mean	3192 uS/cm	
Dissolved Oxygen; mean	8.90 mg/L	

Feeding	Artemia nauplii; frequency NR	
Purity of test substance	99%	
Concentrations measured?	Yes	
Measured is what % of nominal?	72%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	0.026 mL/L	
Concentration 1 Meas (µg/L)	0.045	Reps: 20 w/1 per
Concentration 2 Meas (µg/L)	0.09	Reps: 20 w/1 per
Concentration 3 Meas (µg/L)	0.18	Reps: 20 w/1 per
Concentration 4 Meas (µg/L)	0.365	Reps: 20 w/1 per
Concentration 5 Meas (µg/L)	0.755	Reps: 20 w/1 per
Control	< 0.03 ug/L chlorpyrifos; dilution water; solvent (triethylene glycol, triethylene glycol dimethyl ether, ≤ 0.026 mL/L)	Reps: 20 w/1 per
LC50 (95% ci); ug/L	0.15 (0.09-0.1825)	Non-linear interpolation
NOEC; ug/L	0.09	Chi squared
LOEC; ug/L	0.18	
MATC (GeoMean NOEC,LOEC)	0.13	
% of control at NOEC	100%	
% of control at LOEC	30%	

Toxicity Data Summary

Oncorhynchus mykiss

Study: Holcombe GW, Phipps GL, Tanner DK. 1982. The acute toxicity of kelthane, dursban, disulfoton, pydirn, and permethrin to fathead minnows *Pimephales promelas* and rainbow trout *Salmo gairdneri*. Environ Poll (Series A) 29: 167-178.

Rating: RR

Notes: 24-, 48-, 72- and 96-h LC50s reported

Holcombe et al. 1982		
Parameter	**Value**	**Comment**
Test method cited	USEPA 1975	Cited for "procedures and methods not specified" in text
Phylum	Chordata	
Class	Actinopterygii	
Order	Salmoniformes	
Family	Salmonidae	
Genus	*Oncorhynchus*	
Species	*mykiss*	
Family resides in	North America	
Age/size at start of test/growth phase	Juvenile; 1.0 g	
Source of organisms	Hatchery	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	Yes, but not raw data	
Effect 1	Mortality	
Control response 1	NR	
Effect 2	Equilibrium	No statistical analysis
Effect 3	Coloration	No statistical analysis
Effect 4	Deformities	No statistical analysis
Temperature	12 ^{o}C	
Test type	Flow-through	

Holcombe et al. 1982		
Parameter	**Value**	**Comment**
Photoperiod	16L:8D	
Dilution water	Lake Superior water	
pH	7.0-7.4	
Hardness	45.3 (43.7-46.5) mg/L as $CaCO_3$	
Alkalinity	41.8 (39.6-43.2) mg/L as $CaCO_3$	
Conductivity	NR	
Dissolved Oxygen	9.3 (7.5-11.3) mg/L	
Feeding	Not fed from 24 h before nor through test	
Purity of test substance	99.9%	
Concentrations measured?	Yes; nominal concentrations not given	
Measured is what % of nominal?	92.7%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	None used	
Concentration 1 Nom/Meas (µg/L)	1.5 $\pm$ 0.1	Reps: 2 (10 per tank)
Concentration 2 Nom/Meas (µg/L)	2.7 $\pm$ 0.3	Reps: 2 (10 per tank)
Concentration 3 Nom/Meas (µg/L)	5.0 $\pm$ 0.4	Reps: 2 (10 per tank)
Concentration 4 Nom/Meas (µg/L)	7.7 $\pm$ 0.6	Reps: 2 (10 per tank)
Concentration 5 Nom/Meas (µg/L)	17.0 $\pm$ 2.0	Reps: 2 (10 per tank)
Number of controls	1 with 2 reps (10 per tank)	No carrier used
LCx; indicate calculation method	24-h LC50 = > 17.0 $\pm$ 2.0; 48-h LC50 = 11.4 (10.8-12.2); 72-h LC50 = 8.0 (6.8-9.4); 96-h LC50 = 8.0 (6.8-9.4)	Replicates combined; Trimmed Spearman Karber; value (95% ci) ug/L

Deformities after 30 h to $\geq$ 5.0 ug/L.

USEPA. 1975. The committee on methods for toxicity tests with aquatic organisms. Methods for acute toxicity tests with fish, macroinvertebrates, and amphibians. EPA-660/3-75-009, Duluth MN

Toxicity Data Summary

Oncorhynchus mykiss

Study: Phipps G L, Holcombe GW. 1985. A method for acute multiple species toxicant testing: acute toxicity of 10 chemicals to 5 vertebrates and 2 invertebrates. Environ Poll (Series A) 38: 141-157.

Rating: RR

Notes: Multispecies exposure generating LC50s for each species. Not a multispecies test that is environmentally realistic because species were isolated from each other. Doesn't count as a mesocosm study due to lack of interaction.

Phipps & Holcombe 1985		
Parameter	**Value**	**Comment**
Test method cited	New multispecies method based on ASTM, EPA methods	
Phylum	Chordata	
Class	Actinopterygii	
Order	Salmoniformes	
Family	Salmonidae	
Genus	*Oncorhynchus*	
Species	*mykiss*	
Family resides in	North America	
Age/size at start of test/growth phase	3.0 g	
Source of organisms	Hatchert	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	0 in a separate test of 3680 mg/L dimethylformamide; NR in tests	
Temperature	17.3 $\pm$ 0.6 ^{o}C	
Test type	Flow-through	90% replacement in

Phipps & Holcombe 1985		
Parameter	**Value**	**Comment**
		8 h; 130 ml/min
Photoperiod	16L:8D	
Dilution water	Lake Superior	
pH	7.1-7.8	
Hardness	44.4 (range 40.7-46.6) mg/L as $CaCO_3$	
Alkalinity	45.4 (range 42.3-57.0) mg/L as $CaCO_3$	
Conductivity	NR	
Dissolved Oxygen	7.5 $\pm$ 1.6 mg/L (range 4.7-10.0); $\geq$ 50% saturation	mean $\pm$ sd
Feeding	None	
Purity of test substance	NR	
Concentrations measured?	Yes; average 99.5% of nominal; Measured concentrations ranged from 0.004-0.806 mg/L	Table 1 lists 3 different sets of Dursban measured concentrations, but only one Dursban test was done
Measured is what % of nominal?	99.5%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	108 mg/L dimethylformamide	
Concentration 1 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 2 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 3 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 4 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 5 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Control?	Solvent control; 108 mg/L dimethylformamide	Reps: 2 w 20 per
LC50 (95% ci)	96-h: 0.009 (0.007-0.011) mg/L	Trimmed Spearman-Karber

Toxicity Data Summary

Oncorhynchus tshawytscha

Study: Wheelock CE, Eder KJ, Werner I, Huang H, Jones PD, Brammell BF, Elskus AA, Hammock BD. 2005. Individual variability in esterase activity and CYP1A levels in Chinook salmon (*Oncorhynchus tshawytscha*) exposed to esfenvalerate and chlropyrifos. Aquat Toxicol 74: 172-192.

