Attachment 7 Summary of Toxicity Data for Volatile Organic Compounds in Porewater

A literature search for relevant toxicity studies for the 16 volatile organic compounds (VOCs) detected in porewater samples was conducted using two databases, ECOTOX and BIOSIS. The following sections describe each database, the methods used to search the databases, and the search results. This information was first presented in the porewater data and analysis report (Windward 2006).

DATABASE DESCRIPTIONS

ECOTOX includes three formerly independent databases, AQUIRE, TERRETOX, and PHYTOTOX. The AQUIRE database is the most relevant source available for aquatic toxicology data. AQUIRE includes lethal, sublethal, and residue effects data for saltwater and freshwater aquatic species, with coverage spanning from 1915 to the present. AQUIRE includes more than 227,800 records for more than 7,300 chemicals and 3,700 freshwater and marine organisms. Sources for studies in AQUIRE include journal articles, published and unpublished reports, miscellaneous government databases and files, gray literature, and independent laboratory test results.

For studies to be included in ECOTOX, the author(s) must report the species, chemical information, and exposure duration. Only single chemical studies are included (i.e., studies testing chemical mixtures are excluded). The majority of the literature is from 1972 to the present. ECOTOX is continually updated, but there may be a time lag of up to six months between the time the literature search is conducted and entry of new studies into ECOTOX. Therefore, EPA recommends searching other sources for literature published within the last year.

Therefore, BIOSIS was searched to supplement the ECOTOX search results. BIOSIS is the most comprehensive database available based on the number of records, the number of records added annually, and the number of journals reviewed (6,000 journal titles). BIOSIS contains references to primary journal literature in the biological sciences (botany, ecology, and zoology) as well as medical research. BIOSIS coverage is from 1969 to the present, and it currently includes over 15,000,000 records, with 600,000 new records added each year. BIOSIS does not include unpublished reports, government studies, or independent laboratory results.

DATABASE SEARCH METHODS

The ECOTOX database was searched first for relevant toxicity studies involving invertebrate species with growth, mortality (including immobilization), reproductive, or developmental endpoints. Studies with invertebrates were preferred because, as discussed in the Work Plan (Windward 2004), the purpose of the porewater study is to evaluate risk to benthic invertebrates. However, if there were no invertebrate data in

the ECOTOX database, then fish studies with growth, mortality (including immobilization), reproductive, or developmental endpoints were included in the search. Toxicity data for both freshwater and marine species were included because of the wide salinity range in the Lower Duwamish Waterway (LDW).

After searching ECOTOX, BIOSIS was searched to identify articles published in 2003 to 2005 for each of the 16 VOCs of interest. To make the search comprehensive, each chemical name, its Chemical Abstracts Service (CAS) number, and any chemical name synonyms were searched on BIOSIS for the years 2003 to 2005. In addition, for three VOCs with very few or no data in ECOTOX (1,1-dichloroethane, 1,2-dichloroethene, and vinyl chloride), a more extensive search was conducted using BIOSIS with no restrictions on publication date.

STUDY SELECTION

The studies identified in the literature search were reviewed to assess the most appropriate toxicity data for comparison with the porewater concentrations of individual VOCs. In many cases, very few toxicity data were available. In particular, relatively few data were available for certain chemicals for a range of families, as required for derivation of ambient water quality criteria (AWQC) (Stephan et al. 1985), and very few lowest-observed-adverse-effects levels (LOAELs) were available. Instead, many studies typically reported lethal concentrations for 50% of a test population (i.e., LC50 values) and no-observed-adverse-effects levels (NOAELs) for a range of different species. In addition, only one or two studies were identified for some of the VOCs. Therefore, because of the limitations of the available dataset, the rules for study selection had to be modified from those generally used to select toxicity reference values (TRVs). Ideally, TRVs would be selected by identifying the lowest LOAEL and the highest NOAEL below that LOAEL for the same relevant test species. However, because the available data generally did not support this approach, best professional judgment was required to select the most appropriate toxicity values for each VOC of interest. The following general rules were followed:

- If available, the study identified with the lowest effects level (preferably a LOAEL) for each VOC was selected and reviewed
- If available, the study with the lowest NOAEL for each VOC was selected and reviewed, provided that more one NOAEL was not available for a given test species and endpoint. When there were multiple NOAELs for the same test species/endpoint for a given VOC, the study with the highest NOAEL for that test species/endpoint was selected and reviewed.

In many cases, the available toxicity data were uncertain because LOAELs were rarely reported, NOAELs were dependent on the chosen test dilution series, and very few studies reported both effect and no-effect concentrations for a single species and

endpoint.[1] However, rather than assigning uncertainty factors to the toxicity data in this memorandum, the actual NOAELs, LOAELs, and LC50s are reported.