Rating: RR (for mortality only)

Wheelock et al. 2005		
Parameter	**Value**	**Comment**
Test method cited	None cited	
Phylum	Chordata	
Class	Actinopterygii	
Order	Salmoniformes	
Family	Salmonidae	
Genus	*Oncorhynchus*	
Species	*tshawytscha*	
Family resides in	North America	
Age/size at start of test/growth phase	Juvenile	
Test duration	96 h	
Source of organisms	Hatchery	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Data for multiple times?	No	
Effect 1	Mortality	No stats on mortality data
Control response 1	0%	
Effect 2	Acetylcholineesterase activity	
Control response 2		
Effect 3	Carboxylesterase activity	
Control response 3	CYP1A (P450) levels	
Temperature	14.8 $\pm$ 0.5 ^{o}C	
Test type	Static renewal; 75% replacement every 24 h	Soda-lime flint glass containers
Photoperiod	16L:8D	
Dilution water	Not stated, but appears to be	

Wheelock et al. 2005		
Parameter	**Value**	**Comment**
	well water	
pH	8.4 ± 0.2	
Hardness	NR	
Alkalinity	NR	
Conductivity	680 ± 50 uS/cm	
Dissolved Oxygen	9.1 ± 0.8 mg/L	
Feeding	Not fed one day prior nor through the test	
Purity of test substance	99.5%	
Concentrations measured?	Yes	
Measured is what % of nominal?	Yes	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	50 uL/4L	
Concentration 1 Nom/Meas (µg/L)	1.0/1.2	Reps: 10 (1 fish per)
Concentration 2 Nom/Meas (µg/L)	10/7.3	Reps: 10 (1 fish per)
Concentration 3 Nom/Meas (µg/L)	100/81	Reps: 10 (1 fish per)
Control?	Yes with 50ul MeOH/L	Reps: 10 (1 fish per)
LCx; indicate calculation method	Not calculated in original study; see below	
ECx; indicate calculation method	See below	
NOEC; indicate calculation method	See below	
LOEC; indicate calculation method		
MATC (GeoMean NOEC,LOEC)		
Difference from control at NOEC	See below	
Difference from control at LOEC	See below	
Difference from control at MATC		
Maximum % difference from control		

Mortality

0% in control
0% at 1.2 µg/L
20% at 7.3 µg/L
100% at 81 µg/L

Linear regression equation for rough $LC_{7.5}$, LC_{10}, $LC_{17.5}$, LC_{20}, calculations (Excel v 11.2.5)

Ln(number surviving) = -0.0285 (concentration, μ/L) + 2.3096

$LC_{7.5}$ = 3.0
LC_{10} = 3.9
$LC_{18.2}$ = 7.3
LC_{20} = 8.1
LC_{50} = 24.6

For criteria calculation: LC_{50} by trimmed Spearman-Karber: 15.96 (9.37-27.19) μ/L

NOEC: Acetylcholinesterase activity

Chlorpyrifos (brain): 1.2 ug/L (92% of solvent control)
Chlropyrifos (muscle): 1.2 ug/L (111% of solvent control)

LOEC: AChE activity

Brain: 7.3 ug/L (15% of control)
Muscle: 7.3 ug/L (8% of control)

NOECs: carboxylesterase activity (liver)

Substrate PNPA: < 1.2 ug/L
Substrate Acetate: 1.2 ug/L (115% of solvent control)
Substrate Butyrate: 1.2 ug/L (84% of solvent control)

LOECs: carboxylesterase activity (liver)

Substrate PNPA: 1.2 ug/L (44% of solvent control)
Substrate Acetate: 7.3 ug/L (48% of control)
Substrate Butyrate: 7.3 ug/L (45% of control)

NOEC: CYP1A levels

1.2 ug/L (95% of solvent control)

LOEC: CYP1A levels

7.3 ug/L (72% of solvent control)

Toxicity Data Summary

Orconectes immunis

Study: Phipps G L, Holcombe GW. 1985. A method for acute multiple species toxicant testing: acute toxicity of 10 chemicals to 5 vertebrates and 2 invertebrates. Environ Poll (Series A) 38: 141-157.

Rating: RR

Notes: Multispecies exposure generating LC50s for each species. Not a multispecies test that is environmentally realistic because species were isolated from each other. Doesn't count as a mesocosm study due to lack of interaction.

Phipps & Holcombe 1985		
Parameter	**Value**	**Comment**
Test method cited	New multispecies method based on ASTM, EPA methods	
Phylum	Arthropoda	
Class	Malacostraca	
Order	Decapoda	
Family	Cambaridae	
Genus	*Orconectes*	
Species	*immunis*	
Family resides in	North America	
Age/size at start of test/growth phase	1.8 g	
Source of organisms	Hatchery	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	0 in a separate test of 3680 mg/L dimethylformamide; NR in tests	
Temperature	17.3 $\pm$ 0.6 ^{o}C	
Test type	Flow-through	90% replacement in

Phipps & Holcombe 1985		
Parameter	**Value**	**Comment**
		8 h; 130 ml/min
Photoperiod	16L:8D	
Dilution water	Lake Superior	
pH	7.1-7.8	
Hardness	44.4 (range 40.7-46.6) mg/L as $CaCO_3$	
Alkalinity	45.4 (range 42.3-57.0) mg/L as $CaCO_3$	
Conductivity	NR	
Dissolved Oxygen	7.5 $\pm$ 1.6 mg/L (range 4.7-10.0); $\geq$ 50% saturation	mean $\pm$ sd
Feeding	None	
Purity of test substance	NR	
Concentrations measured?	Yes; average 99.5% of nominal; Measured concentrations ranged from 0.004-0.806 mg/L	Table 1 lists 3 different sets of Dursban measured concentrations, but only one Dursban test was done
Measured is what % of nominal?	99.5%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	108 mg/L dimethylformamide	
Concentration 1 Nom/Meas (µg/L)	See above	Reps: 2 w/10 per
Concentration 2 Nom/Meas (µg/L)	See above	Reps: 2 w/10 per
Concentration 3 Nom/Meas (µg/L)	See above	Reps: 2 w/10 per
Concentration 4 Nom/Meas (µg/L)	See above	Reps: 2 w/10 per
Concentration 5 Nom/Meas (µg/L)	See above	Reps: 2 w/10 per
Control?	Solvent control; 108 mg/L dimethylformamide	Reps: 2 w 10 per
LC50 (95% ci)	96-h: 0.006 (0.004-0.009) mg/L	Trimmed Spearman-Karber

Toxicity Data Summary

Pimephales promelas

Study: Belden JB, Lydy MJ. 2006. Joint toxicity of chlorpyrifos and esfenvalerate to fathead minnows and midge larvae. Environ Toxicol Chem 25: 623-629.

Rating: RR

Belden & Lydy 2006		
Parameter	**Value**	**Comment**
Test method cited	EPA/600/4-91/002	USEPA 1994
Phylum	Chordata	
Class	Actinopterygii	
Order	Cyriniformes	
Family	Cyprinidae	
Genus	*Pimephales*	
Species	*promelas*	
Family resides in	North America	
Age/size at start of test/growth phase	< 24 h	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	48 h	
Data for multiple times?	No	
Effect 1	Mobility	
Control response 1	< 10% mortality	
Temperature	21 ± 2^{o} C	
Test type	Static renewal; 24-h renewal	
Photoperiod/light intensity	NR	
Dilution water	Moderately hard synthetic (MHSFW)	
pH	7.8-8.3	
Hardness	MHSFW	
Alkalinity	MHSFW	
Conductivity	MHSFW	
Dissolved Oxygen	> 70%	
Feeding	Twice per day	

Belden & Lydy 2006		
Parameter	**Value**	**Comment**
Purity of test substance	> 98%	
Concentrations measured?	No, but stability confirmed in separate study	
Measured is what % of nominal?	90% pre-test; 85% post-test	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	None	
Concentration 1 Nom/Meas (μg/L)	NR	Reps and #: 4 w 10 per
Concentration 2 Nom/Meas (μg/L)	NR	Reps and #: 4 w 10 per
Concentration 3 Nom/Meas (μg/L)	NR	Reps and #: 4 w 10 per
Concentration 4 Nom/Meas (μg/L)	NR	Reps and #: 4 w 10 per
Concentration 5 Nom/Meas (μg/L)	NR	Reps and #: 4 w 10 per
Control	Not described; presumably dilution water	Reps and #: 4 w 10 per
ECx (95% ci)	EC10: 110 (80-130) ug/L EC50: 200 (180-230) ug/L	Log-probit

Toxicity Data Summary

Pimephales promelas

Study: Geiger DL, Call DJ, Brooke LT. 1988. Acute toxicities of organic chemicals to fathead minnows (*Pimephales promelas*) Volume IV. Center for Lake Superior Environmental Studies. University of Wisconsin-Superior, Superior, WI. pp. 195-197.

Rating: RR

Notes: Test 1 and Test 2 summarized here

Geiger et al. 1988		
Parameter	**Value**	**Comment**
Test method cited	No standard method cited, but compare to EPA methods	
Phylum	Chordata	
Class	Actinopterygii	
Order	Cyriniformes	
Family	Cyprinidae	
Genus	*Pimephales*	
Species	*promelas*	
Family resides in	N. America	
Age/size at start of test/growth phase	Test 1: 32 d Test 2: 44 d	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	96 h	
Data for multiple times?	Yes for test 1, raw data given	
Effect 1	Mortality	
Control response 1	Test 1: 0% Test 2: 0%	
Temperature	Test 1: 25.1 $\pm$ 0.41 ^{o}C Test 2: 16.3 $\pm$ 0.5 ^{o}C	
Test type	Flow-thru	
Photoperiod	NR	
Dilution water	Filtered Lake Superior water or dechlorinated	chemical parameters very

Geiger et al. 1988		
Parameter	**Value**	**Comment**
	tapwater	similar
pH	Test 1: 7.2 ± 0.9 Test 2: 7.5 ± 0.03	
Hardness	Test 1: 46 ± 0.5 mg/L; Test 2: 44.4 ± 0.29 mg/L	As $CaCO_3$
Alkalinity	Test 1: 41.6 ± 0.5 mg/L; Test 2: 47.0 ± 3.21 mg/L	As $CaCO_3$
Conductivity	NR	
Dissolved Oxygen	Test 1: 7.4 ± 0.19; Test 2: 8.1 ± 1.20	
Feeding	None	
Purity of test substance	99.9%	
Concentrations measured?	Yes	
Measured is what % of nominal?	NR	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	None used	
Concentration 1 Meas (µg/L)	Test 1:45.1-48.1; Test 2: 160-175	Reps: 2 w/50 per (test 1); 2 w/10 per (test 2)
Concentration 2 Meas (µg/L)	Test 1: 69.1-71.1; Test 2: 256-262	Reps: 2 w/50 per (test 1); 2 w/10 per (test 2)
Concentration 3 Meas (µg/L)	Test 1: 115-130; Test 2: 258-265	Reps: 2 w/50 per (test 1); 2 w/10 per (test 2)
Concentration 4 Meas (µg/L)	Test 1: 210-230; Test 2: 421-447	Reps: 2 w/50 per (test 1); 2 w/10 per (test 2)
Concentration 5 Meas (µg/L)	Test 1: 370-395; Test 2: 544-840	Reps: 2 w/50 per (test 1); 2 w/10 per (test 2)
Control	1-1.5 ug/L chlorpyrifos in dilution water	Reps: 2 w/50 per (test 1); 2 w/10 per (test 2)
LC50 (95% ci); ug/L	Test 1: 200 (190-220); Test 2: 506 (231-1110)	Trimmed Spearman-Karber

Other data: Could be used for acute-to-chronic estimation if no measured chronic data are available.

Raw mortality data for test 1 by replicate (no. dead out of 50):

Hr	Ct1	Ct2	A1	A2	B1	B2	C1	C2	D1	D2	E1	E2
24	0	0	0	3	3	0	3	1	15	12	33	28

48	0	0	0	0	3	0	3	1	17	22	43	41
72	0	0	0	0	3	1	4	1	23	27	47	46
96	0	0	0	0	3	1	4	1	30	31	48	47

Toxicity Data Summary

Pimephales promelas

Study: Holcombe GW, Phipps GL, Tanner DK. 1982. The acute toxicity of kelthane, dursban, disulfoton, pydirn, and permethrin to fathead minnows *Pimephales promelas* and rainbow trout *Salmo gairdneri*. Environ Poll (Series A) 29: 167-178.