STUDY ACCEPTABILITY

Criteria were established to determine the acceptability of each study. These criteria are based on Stephan et al. (1985), which presents guidelines used to develop Environmental Protection Agency's (EPA's) AWQC, and on Suter and Tsao (1996), which presents methods used to derive Tier II values.[2] Two types of criteria were developed in which some criteria were required, while others were preferred, but not required. Studies had to meet the following required criteria to be accepted:

- Negative control tests must be used.
- For a no-effect result, the exposure period must be no less than 48 hours for daphnids, and no less than 96 hours for fish.
- The salinity must be no greater than 35 parts per thousand in tests using *Artemia salina* (brine shrimp), to represent conditions relevant to those found in the LDW.

The following additional criteria were preferred, but not required, for a study to be accepted:

- Test containers should be covered to minimize volatilization.[3]
- Standard test methods should be used for those tests/organisms/endpoints that have standardized protocols.
- Reported effects in tests should be compared to controls using statistical methods.
- Control media and test media should be identical in all respects except for the treatment.

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[1] The actual effect threshold is uncertain for a NOAEL without a corresponding LOAEL.

[2] Tier II values are secondary acute and chronic values derived for chemicals with some toxicity data, but not enough to meet the data requirements for development of AWQC.

[3] Most of the studies reviewed noted that test vessels were covered to minimize volatilization during toxicity testing. However, a few studies did not comment on whether test vessels were covered. If test vessels were not covered during testing, but the VOC concentration was measured throughout the study, coverage should not impact the result as long as the concentration remained stable. On the other hand, if the concentration was not measured or the concentration declined over the course of the study, then the effects concentration could be an overestimate (i.e., effects could be occurring at a lower concentration than the nominal concentration). Therefore, although the lack of coverage documentation leads to additional uncertainty, rejection of a study (without another study available at a lower effects concentration) would lead to the selection of study with a higher effects concentration which could be argued to be less protective. Therefore, this criterion was included in the preferred category rather than the required category.

- Flow-through tests are preferred, followed by static renewal and then static tests.
- Organisms should be less than 24 hours old for acute and chronic daphnid tests and up to third instar for midge acute tests; juvenile or larval life stages are preferred for acute tests for other organisms.
- Chemical concentrations should be measured in the test rather than presented as nominal concentrations.
- The chemistry of the test environment (e.g., dissolved oxygen (DO), pH, temperature, salinity) should be reported.
- DO should not fall below 40% saturation in static tests and should not fall below 60% saturation in flow-through tests.
- Test organisms should not be fed during acute tests, with the exception of saltwater annelids and mysids.
- Methods used to prepare treatment solutions should be described in detail.
- The study should report dose-related toxicity information, and preferably report both a NOAEL and LOAEL.
- The chemical source and purity should be noted.

LITERATURE SEARCH RESULTS

Table 1 summarizes the results of the literature search. NOAELs and LOAELs found in the literature search are presented. Because a large number of the available values for some chemicals represented LC50, only the lowest LC50 for a given test organism is shown in Table 1.

In the course of the literature search, several papers were identified that established NOAELs for specific VOCs (e.g., De Rooij et al. 2004a, b; Van Wijk et al. 2004). These papers contained summaries of aquatic toxicity studies, which the authors classified as either: 1) valid without restriction, 2) valid with restrictions to be considered with care, 3) invalid, or 4) not assignable. Only those studies classified as either 1 or 2 are included in Table 1.