Rating: RR

Notes: 24-, 48-, 72- and 96-h LC50s reported

Holcombe et al. 1982		
Parameter	**Value**	**Comment**
Test method cited	USEPA 1975	Cited for "procedures and methods not specified" in text
Phylum	Chordata	
Class	Actinopterygii	
Order	Cyriniformes	
Family	Cyprinidae	
Genus	*Pimephales*	
Species	*promelas*	
Family resides in	North America	
Age/size at start of test/growth phase	31-32 d; 0.1 g	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96-h	
Data for multiple times?	Yes, but no raw data	
Effect 1	Mortality	
Control response 1	NR	
Effect 2	Equilibrium	
Effect 3	Behaviour	
Effect 4	Deformities	
Temperature	$25.1 \pm 1.3\ ^{o}C$	
Test type	Flow-through	Glass tanks; 74 ml/min flow with 90% replacement

Holcombe et al. 1982		
Parameter	**Value**	**Comment**
		every 9 h
Photoperiod	16L:8D	
Dilution water	Lake Superior water	
pH	7.0-7.4	
Hardness	45.3 (43.7-46.5) mg/L as $CaCO_3$	
Alkalinity	41.8 (39.6-43.2) mg/L as $CaCO_3$	
Conductivity	NR	
Dissolved Oxygen	7.3 (6.7-7.7) mg/L	
Feeding	Not fed from 24 h before nor through test	
Purity of test substance	99.9%	
Concentrations measured?	Yes; only measured shown below	
Measured is what % of nominal?	92.7%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	None used	
Concentration 1 Meas (µg/L)	47.0 $\pm$ 5.0	Reps: 2 (50 per tank)
Concentration 2 Meas (µg/L)	70.0 $\pm$ 3.0	Reps: 2 (50 per tank)
Concentration 3 Meas (µg/L)	122.0 $\pm$ 16.0	Reps: 2 (50 per tank)
Concentration 4 Meas (µg/L)	220 $\pm$ 35.0	Reps: 2 (50 per tank)
Concentration 5 Meas (µg/L)	383.0 $\pm$ 21.0	Reps: 2 (50 per tank)
Number of controls	1 with 2 reps (50 per tank)	No carriers used
LCx; indicate calculation method	24-h LC50 = 320 (285-360); 48-h LC50 = 248 (225-273); 72-h LC50 = 220 (204-236); 96-h LC50 = 203 (191-217)	Replicates combined; Trimmed Spearman Karber; value (95% ci) ug/L

Other notes:

Fathead minnow schooling behavior disrupted above 47 ug/L from 24 h on. Deformities after 48 h at all concentrations.

USEPA. 1975. The committee on methods for toxicity tests with aquatic organisms. Methods for acute toxicity tests with fish, macroinvertebrates, and amphibians. EPA-660/3-75-009, Duluth MN

Toxicity Data Summary

Pimephales promelas

Study: Jarvinen AW, Tanner DK. 1982. Toxicity of selected controlled release and corresponding unformulated technical grade pesticides to the fathead minnow *Pimephales promelas*. Environ Poll (Series A). 27: 179-195.

Rating: RR

Jarvinen & Tanner 1982		
Parameter	**Value**	**Comment**
Test method cited	USEPA 1975 (acute studies); ERL Duluth 1979 (embryo-larval)	
Phylum	Chordata	
Class	Actinopterygii	
Order	Cypriniformes	
Family	Cyprinidae	
Genus	*Pimephales*	
Species	*promelas*	
Family resides in	North America	
Age/size at start of test/growth phase	Newly hatched (4-d tests); Newly hatched (embryo-larval)	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	96-h static; 96-h flow-through acute; 32-d flow-through embryo-larval	
Data for multiple times?	No	
Effect 1	Mortality (static and FT)	
Control response 1	Acute: NR; 32-d exposure: 100%	
Effect 2	Weight	
Control response 2	NR	
Temperature	23.5-26.0 ^{o}C	
Test type	Static (pyrex beakers)	Flow-through at 15

Jarvinen & Tanner 1982		
Parameter	**Value**	**Comment**
	Flow-through	ml/min; 99% replacement in 3 h
Photoperiod	16L:8D	
Dilution water	Lake Superior; sand-filtered, sterilized	
pH	7.4-7.8	
Hardness	45.8 mg/L	
Alkalinity	43.1 mg/L	
Conductivity	NR	
Dissolved Oxygen	Flow-through: > 75% saturation; 6.5-8.4 mg/L in all	
Feeding	Acute: not mentioned; 32-d: 2-3 X daily (nauplii)	
Purity of test substance	Technical: 98.7%; Dursban 10 CR: 10.6%	
Concentrations measured?	Yes	
Measured is what % of nominal?	> 90%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	None used	
Concentration 1 Meas (**m**g/L)	Acute studies: NR Chronic technical: 0.0009 $\pm$ 0.0001; Chronic 10 CR: 0.0007 $\pm$ 0.0002	Reps: Static: 2 w/10 per; 4-d FT: 2 w/20 per; 32-d FT: 2 w/15 per
Concentration 2 Meas (**m**g/L)	Acute studies: NR Chronic technical: 0.0016 $\pm$ 0.0004 Chronic 10 CR: 0.0013 $\pm$ 0.0002	Reps: Static: 2 w/10 per; 4-d FT: 2 w/20 per; 32-d FT: 2 w/15 per
Concentration 3 Meas (**m**g/L)	Acute studies: NR Chronic technical: 0.0032 $\pm$ 0.0005; Chronic 10 CR: 0.0022 $\pm$ 0.0004	Reps: Static: 2 w/10 per; 4-d FT: 2 w/20 per; 32-d FT: 2 w/15 per
Concentration 4 Meas (**m**g/L)	Acute studies: NR Chronic technical: 0.0057 $\pm$ 0.0008; Chronic 10 CR: 0.0048 $\pm$ 0.0007	Reps: Static: 2 w/10 per; 4-d FT: 2 w/20 per; 32-d FT: 2 w/15 per
Concentration 5 Meas (**m**g/L)	Acute studies: NR Chronic technical: 0.0102 $\pm$ 0.001;	Reps: Static: 2 w/10 per; 4-d FT: 2 w/20 per;

Jarvinen & Tanner 1982		
Parameter	**Value**	**Comment**
	Chronic 10 CR: 0.0086 ± 0.0008	32-d FT: 2 w/15 per
Control?	0.00007-0.0001 mg/L; no carriers	Reps: Static: 2 w/10 per; 4-d FT: 2 w/20 per; 32-d FT: 2 w/15 per
LC50 (95% ci); **m**g/L	Static, 96-h, technical, un-aged: 0.17 (0- infinity); Static, 96-h, technical, aged: 0.15 (0.12-0.29); Static, 96-h, 10 CR, un-aged: 0.13 (0-infinity); Static, 96-h, 10 CR, aged: 0.28 (0.22-0.36); FT, 96-h, technical: 0.14 (0.12-0.16); FT, 96-h, 10 CR: 0.12 (0.11-0.13)	Moving average
NOEC; (32-d FT); **m**g/L	Survival, technical: 0.0032; Weight, technical: 0.0016; Survival, 10 CR: 0.0022; Weight, 10 CR: 0.0022	ANOVA; Dunnett's
LOEC; **m**g/L	Survival, technical: 0.0057; Weight, technical: 0.0032; Survival, 10 CR: 0.0048; Weight, 10 CR: 0.0048	
MATC (GeoMean NOEC,LOEC)	Survival, technical: 0.0043; Weight, technical: 0.0023; Survival, 10 CR: 0.0032; Weight, 10 CR: 0.0032	
% of control at NOEC	Survival, technical: 90%; Weight, technical: 101%; Survival, 10 CR: 90%; Weight, 10 CR: 94%	
% of control at LOEC	Survival, technical: 86%; Weight, technical: 84%; Survival, 10 CR: 61.2%; Weight, 10 CR: 68%	

Other data:

$t_{1/2}$ = 41 d for technical grade; determined in static half-life studies using Lake Superior water separate from tox studies
$t_{1/2}$ = > 200 d for 10 CR

Toxicity Data Summary

Pimephales promelas

Study: Phipps G L, Holcombe GW. 1985. A method for acute multiple species toxicant testing: acute toxicity of 10 chemicals to 5 vertebrates and 2 invertebrates. Environ Poll (Series A) 38: 141-157.

Rating: RR

Notes: Multispecies exposure generating LC50s for each species. Not a multispecies test that is environmentally realistic because species were isolated from each other. Doesn't count as a mesocosm study due to lack of interaction.

Phipps & Holcombe 1985		
Parameter	**Value**	**Comment**
Test method cited	New multispecies method based on ASTM, EPA, APHA methods	
Phylum	Chordata	
Class	Actinopterygii	
Order	Cyriniformes	
Family	Cyprinidae	
Genus	*Pimephales*	
Species	*promelas*	
Family resides in	North America	
Age/size at start of test/growth phase	0.5 g	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	0 in a separate test of 3680 mg/L dimethylformamide; NR in tests	
Temperature	17.3 $\pm$ 0.6 ^{o}C	
Test type	Flow-through	90% replacement in

Phipps & Holcombe 1985		
Parameter	**Value**	**Comment**
		8 h; 130 ml/min
Photoperiod	16L:8D	
Dilution water	Lake Superior	
pH	7.1-7.8	
Hardness	44.4 (range 40.7-46.6) mg/L as $CaCO_3$	
Alkalinity	45.4 (range 42.3-57.0) mg/L as $CaCO_3$	
Conductivity	NR	
Dissolved Oxygen	7.5 $\pm$ 1.6 mg/L (range 4.7-10.0); $\geq$ 50% saturation	mean $\pm$ sd
Feeding	None	
Purity of test substance	NR	
Concentrations measured?	Yes; average 99.5% of nominal; Measured concentrations ranged from 0.004-0.806 mg/L	Table 1 lists 3 different sets of Dursban measured concentrations, but only one Dursban test was done
Measured is what % of nominal?	99.5%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	108 mg/L dimethylformamide	
Concentration 1 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 2 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 3 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 4 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 5 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Control?	Solvent control; 108 mg/L dimethylformamide	Reps: 2 w 20 per
LC50 (95% ci)	96-h: 0.542 (0.225-1.31) mg/L	Trimmed Spearman-Karber

Toxicity Data Summary

Pimephales promelas

Study: Jarvinen AW, Nordling BR, Henry ME. 1983. Chronic toxicity of Dursban (chlorpyrifos) to the fathead minnow (*Pimephales promelas*) and the resultant acetylcholinesterase inhibition. Ecotoxicol Environ Saf 7: 423-434.

Rating: RR

Jarvinen et al. 1983		
Parameter	**Value**	**Comment**
Test method cited	Benoit 1981 (EPA-600/8-81-011)	
Phylum	Chordata	
Class	Actinopterygii	
Order	Cyriniformes	
Family	Cyprinidae	
Genus	*Pimephales*	
Species	*promelas*	
Family resides in	North America	
Age/size at start of test/growth phase	< 24 h	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	30, 60, 136, 200 d	
Data for multiple times?	Yes	
Effect 1	Survival	
Control response 1	1st generation: NR 2nd generation (30d): 100 ± 0%	
Effect 2	Growth (length mm)	
Control response 2	30-d: 26.5 ± 2.8; 60-d: 33.6 ± 3.6; 136-d: 49.7 ± 4.9; 200-d: 62.6 ± 7.9	
Effect 3	2nd generation growth (weight mg; length mm)	

Jarvinen et al. 1983		
Parameter	**Value**	**Comment**
Control Response 3	191 ± 49.8 mg; 29.1 ± 2.5 mm	
Effect 4	Maturation rate	
Control response 4	NR	
Effect 5	Mean spawns per spawning pair	
Control response 5	8.0 ± 1.4	
Effect 6	Mean eggs per spawn per spawning pair	
Control response 6	150.1 ± 57.2	
Effect 7	Total egg production	
Control response 7	5003 ± 1126	
Effect 8	Embryo hatchability	
Control response 8	95.4 ± 1.7	
Effect 9	Normal (lack of deformities); 2nd generation	
Control response 9	100 ± 0%	
Effect 10	2nd generation viable biomass (g)	
Control response 10	902 ± 99.2 g	
Effect 11	AChE inhibition	
Control response 11	NR	
Temperature	24.3-25.9 °C	
Test type	Flow-through	99% turnover per 10 h
Photoperiod	16L:8D	
Dilution water	Sand-filtered, sterilized Lake Superior	
pH	7.2-7.7	
Hardness	43.1 mg/L	
Alkalinity	41.9 mg/L	
Conductivity	NR	
Dissolved Oxygen	> 75% saturation; 6.3-8.7 mg/L	
Feeding	Brine shrimp daily; excess siphoned out	
Purity of test substance	Not given for Dursban formulation; technical grade: 98.7%	Dursban 10 CR
Concentrations measured?	Yes	
Measured is what % of nominal?	67-89%; mean = 78.7%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in	None used	