Table 1. Aquatic toxicity data obtained from the literature search

VOC	Reported Concentration (µg/L)	Effect Level	Test Organism	Test Duration	Endpoint	Source[a]
1,1-Dichloroethane	202,000	LC50	*Poecilia reticulate* (guppy)	14d	mortality	Könemann (1981)
	7,800	FCV	Based on narcosis model	na	na	DiToro et al. (2000)
	39,600	FAV	Based on narcosis model	na	na	DiToro et al. (2000)
1,1-Dichloroethene	**2,400**	NOAEL	*Daphnia magna* (water flea)	48h	mortality	LeBlanc (1980)
	11,600	LC50	*Daphnia magna* (water flea)	48h	mortality	Dill et al. (1980)
	79,000	LC50	*Daphnia magna* (water flea)	48h	mortality	LeBlanc (1980)
	224,000	LC50	*Americamysis bahia* (opossum shrimp)	96h	mortality	ECOTOX, Reference No. 9607
1,2-dichlorobenzene	1970	LC50	*Americamysis bahia* (opossum shrimp)	96h	mortality	ECOTOX, Reference No. 9607
	26,000	LD50	*Cloeon dipterum* (may fly)	24h	mortality	ECOTOX, Reference No. 6954
	26,000	LD50	*Cloeon dipterum* (may fly)	48h	mortality	ECOTOX, Reference No. 6954
	1,000	LOEL	*Crassostrea virginica* (American oyster)	24h	growth	ECOTOX, Reference No. 3708
	550	EC50	*Daphnia magna* (water flea)	14d	reproduction	ECOTOX, Reference No. 15526
	2,400	LC50	*Daphnia magna* (water flea)	24h	mortality	ECOTOX, Reference No. 5184
	68,000	LC50	*Daphnia magna* (water flea)	24h	mortality	ECOTOX, Reference No. 5718
	2,400	LC50	*Daphnia magna* (water flea)	48h	mortality	ECOTOX, Reference No. 5184
	2,200	LC50	*Daphnia magna* (water flea)	48h	mortality	ECOTOX, Reference No. 6629
	630	NOAEL	*Daphnia magna* (water flea)	21d	reproduction	ECOTOX, Reference No. 847
	> 100,000	EC50	*Mercenaria mercenaria* (hard clam)	48h	develop	ECOTOX, Reference No. 2400
	> 100,000	EC50	*Mercenaria mercenaria* (hard clam)	12d	mortality	ECOTOX, Reference No. 2400
	14,300	LC50	*Palaemonetes pugio* (grass shrimp)	24h	mortality	ECOTOX, Reference No. 875
	10,300	LC50	*Palaemonetes pugio* (grass shrimp)	48h	mortality	ECOTOX, Reference No. 875
	9,400	LC50	*Palaemonetes pugio* (grass shrimp)	96h	mortality	ECOTOX, Reference No. 875
	10,000	LC50	*Palaemonetes pugio* (grass shrimp)	96h	mortality	ECOTOX, Reference No. 2965
	2,300	EC50	*Tanytarsus dissimilis* (midge)	48h	mortality	ECOTOX, Reference No. 16044
	19,900	LC50	*Tanytarsus dissimilis* (midge)	24h	mortality	ECOTOX, Reference No. 10579
	12,000	LC50	*Tanytarsus dissimilis* (midge)	48h	mortality	ECOTOX, Reference No. 10579
	11,800	LC50	*Tanytarsus dissimilis* (midge)	48h	mortality	ECOTOX, Reference No. 16044
	51,000	EC50	*Tetrahymena pyriformis* (ciliate)	24h	growth	ECOTOX, Reference No. 11258
1,2-Dichloroethane	**6,927**	LC50	*Artemia salina* (brine shrimp)	72h	mortality	Sanchez-Fortun et al. (1997)
	11,000	NOAEL	*Daphnia magna* (water flea)	28d	reproduction	Richter et al. (1983)
	42,000	NOAEL	*Daphnia magna* (water flea)	28d	growth	Richter et al. (1983)
	< 68,000	NOAEL	*Daphnia magna* (water flea)	28d	mortality	Richter et al. (1983)

VOC	Reported Concentration (µg/L)	Effect Level	Test Organism	Test Duration	Endpoint	Source[a]
	> 100,000	LC50	*Gammarus fasciatus* (scud)	96h	mortality	ECOTOX, Reference No. 6797
	> 100,000	LC50	*Pteronarcys californicus* (stonefly)	96h	mortality	ECOTOX, Reference No. 6797
	113,000	LC50	*Americamysis bahia* (opossum shrimp)	96h	mortality	ECOTOX, Reference No. 9607
	186,000	LC50	*Elminius modestus* (Australian barnacle)	48h	mortality	ECOTOX, Reference No. 13535
	220,000	LC50	*Daphnia magna* (water flea)	48h	mortality	Richter et al. (1983)
	900,000	LC50	*Ophryotrocha labronica* (polychaete)	96h	mortality	ECOTOX, Reference No. 5902
1,2-Dichloropropane	**42,000**	LC50	*Daphnia magna* (water flea)	48h	mortality	ECOTOX, Reference No. 5184
	> 100,000	LC50	*Crangon crangon* (sand shrimp)	48h	mortality	ECOTOX, Reference No. 906
	58,000	LC50	*Daphnia magna* (water flea)	24h	mortality	ECOTOX, Reference No. 5184
	53,000	LC50	*Elminius modestus* (Australian barnacle)	48h	mortality	ECOTOX, Reference No. 19535
	< 22,000		*Daphnia magna* (water flea)	48h	mortality	ECOTOX, Reference No. 5184
1,4-Dichlorobenzene	1,990	LC50	*Americamysis bahia* (opossum shrimp)	96h	mortality	ECOTOX, Reference No. 9607
	93	LC50	*Artemia salina* (brine shrimp)	24h	mortality	ECOTOX, Reference No. 11926
	16,500	EC50	*Brachionus calycilorus* (rotifer)	48h	reproduction	ECOTOX, Reference No. 20484
	3125	NOAEL	*Brachionus calycilorus* (rotifer)	48h	reproduction	ECOTOX, Reference No. 20484
	9,400	LC50	*Chironomus thummi* (midge)	48h	mortality	ECOTOX, Reference No. 4072
	940	NOAEL	*Chironomus thummi* (midge)	48h	mortality	ECOTOX, Reference No. 4072
	930	EC50	*Daphnia magna* (water flea)	14d	reproduction	ECOTOX, Reference No. 15526
	17,000	LC50	*Daphnia magna* (water flea)	24h	mortality	ECOTOX, Reference No. 5184
	9,800	LC50	*Daphnia magna* (water flea)	24h	mortality	ECOTOX, Reference No. 12055
	19,400	LC50	*Daphnia magna* (water flea)	24h	mortality	ECOTOX, Reference No. 12055
	14,800	LC50	*Daphnia magna* (water flea)	24h	mortality	ECOTOX, Reference No. 12055
	6,600	LC50	*Daphnia magna* (water flea)	48h	mortality	ECOTOX, Reference No. 5184
	9,900	LC50	*Daphnia magna* (water flea)	48h	mortality	ECOTOX, Reference No. 12055
	11,500	LC50	*Daphnia magna* (water flea)	48h	mortality	ECOTOX, Reference No. 12055
	9,500	LC50	*Daphnia magna* (water flea)	48h	mortality	ECOTOX, Reference No. 12055
	2,200	LC50	*Daphnia magna* (water flea)	48h	mortality	ECOTOX, Reference No. 6629
	300	NOAEL	*Daphnia magna* (water flea)	21d	reproduction	ECOTOX, Reference No. 847
	400	NOAEL	*Daphnia magna* (water flea)	21d	reproduction	ECOTOX, Reference No. 20484
	100,000	LC50	*Palaemonetes pugio* (grass shrimp)	48h	mortality	ECOTOX, Reference No. 875
	60,500	LC50	*Palaemonetes pugio* (grass shrimp)	96h	mortality	ECOTOX, Reference No. 875
	36,000	LC50	*Palaemonetes pugio* (grass shrimp)	96h	mortality	ECOTOX, Reference No. 2965
	147	LC50	*Portunus pelagicus* (crab)	10h	mortality	ECOTOX, Reference No. 4745
	14,700	LC50	*Portunus pelagicus* (crab)	1000h	mortality	ECOTOX, Reference No. 4745