Jarvinen et al. 1983		
Parameter	**Value**	**Comment**
test solutions		
Concentration 1 Nom/Meas (μg/L)	0.18/0.12 ± 0.02 (sd)	Reps: 35 from 0-60 d; 25 from 60-200; 25 for 2nd gen studies; 10 for 60 d AChE
Concentration 2 Nom/Meas (μg/L)	0.37/0.27 ± 0.06	Reps: 35 from 0-60 d; 25 from 60-200; 25 for 2nd gen studies; 10 for 60 d AChE
Concentration 3 Nom/Meas (μg/L)	0.75/0.63 ± 0.09	Reps: 35 from 0-60 d; 25 from 60-200; 25 for 2nd gen studies; 10 for 60 d AChE
Concentration 4 Nom/Meas (μg/L)	1.50/1.21 ± 0.15	Reps: 35 from 0-60 d; 25 from 60-200; 25 for 2nd gen studies; 10 for 60 d AChE
Concentration 5 Nom/Meas (μg/L)	3.00/2.68± 0.26	Reps: 35 from 0-60 d; 25 from 60-200; 25 for 2nd gen studies; 10 for 60 d AChE
Control	Dilution water	Reps: 35 from 0-60 d; 25 from 60-200; 25 for 2nd gen studies; 10 for 60 d AChE
NOEC; method not indicated	1st gen survival between 30 and 60 d: 1.21 ug/L; 30 d growth: 1.21 ug/L; 60 d growth: 0.63 ug/L; 136 d growth: 1.21 ug/L; 200 d growth: 2.68 ug/L; 136 d maturation: < 0.12	2nd gen survival, normalcy, growth is at 30 d.

Jarvinen et al. 1983		
Parameter	**Value**	**Comment**
	ug/L; Mean spawns per spawning pair: 1.21 ug/L; Mean eggs per spawn per spawning pair: 1.21 ug/L; Total egg production: 0.27 ug/L; Embryo hatchability: 1.21 ug/L; 2^{nd} gen survival: 2.68 ug/L; 2^{nd} gen normal: 1.21 ug/L; 2^{nd} gen weight: 0.63 ug/L; 2^{nd} gen length: 0.63 ug/L; 2^{nd} gen biomass: < 0.012 ug/L 60-d AChE inh: 0.012 ug/L	
LOEC	1^{st} gen survival between 30 and 60 d: 2.68 ug/L; 30 d growth: 2.68 ug/L; 60 d growth: 1.21 ug/L; 136 d growth: 2.68 ug/L; 200 d growth: > 2.68 ug/L; 136 d maturation: 0.12 ug/L; Mean spawns per spawning pair: 2.68 ug/L; Mean eggs per spawn per spawning pair: 0.63 ug/L; Total egg production: 0.63 ug/L; Embryo hatchability: 2.68 ug/L; 2^{nd} gen survival: > 2.68 ug/L; 2^{nd} gen normal: 2.68 ug/L; 2^{nd} gen weight: 1.21 ug/L; 2^{nd} gen length: 1.21 ug/L; 2^{nd} gen biomass: 0.012 ug/L 60-d AChE inh: < 0.012 ug/L	
MATC (GeoMean NOEC,LOEC)	1^{st} gen survival between 30 and 60 d: 1.80 ug/L; 30 d growth: 1.80 ug/L;	

Jarvinen et al. 1983		
Parameter	**Value**	**Comment**
	60 d growth: 0.87 ug/L; 136 d growth: 1.80 ug/L; 200 d growth: NC; 136 d maturation: NC; Mean spawns per spawning pair: 1.80 ug/L; Mean eggs per spawn per spawning pair: 0.87 ug/L; Total egg production: 0.41 ug/L; Embryo hatchability: 1.80 ug/L; 2^{nd} gen survival: NC; 2^{nd} gen normal: 1.80 ug/L; 2^{nd} gen weight: 0.87 ug/L; 2^{nd} gen length: 0.87 ug/L; 2^{nd} gen biomass: NC; 60-d AChE inh: NC	
Difference from control at NOEC	1^{st} gen survival between 30 and 60 d: NC 30 d growth: 98% 60 d growth: 99% 136 d growth: 97% 200 d growth: 91% 136 d maturation: NC Mean spawns per spawning pair: **54%** Mean eggs per spawn per spawning pair: 72% Total egg production: **56%** Embryo hatchability: 94% 2^{nd} gen survival: **54%** 2^{nd} gen normal: 945 2^{nd} gen weight: 94% 2^{nd} gen length: 99% 2^{nd} gen biomass: NC 60-d AChE inh: 0-10%	Mean eggs per spawn: interrupted dose response; LOEC is lower than NOEC; Same for 2^{nd} gen weight and length Values in bold indicate effects that are too large at the NOEC

Jarvinen et al. 1983		
Parameter	**Value**	**Comment**
Difference from control at LOEC	1st gen survival between 30 and 60 d: NC 30 d growth: 84.5% 60 d growth: 95.8% 136 d growth: 81.7% 200 d growth: NC 136 d maturation: 25% Mean spawns per spawning pair: 28.8% Mean eggs per spawn per spawning pair: 55.5% Total egg production: 36% Embryo hatchability: 87% 2nd gen survival: NC 2nd gen normal: 24% 2nd gen weight: 91% 2nd gen length: 97% 2nd gen biomass: 46.5% 60-d AChE inh: 21-41%	

Toxicity Data Summary

Study: Anderson BS, Phillips BM, Hunt JW, Connor V, Richard N, Tjeerdema RS. 2006. Identifying primary stressors impacting macroinvertebrates in the Salinas River (California, USA): Relative effects of pesticides and suspended particles. Environ Poll 141: 402-408.

Details of control survival and LC_{50}s for individual tests taken from original laboratory data sheets provided by the authors.