VOC	Reported Concentration (µg/L)	Effect Level	Test Organism	Test Duration	Endpoint	Source[a]
	3,000	EC50	*Tanytarsus dissimilis* (midge)	2h	mortality	ECOTOX, Reference No. 16044
	19,200	EC50	*Tanytarsus dissimilis* (midge)	24h	mortality	ECOTOX, Reference No. 10579
	10,900	EC50	*Tanytarsus dissimilis* (midge)	48h	mortality	ECOTOX, Reference No. 10579
	13,000	EC50	*Tanytarsus dissimilis* (midge)	48h	mortality	ECOTOX, Reference No. 16044
	32,000		*Chironomus thummi* (midge)	48h	mortality	ECOTOX, Reference No. 4072
	680		*Daphnia magna* (water flea)	48h	mortality	ECOTOX, Reference No. 5184
	400		*Daphnia magna* (water flea)	28f	reproduction	ECOTOX, Reference No. 10712
1,2-Dichloroethene (cis or trans)	**6,785**	LC50	*Artemia salina* (brine shrimp)	72h	mortality	Sanchez-Fortun et al. (1997)
	140,000	LC50	*Lepomis macrochirus* (bluegill)	24-96h	mortality	ECOTOX, Reference No. 590
Benzene	180	NOAEL	*Cancer magister* (Dungeness crab)	24d	mortality, growth, development	Caldwell et al. (1976)
	1,100	LC100	*Cancer magister* (Dungeness crab)	24d	mortality	Caldwell et al. (1976)
	2,968	NOAEL	*Ceriodaphnia dubia* (water flea)	7d	reproduction	Niederlehner et al. (1998)
	6,000	LC50	*Gammarus* sp. (scud)	96h	mortality	ECOTOX, Reference No. 13419
	10,000	LC50	*Ischnura elegans* (damselfly)	48h	mortality	ECOTOX, Reference No. 15788
	12,419	LC50	*Ceriodaphnia dubia* (water flea)	7d	mortality	Niederlehner et al. (1998)
	15,000	LC50	*Daphnia pulex* (water flea)	96h	mortality	ECOTOX, Reference No. 15337
	16,796	LC50	*Crangon franciscorum* (shrimp)	96h	mortality	ECOTOX, Reference No. 558
	21,000	LC50	*Artemia salina* (brine shrimp)	48h	mortality	ECOTOX, Reference No. 2408
	27,000	LC50	*Palaemonetes pugio* (shrimp)	96h	mortality	ECOTOX, Reference No. 420
	34,000	LC50	*Cloeon dipterum* (mayfly)	48h	mortality	ECOTOX, Reference No. 15788
	48,000	LC50	*Corixa* sp. (water boatman)	48h	mortality	ECOTOX, Reference No. 15788
	59,600	LC50	*Daphnia magna* (water flea)	48h	mortality	ECOTOX, Reference No. 7069
	71,000	LC50	*Culex pipiens* (northern house mosquito)	48h	mortality	ECOTOX, Reference No. 10574
	74,000	LC50	*Dugesia lugubris* (vortex worm)	48h	mortality	ECOTOX, Reference No. 15788
	82,000	LC50	*Diaptomus forbesi* (copepod)	≤96h	mortality	ECOTOX, Reference No. 7800
	100,000	LC50	*Chironomus thummi* (midge)	48h	mortality	ECOTOX, Reference No. 15788
	111,800	LC100	*Homarus americanus* (American lobster)	1h	mortality	ECOTOX, Reference No. 5353
	120,000	LC50	*Asellus aquaticus* (aquatic sowbug)	48h	mortality	ECOTOX, Reference No. 15788
	130,000	LC50	*Nemoura cinerea* (stonefly)	48h	mortality	ECOTOX, Reference No. 15788
	190,000	LC50	*Katelysia opima* (marine bivalve)	96h	mortality	ECOTOX, Reference No. 9017
	200,000	LC50	*Aedes aegypti* (yellow fever mosquito)	48h	mortality	ECOTOX, Reference No. 14863
	230,000	LC50	*Lymnaea stagnalis* (great pond snail)	48h	mortality	ECOTOX, Reference No. 15788
	> 320,000	LC50	*Erpobdella octoculata* (leech)	48h	mortality	ECOTOX, Reference No. 15788
	> 320,000	LC50	*Tubificidae* (oligochaete)	48h	mortality	ECOTOX, Reference No. 15788

VOC	Reported Concentration (µg/L)	Effect Level	Test Organism	Test Duration	Endpoint	Source[a]
	356,000	LC50	*Daphnia cucullata* (water flea)	48h	mortality	ECOTOX, Reference No. 2017
	377,000	LC50	*Crassostrea gigas* (Pacific oyster)	48h	mortality	ECOTOX, Reference No. 8621
	550,000[b]	LC50	*Lymnaea stagnalis* (great pond snail)	120h	mortality	ECOTOX, Reference No. 13419
Carbon disulfide	**1,900**	LC50	*Daphnia magna* (water flea)	48h	mortality	ECOTOX, Reference No. 11455
Chlorobenzene	320	NOAEL	*Daphnia magna* (water flea)	16d	reproduction	Hermens et al. (1984)
	< 1,400	NOAEL	*Daphnia magna* (water flea)	10d	mortality	Cowgill and Milazzo (1991)
	2,500	EC50	*Daphnia magna* (water flea)	14d	reproduction	Calamari et al. (1983)
	3,890	NOAEL	*Ceriodaphnia dubia* (water flea)	7-10d	mortality	ECOTOX, Reference No. 212
	12,000	NOAEL	*Ceriodaphnia dubia* (water flea)	7-10d	reproduction	ECOTOX, Reference No. 212
	16,400	LC50	*Americamysis bahia* (opossum shrimp)	96h	mortality	ECOTOX, Reference No. 9607

VOC	Reported Concentration (µg/L)	Effect Level	Test Organism	Test Duration	Endpoint	Source[a]
Tetrachloroethene	**331**	NOAEL	*Ceriodaphnia dubia* (water flea)	7d	reproduction	Niederlehner et al. (1998)
	332	LC50	*Artemia salina* (brine shrimp)	72h	mortality	Sanchez-Fortun et al. (1997)
	400	NOAEL	*Daphnia magna* (water flea)	21d	reproduction	ECOTOX, Reference No. 56345
	829	LC50	*Ceriodaphnia dubia* (water flea)	7d	mortality	Niederlehner et al. (1998)
	900	EC50	*Dugesia japonica* (flatworm)	7d	growth	ECOTOX, Reference No. 12513
	1,300	LC50	*Palaemonetes pugio* (grass shrimp)	96h	mortality	ECOTOX, Reference No. 14563
	1,300	LC50	*Nereis arenaceodentata* (polychaete)	96h	mortality	ECOTOX, Reference No. 14563
	1,400	LC50	*Dugesia japonica* (flatworm)	7d	mortality	ECOTOX, Reference No. 12513
	1,800	LC50	*Moina macrocopa* (water flea)	3h	mortality	ECOTOX, Reference No. 12513
	3,500	LC50	*Elminius modestus* (Australian barnacle)	48h	mortality	ECOTOX, Reference No. 19535
	3,600	LC50	*Tallaperia maria* (stonefly)	96h	mortality	ECOTOX, Reference No. 14563
	7,000	LC50	*Tanytarsus dissimilis* (midge)	48h	mortality	ECOTOX, Reference No. 16044
	9,100	LC50	*Gammarus annulata* (scud)	96h	mortality	ECOTOX, Reference No. 14563
	9,100	LC50	*Daphnia magna* (water flea)	48h	mortality	ECOTOX, Reference No. 15981
	10,200	LC50	*Americamysis bahia* (opossum shrimp)	96h	mortality	ECOTOX, Reference No. 9607
	13,200	LC50	*Acartia tonsa* (calanoid copepod)	96h	mortality	ECOTOX, Reference No. 14563
	17,400	LC50	*Crangon septemspinosa* (bay shrimp)	96h	mortality	ECOTOX, Reference No. 14563
	21,600	NOAEL	*Gammarus minus* (scud)	96h	mortality	ECOTOX, Reference No. 14563
	93,400	LC50	*Physa heterostropha* (pond snail)	96h	mortality	ECOTOX, Reference No. 14563