Relevance
Score: 100 for test 2; 92.5 for tests 1 and 3 (control survival < 90%)
Rating: R for all tests

Reliability
Score: 84.5 for test 1; 87.5 for test 2; 84.5 for test 3
Rating: R for all tests

Anderson et al. 2006		
Parameter	**Value**	**Comment**
Test method cited	USEPA 1993	Pers. Comm.; full reference below
Phylum	Arthropoda	
Class	Insecta	
Order	Ephemeroptera	
Family	Baetidae	
Genus	*Procloeon*	
Species	sp.	
Found in	N. America	
Age/size at start of test/growth phase	0.5-1cm (age unknown)	
Source of organisms	Field collected from clean site	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	48 h	
Data for multiple times?	No	
Effect 1	Mortality	

Anderson et al. 2006		
Parameter	**Value**	**Comment**
Control response 1	Test 1: 84% Test 2: 96% Test 3: 84%	Results for methanol controls
Temperature	21.3°C	From data sheet
Test type	Static renewal; daily	
Photoperiod/light intensity	NR	
Dilution water	Well water	
pH	7.5-7.9	From data sheet
Hardness	NR	
Alkalinity	NR	
Conductivity	683-721 µS/cm	From data sheet
Dissolved Oxygen	7.5-8.4 mg/L	From data sheet
Feeding	None	
Purity of test substance	99%	
Concentrations measured?	Yes	
Measured is what % of nominal?	97% (range: 79-118%)	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	1% methanol (10 mL/L)	
Concentration 1 Nom/Meas (µg/L)	Test 1: NA Test 2: 0.063/0.06 Test 3: 0.063/0.054	Reps: 3-5 w/5 per
Concentration 2 Nom/Meas (µg/L)	Test 1: 0.125/0.087 Test 2: 0.125/0.097 Test 3: 0.125/0.101	Reps: 3-5 w/5 per
Concentration 3 Nom/Meas (µg/L)	Test 1: 0.25/0.215 Test 2: 0.25/0.23 Test 3: 0.25/0.272	Reps: 3-5 w/5 per
Concentration 4 Nom/Meas (µg/L)	Test 1: 0.5/0.527 Test 2: 0.5/0.615 Test 3: 0.5/0.569	Reps: 3-5 w/5 per
Control	Dilution water; 1% methanol	Reps: 3-5 w/5 per
LC50; µg/L	Test 1: 0.1791 Test 2: 0.0704 Test 3: 0.0798	Trimmed Spearman-Karber
NOEC: µg/L	Test 1: 0.087 Test 2: < 0.06 Test 3: .054	ANOVA; Dunnett's; p = 0.05; Test 1 MSD = 0.30 Test 2 MSD = 0.269 Test 3: MSD =

Anderson et al. 2006		
Parameter	**Value**	**Comment**
		0.239
LOEC: µg/L	Test 1: 0.215 Test 2: 0.06 Test 3: 0.101	
MATC: µg/L	Test 1: 0.137 Test 2: NC Test 3: 0.074	
% of control at NOEC	Test 1: 81% Test 2: NC Test 3: 100%	
% of control at LOEC	Test 1: 43% Test 2: 71% Test 3: 9.5%	

USEPA. 1993. Methods for measuring the acute toxicity of effluents and receiving waters to freshwater and marine organisms. Fourth edition. Weber, C. I., ed. Environmental Monitoring Systems Laboraotry, Office of Research and Development, United States Environmental Protection Agency, Cincinnati, OH.

Toxicity Data Summary

Pungitius pungitius

Study: Van Wijngaarden R, Leeuwangh P, Lucassen WGH, Romijn K, Ronday R, Van Der Velde R, Willigenburg W. 1993. Acute toxicity of chlorpyrifos to fish, a newt, and aquatic inverterbrates. Bull Environ Contam Toxicol 51: 716-723.

Rating: RR

Van Wijngaarden et al. 1993		
Parameter	**Value**	**Comment**
Test method cited	No standard method cited	
Phylum	Chordata	
Class	Actinopterygii	
Order	Gasterosteiformes	
Family	Gasterosteidae	
Genus	*Pungitius*	
Species	*pungitius*	
Family resides in	North America	
Age/size at start of test/growth phase	Adult	
Test duration	48, 96 h	
Source of organisms	Ditches	
Have organisms been exposed to contaminants?	NR	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Data for multiple times?	Yes	
Effect 1	Mortality	
Control response 1	$\leq$ 10%	
Temperature	19 $\pm$ 0.8 ^{o}C	
Test type	Discontinuous flow-through; 1.85 L/h	
Photoperiod	14L:10D	
Dilution water	Tapwater	
pH	6.6-8.2	
Hardness	110 mg/L as $CaCO_3$	
Alkalinity	NR	
Conductivity	NR	

Van Wijngaarden et al. 1993		
Parameter	**Value**	**Comment**
Dissolved Oxygen	3.6-7.7 mg/L	on excursion to 1.1 mg/L in control; no apparent effects
Feeding	Daily; dry food and guppies	
Purity of test substance	99.8%	
Concentrations measured?	Yes	
Measured is what % of nominal?	99.4%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	$\leq$ 0.1 mL/L acetone	
Concentration 1-5 or 6 Meas (μg/L)	0.6-13.9; factor of 2 between concentrations	Reps: 1? w/10 per
Control	Tapwater; separate carrier tests showed no toxicity	Reps: 1? w/10 per
LCx (95% ci); ug/L; based on mean concentrations measured daily	48-h LC10: 2.3 (1.2-5.5); 48-h LC50: 5.7 (4.4-7.5); 96-h LC10: 2.1 (1.3-4.6); 96-h LC50: 4.7 (3.6-6.0)	Log-log regression

Other notes: test was duplicated; the text is confusing as to how many replicates were in each test; it appear that the tests may have been done with one replicate per concentration.

Toxicity Data Summary

Simulium vittatum IIIL-1

Study: Hyder AH, Overmyer JP, Noblet R. 2004. Influence of developmental stage on susceptibilities and sensitivities of *Simulium vittatum* IS-7 and *Simulium vittatum* IIIL-1 (Diptera: Simulidae) to chlorpyrifos. Environ Toxicol Chem 23: 2856-2862.