VOC	Reported Concentration (µg/L)	Effect Level	Test Organism	Test Duration	Endpoint	Source[a]
Toluene (methylbenzene)	**737**	NOAEL	*Ceriodaphnia dubia* (water flea)	7d	reproduction	Niederlehner et al. (1998)
	1,000	NOAEL	*Daphnia magna* (water flea)	21d	reproduction	ECOTOX, Reference No. 847
	5,600	NOAEL	*Chironomus thummi*	48h	mortality	ECOTOX, Reference No. 4072
	9,500	LC50	*Palaemonetes pugio* (daggerblade shrimp)	96h	mortality	Tatem and Johnson (1978)
	14,700	LC50	*Eualus* sp. (shrimp)	96h	mortality	Korn et al. (1979)
	23,500	LC50	*Hemigrapsus nudus* (shore crab)	8d	mortality	ECOTOX, Reference No. 12879
	24,200	LC50	*Nitocra spinipes* (harpacticoid copepod)	96h	mortality	ECOTOX, Reference No. 7800
	28,000	LC50	*Cancer magister* (Dungeness crab)	96h	mortality	ECOTOX, Reference No. 5035
	33,000	LC50	*Artemia* sp. (brine shrimp)	24h	mortality	ECOTOX, Reference No. 2408
	38,900	NOAEL	*Physa heterostropha* (pond snail)	96h	mortality	ECOTOX, Reference No. 14396
	58,000	LC50	*Gammarus minus* (scud)	96h	mortality	ECOTOX, Reference No. 14396
	113,000	LC50	*Brachionus sp.* (rotifer)	24h	mortality	ECOTOX, Reference No. 9385
	172,000	LC50	*Crassostrea gigas* (Pacific oyster)	48h	mortality	ECOTOX, Reference No. 8621
	225,000	LC50	*Katelysia opima* (marine bivalve)	96h	mortality	ECOTOX, Reference No. 9017
	447,000	LC50	*Diaptomus forbesi* (calanoid copepod)	96h	mortality	ECOTOX, Reference No. 11282
	1,047,000	EC50	*Crassostrea gigas* (Pacific oyster)	48h	development	ECOTOX, Reference No. 8621
	1,100,000	LC50	*Melanoides tuberculata* (snail)	96h	mortality	ECOTOX, Reference No. 18198
Trichloroethene	1,700	LC50	*Platyhelminthes* sp. (flatworm)	7d	mortality	Yoshioka et al. (1986)
	2,200	NOAEL	*Daphnia magna* (water flea)	48h	mortality	LeBlanc (1980)
	2,300	LC50	*Daphnia* sp. (water flea)	3h	mortality	Yoshioka et al. (1986)
	2,300	NOAEL	*Daphnia magna* (water flea)	21d	reproduction	ECOTOX, Reference No. 56378
	7,095	NOAEL	*Ceriodaphnia dubia* (water flea)	7d	reproduction	Niederlehner et al. (1998)
	8,000	LOAEL	*Daphnia magna* (water flea)	21d	reproduction	ECOTOX, Reference No. 56378
	14,000	LC50	*Mysidopsis bahia* (mysid shrimp)	96h	mortality	Ward et al. (1986)
	16,951	LC50	*Ceriodaphnia dubia* (water flea)	7d	mortality	Niederlehner et al. (1998)
	18,000	LC50	*Daphnia magna* (water flea)	48h	mortality	LeBlanc (1980)
	20,000	LC50	*Elminius modestus* (Australian barnacle)	48h	mortality	ECOTOX, Reference No. 19535
	24,000	LC50	*Gammarus pulex* (scud)	48h	mortality	ECOTOX, Reference No. 15788
	30,000	LC50	*Asellus aquaticus* (aquatic sowbug)	48h	mortality	ECOTOX, Reference No. 15788
	39,000	LC50	*Daphnia pulex* (water flea)	48h	mortality	ECOTOX, Reference No. 2017
	42,000	LC50	*Cloeon dipterum* (mayfly)	48h	mortality	ECOTOX, Reference No. 15788
	48,000	LC50	*Aedes aegypti* (yellow fever mosquito)	48h	mortality	ECOTOX, Reference No. 14863
	49,000	LC50	*Ischnura elegans* (damselfly)	48h	mortality	ECOTOX, Reference No. 15788
	55,000	LC50	*Culex pipiens* (northern house mosquito)	48h	mortality	ECOTOX, Reference No. 10574

VOC	Reported Concentration (µg/L)	Effect Level	Test Organism	Test Duration	Endpoint	Source[a]
	56,000	LC50	*Lymnaea stagnalis* (great pond snail)	24 to 48h	mortality	ECOTOX, Reference No. 10574
	56,000	LC50	*Daphnia cucullata* (water flea)	48h	mortality	ECOTOX, Reference No. 2017
	64,000	LC50	*Chironomus* (midge)	48h	mortality	ECOTOX, Reference No. 15788
	70,000	LC50	*Nemoura cinerea* (stonefly)	48h	mortality	ECOTOX, Reference No. 15788
	75,000	LC50	*Hydra oligactix* (hydra)	48h	mortality	ECOTOX, Reference No. 10574
	75,000	LC50	*Erpobdella octoculata* (leech)	48h	mortality	ECOTOX, Reference No. 15788
	132,000	LC50	*Tubificidae* (oligochaete)	48h	mortality	ECOTOX, Reference No. 15788
Vinyl chloride (chloroethene)	**12,800**	FCV	Based on narcosis model	na	na	DiToro et al. (2000)
	65,300	FAV	Based on narcosis model	na	na	DiToro et al. (2000)
	128,000	NOAEL	*Brachydanio rerio* (zebrafish)	96h	mortality	Groeneveld et al. (1993), as cited in de Rooij et al. (2004b)
	388,000	LC100	*Esox lucius* (northern pike)	10d	mortality	Brown et al. (1977)

[a] References for ECOTOX sources can be found at: http://cfpub.epa.gov/ecotox/advanced_query.htm.

[b] Additional higher concentrations were reported in ECOTOX

d – days
EC50 – effects concentration for 50% of a test population
FAV – final acute value
FCV – final chronic value
h – hours
LC50 – lethal concentration for 50% of a test population
LC100 - lethal concentration for 100% of a test population
LOAEL – lowest-observed-effect concentration
na – not available
NOAEL – no-observed-effect concentration
VOC – volatile organic compound
Bold identifies concentrations that were selected as toxicity reference values.

SUMMARY OF SELECTED TOXICOLOGICAL STUDIES

1,1-Dichloroethane and vinyl chloride

There were no invertebrate and very few fish toxicity data available for 1,1-dichloroethane and vinyl chloride. Therefore, the toxicity values for these two chemicals were derived using the narcosis toxicity model for aquatic organisms presented in DiToro et al. (2000). The narcosis model is based on the calculation of chemical concentrations in the target lipid phase of the organism associated with narcotic mortality. This model was calibrated by DiToro et al. (2000) using a database of LC50s for 156 organic chemicals and 33 species including fish, amphibians, arthropods, mollusks, polychaetes, coelenterates, and protozoans. The predicted chronic values (PCVs) for 1,1-dichloroethane and vinyl chloride were obtained from the final acute values (FAVs) by using an acute-to-chronic ratio of 5.09, which was calculated by DiToro et al. (2000) as the geometric mean of the available acute-to-chronic ratios.

1,1-Dichloroethene

The NOAEL and LOAEL were selected from two different studies. The lowest LOAEL for 1,1-dichloroethene was reported in a study using *Daphnia magna* (Dill et al. 1980). In this study, *Daphnia magna* (< 24 hours old) were exposed to 1,1-dichloroethene for 48 hours in a static environment. The mortality rate was determined at test termination, and an LC50 of 11, 600 µg/L was calculated. The NOAEL was selected from a similar study with *Daphnia magna* (LeBlanc 1980). *Daphnia magna* (< 24 hours old) were exposed to 1,1-dichloroethene for 48 hours in a static test. The NOAEL was 2,400 µg/L.

1,2-Dichlorobenzene

The lowest LOAEL was selected from a study using *Daphnia magna* (Calamari et al. 1983). In this study, *Daphnia magna* were exposed to 1,2-dichlorobenzene for 14 days. The LOAEL was based on a reproductive EC50 of 550 µg/L. Because the selected LOAEL was lower than any NOAEL reported in the literature, a NOAEL of 11 µg/L was derived by dividing the LOAEL by 50.

1,2-Dichloroethane

The LOAEL for 1,2-dichloroethane was selected from a study using *Artemia salina* (Sanchez-Fortun et al. 1997). In this study, *Artemia* shrimp larvae were exposed to 1,2-dichloroethane for 72 hours. The mortality rate was determined at test termination, and an LC50 of 6,927 µg/L was calculated. Because the selected LOAEL was lower than any NOAEL reported in the literature, a NOAEL of 139 µg/L was derived by dividing the LOAEL by 50.

1,2-Dichloropropane
The lowest LOAEL was selected from a study using *Daphnia magna* (LeBlanc 1980). In this study, *Daphnia magna* were exposed to 1,2-dichlorobenzene for 48 hours. The mortality rate was determined at test termination and an LC50 of 6,927 µg/L was calculated. Because no NOAEL was available in the literature, a NOAEL of 840 µg/L was derived by dividing the LOAEL by 50.

1,4-Dichlorobenzene
The lowest LOAEL was selected from a study using *Portunus pelagicus* (Mortimer and Connell 1994). In this study, *Portunus pelagicus* were exposed to 1,4-dichlorobenzene for 10 hours. The mortality rate was determined at test termination and an LC50 of 147 µg/L was calculated. Because no NOAEL was available in the literature, a NOAEL of 3 µg/L was derived by dividing the LOAEL by 50.