Rating: RR

Hyder et al. 2004		
Parameter	**Value**	**Comment**
Test method cited	ASTM (1992); E 729-88a	
Phylum	Arthropoda	
Class	Insecta	
Order	Diptera	
Family	Simuliidae	
Genus	*Simulium*	
Species	*vittatum* IIIL-1	
Family resides in	North America	
Age/size at start of test/growth phase	1) 4^{th} and 5^{th} instar; 2) 6^{th} and 7^{th} instar	Eggs collected from contaminated site
Source of organisms	Field	
Have organisms been exposed to contaminants?	Yes	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	24 h	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	< 10%	
Temperature	19 ^{o}C	
Test type	Static on orbital shaker	
Photoperiod	NR	
Dilution water	Moderately hard water	
pH	7.6	
Hardness	86.8 mg/L as $CaCO_3$	
Alkalinity	64.8 mg/L as $CaCO_3$	
Conductivity	NR	
Dissolved Oxygen	68%	
Feeding	None	

Hyder et al. 2004		
Parameter	**Value**	**Comment**
Purity of test substance	98%	
Concentrations measured?	Yes	
Measured is what % of nominal?	72.58-94%; mean = 83.3%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	NR	
Concentration Range Meas; (µg/L); 5 concentrations	4^{th} & 5^{th} instar: 0.08-1.28; 6^{th} & 7^{th} instar: 0.2-3.2	Reps: 5 w/15 per
Control	Acetone control; concentration not reported, but no adverse effects in controls	3 controls w/ 5 reps each w/ 15 per
LC50 (se); ug/L; mean of 3 tests	4^{th} & 5^{th} instar: 0.13 (0.01); 6^{th} & 7^{th} instar: 0.91 (0.16)	Probit with Abbott's correction for control mortality

Toxicity Data Summary

Simulium vittatum IS-7

Study: Hyder AH, Overmyer JP, Noblet R. 2004. Influence of developmental stage on susceptibilities and sensitivities of *Simulium vittatum* IS-7 and *Simulium vittatum* IIIL-1 (Diptera: Simulidae) to chlorpyrifos. Environ Toxicol Chem 23: 2856-2862.

Rating: RR

Hyder et al. 2004		
Parameter	**Value**	**Comment**
Test method cited	ASTM (1992); E 729-88a	
Phylum	Arthropoda	
Class	Insecta	
Order	Diptera	
Family	Simuliidae	
Genus	*Simulium*	
Species	*vittatum* IS-7	
Family resides in	North America	
Age/size at start of test/growth phase	1) 2^{nd} and 3^{rd} instar; 2) 4^{th} and 5^{th} instar; 3) 6^{th} and 7^{th} instar	Laboratory cultures
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	Possibly	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	24 h	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	< 10%	
Temperature	19 ^{o}C	
Test type	Static on orbital shaker	
Photoperiod	NR	
Dilution water	Moderately hard water	
pH	7.6	
Hardness	86.8 mg/L as $CaCO_3$	
Alkalinity	64.8 mg/L as $CaCO_3$	
Conductivity	NR	
Dissolved Oxygen	68%	

Hyder et al. 2004		
Parameter	**Value**	**Comment**
Feeding	None	
Purity of test substance	98%	
Concentrations measured?	Yes	
Measured is what % of nominal?	72.58-94%; mean = 83.3%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	NR	
Concentration Range Meas; (µg/L); 5 concentrations	2^{nd} & 3^{rd} instar: 0.008-0.128; 4^{th} & 5^{th} instar: 0.08-1.28; 6^{th} & 7^{th} instar: 0.2-3.2	Reps: 5 w/15 per
Control	Acetone control; concentration not reported, but no adverse effects in controls	3 controls w/ 5 reps each w/ 15 per
LC50 (se); ug/L; mean of 3 tests	2^{nd} & 3^{rd} instar: 0.06 (0.02) 4^{th} & 5^{th} instar: 0.11 (0.13); 6^{th} & 7^{th} instar: 0.68 (0.19)	Probit with Abbott's correction for control mortality

Toxicity Data Summary

Study: El-Merhibi A, Kumar A, Smeaton T. 2004. Role of piperonyl butoxide in the toxicity of chlorpyrifos to *Ceriodaphnia dubia* and *Xenopus laevis*. Ecotox Environ Safety 57: 202-212.

Relevance
Score: 100
Rating: R

Reliability
Score: 74 for acute; 71 for chronic
Rating: R for acute; L for chronic

El-Merhibi et al. 2004		
Parameter	**Value**	**Comment**
Test method cited	ASTM FETAX 1998;	
Phylum	Chordata	
Class	Amphibia	
Order	Anura	
Family	Pipidae	
Genus	*Xenopus*	
Species	*laevis*	
Found in	North America	
Age/size at start of test/growth phase	< 24 h	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	Acute: 96 h Chronic: 10 d	
Data for multiple times?	Yes	
Effect 1	Mortality	
Control response 1	< 10%	
Effect 2	AChE inhibition	
Control response 2	Baseline	
Effect 3	Teratogenesis	
Control response 3	None	
Temperature	$24.7 \pm 5^{o}C$	
Test type	Static-renewal; daily	

El-Merhibi et al. 2004		
Parameter	**Value**	**Comment**
Photoperiod/light intensity	16L:8D	
Dilution water	Modified FETAX solution (MFS)	FETAX = Frog embryo teratogenesis assay: *Xenopus*
pH	7.6 ± 0.2	
Hardness	NA	
Alkalinity	NA	
Conductivity	1476 µS/cm	
Dissolved Oxygen	7.4 ± 0.1 mg/L	
Feeding	None in acute test; Wardley's Goldfish Food at renewal interval	
Purity of test substance	99.8%	
Concentrations measured?	No	
Measured is what % of nominal?	NA	
Chemical method documented?	NA	
Concentration of carrier (if any) in test solutions	< 0.1% (1 mL/L); level shown to be non-toxic	
Concentration 1 Nom (µg/L)	5-5000; appears to be 11 concentrations with a dilution factor of 2	Reps: NR, but std method
Control	MFS; solvent (acetone)	Reps: NR, but std method
LC50; µg/L	96 h: 2410 10 d: 92.5	Trimmed Spearmann-Karber
EC50 (95% ci); µg/L	96 h malformations: 511 10 d malformations: 35	Trimmed Spearman-Karber
NOEC; µg/L	96 h mortality: 1280 10 d mortality: 20 96 h malformations: 320 10 d mortality: 20 96 h AChE: 5 10 d AChE: 5	Method: Dunnett's or Bonferroni t-test p: NR MSD: NR
LOEC; indicate calculation method	96 h mortality: 2560 10 d mortality: 40 96 h malformations: 640 10 d mortality: 40 96 h AChE: 10 10 d AChE: 10	Assuming monotonic dose response curve and dilution factor of 2

El-Merhibi et al. 2004		
Parameter	**Value**	**Comment**
MATC (GeoMean NOEC,LOEC)	96 h mortality: 1810 10 d mortality: 28 96 h malformations: 450 10 d mortality: 28 96 h AChE: 7.1 10 d AChE: 7.1	Assuming monotonic dose response curve and dilution factor of 2
% control at NOEC	NC; data not provided	