1,2-Dichloroethene (cis or trans)
The lowest LOAEL was selected from a study using *Artemia salina* (Sanchez-Fortun et al. 1997). In this study, *Artemia* shrimp larvae were exposed to 1,2-dichloroethane for 72 hours. The mortality rate was determined at test termination and an LC50 of 6,785 µg/L was calculated. The only other toxicity data available for this chemical is an LC50 of 140,000 g/L from a bluegill study. Therefore, a NOAEL of 136 µg/L was derived by dividing the LOAEL by 50.

Benzene
The LOAEL for benzene was selected from a study by Caldwell et al. (1976). This study was conducted with larval stages of the Dungeness crab, *Cancer magister*. Larvae were exposed to benzene solutions within a few hours after larvae were hatched and mortality, growth, and development were monitored for up to 50 days. At a benzene concentration of 1,100 µg/L, all larvae died after 24 days of exposure. No effects on mortality, growth, or development were observed at the next lowest concentration of 180 µg/L. Therefore, these concentrations were selected as the LOAEL and NOAEL, respectively, for benzene.

Carbon disulfide
The lowest LOAEL was selected from a study using *Daphnia magna* (Van Leeuwen et al. 1985). In this study, *Daphnia magna* were exposed to carbon disulfide for 48 hours. The mortality rate was determined at test termination and an LC50 of 1,900 µg/L was calculated. Because no NOAEL was available in the literature, a NOAEL of 38 µg/L was derived by dividing the LOAEL by 50.

Chlorobenzene
The NOAEL and LOAEL were selected from two different studies. The lowest LOAEL was selected from a study using *Daphnia magna* (Calamari et al. 1983). In this study, *Daphnia magna* were exposed to chlorobenzene for 14 days in a static renewal environment. The LOAEL was based on a reproductive EC50 of 2,500 µg/L. The

NOAEL was selected from a study by Cowgill and Milazzo (1991). In this study, *Daphnia magna* were exposed to chlorobenzene for 10 days in a renewed static environment. No effect on mortality was observed at a chlorobenzene concentration of <1,400 µg/L. Therefore, 1,400 µg/L was selected as the NOAEL for chlorobenzene.

Tetrachloroethene

The NOAEL and LOAEL were selected from two different studies. The lowest LOAEL for tetrachloroethene was selected from a study using *Artemia salina* (Sanchez-Fortun et al. 1997). In this study, *Artemia* shrimp larvae were exposed to tetrachloroethene for 72 hours. The mortality rate was determined at test termination and an LC50 of 332 µg/L was calculated. The NOAEL was selected from a study using *Ceriodaphnia dubia* (Niederlehner et al. 1998). In this study, *Ceriodaphnia dubia* were exposed to tetrachloroethene for 7 days in a static environment. At test termination the LC50 was reported as 829 µg/L and the reproductive NOAEL as 331 µg/L. Because the LC50 reported for *Artemia* was lower than the LC50 reported for *Ceriodaphnia dubia*, the *Artemia* LC50 was selected as the LOAEL.

Toluene

The NOAEL and LOAEL were selected from two different studies. The lowest LOAEL available in the literature was not selected because the authors did not indicate whether a negative control was used (Tatem et al. 1978). Instead, the LOAEL was selected from a study by Korn et al. (1979). In this study, adult shrimp (*Eualus* spp.) were exposed to toluene for 96 hours in a static environment. The mortality rate was determined at test termination and an LC50 of 14,700 µg/L was calculated. Methods used to reduce evaporative losses were not discussed in the study and comparison of measured concentrations at both test initiation and termination showed that toluene declined substantially during the test, thus indicating that the LC50 may be an overestimate (i.e., the actual LC50 may be lower). However, because this LC50 was the lowest concentration at which an effect was reported, it was selected as the LOAEL. The NOAEL for toluene was selected from a study using *Ceriodaphnia dubia* (Niederlehner et al. 1998). In this study, *Ceriodaphnia dubia* were exposed to toluene for 7 days in a static environment. A reproductive NOAEL of 737 µg/L was reported at test termination.

Trichloroethene

The two lowest LOAEL for trichloroethene were from two studies by Yoshioka et al. (1986). Both studies were considered unacceptable either because the test did not represent a relevant environmental stressor (heads were removed from flatworms and the endpoints were abnormal head regeneration and mortality) or very few study details were presented and the use of a negative control was not discussed. The third lowest concentration where effects were observed was a reproductive LOAEL of 8,000 µg/L, but the derivation of this value could not be reviewed because the paper was in German. The fourth lowest concentration with effects was from an acceptable study by Ward et al. (1986). In this study, *Mysidopsis bahia* (mysid shrimp) were exposed to

trichloroethene for 96 hours in a static environment. The mortality rate was determined at test termination and an LC50 of 14,000 µg/L was calculated. The lowest NOAEL for trichloroethene was selected from a study by LeBlanc (1980). In this study, *Daphnia magna* (< 24 hours old) were exposed to trichloroethene for 48 hours in a static environment. The NOAEL was 2,200 µg/L.

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