Appendix C. Technical Memorandum: Toxicity Data for Evaluation of VOCs in Porewater

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Acronyms

ACRONYM	Definition
AWQC	ambient water quality criterion
DO	dissolved oxygen
EC50	effects concentration for 50% of a test population
EPA	US Environmental Protection Agency
ERA	ecological risk assessment
GWI	Great Western International
LC50	lethal concentration for 50% of a test population
LOEC	lowest-observed-effect concentration
LDW	Lower Duwamish Waterway
LDWG	Lower Duwamish Waterway Group
MLLW	mean lower low water
NOEC	no-observed-effect concentration
PPT	parts per thousand
QAPP	quality assurance project plan
TRV	toxicity reference value
VOC	volatile organic compound

1.0 Introduction

The Lower Duwamish Waterway Group (LDWG) has submitted the draft final porewater quality assurance project plan (QAPP) (Windward 2005) to the US Environmental Protection Agency (EPA) and Washington Department of Ecology for review. The results of the porewater study, as described in the Phase 2 Work Plan (Windward 2004), will be used to assess risks to benthic invertebrates from potential exposure to volatile organic compounds (VOCs) in porewater within sediments of the Lower Duwamish Waterway (LDW).

This technical memorandum presents toxicity data needed for the following two purposes:

- To compare to the concentrations of VOCs detected in samples collected from piezometers inserted 1 ft into the sediment and deployed at depths of 5 to 15 ft below mean lower low water (MLLW) at each of two focus areas as described in the porewater QAPP (Windward 2005). If VOC concentrations in any of those samples exceed any of the selected toxicity data, peepers will be deployed in near-surface sediments at those piezometer sampling locations to collect additional porewater samples for VOC analysis.
- To compare VOC concentrations detected in porewater samples collected from peepers deployed 10 to 12 cm below the mudline at depths of 0 to 3 ft below MLLW within the intertidal zone of each focus area (or in any peepers that may be deployed at the piezometer locations). This comparison will be made in the porewater data and analysis report and also in the Phase 2 ecological risk assessment (ERA). EPA and Ecology may request modification of the toxicity data presented in this report for use in the Phase 2 ERA.

Toxicity data are needed for VOCs of interest associated with the two focus areas of the porewater study—river mile (RM) 2.3 to 2.4 (Great Western International [GWI]) and RM 3.5 to 3.6 (Boeing Plant 2/Jorgensen Forge). These areas were selected because they represent the likely worst-case exposure areas for VOCs in LDW porewater. Because there are no federal or state water quality criteria for VOCs for the protection of aquatic organisms (EPA 2002, WAC 173-201A), toxicity data were compiled from the literature, as described in this memorandum.

The memorandum is organized into the following sections:

- Section 2 – selection of VOCs of interest
- Section 3 – literature search
- Section 4 – selection of toxicity data
- Section 5 – references

2.0 Selection of VOCs of Interest

As described in the draft final porewater QAPP (Windward 2005), ecologically relevant toxicity data are needed for VOCs of interest at the two areas where porewater sampling will be conducted, GWI and Boeing Plant 2/Jorgensen Forge. At GWI, the VOCs of interest are VOCs previously detected in seeps, Gore-Sorber modules, or in the closest groundwater wells to the LDW (see Tables 2-2, 2-3, and 3-1 in the QAPP). At Boeing Plant 2, the VOCs of interest are VOCs previously detected in seeps or in the closest groundwater wells to the LDW sampled in 2004 (see Tables 2-2 and 2-3 in the QAPP). A summary of these chemicals is provided in Table 2-1.

Table 2-1. List of VOCs of interest

VOC	Great Western International	Boeing Plant 2/ Jorgensen Forge
1,1,1-Trichloroethane	x	
1,1,2-Trichloroethane	x	
1,1-Dichloroethane	x	x
1,1-Dichloroethene	x	
1,2-Dichloroethane	x	
1,2-Dichloroethene (cis or trans)	x	x
Acetone (2-propanone)	x	x
Benzene	x	x
Chlorobenzene	x	
Tetrachloroethene	x	
Toluene (methylbenzene)	x	
Trichloroethene	x	x
Vinyl chloride (chloroethene)	x	x
Xylene	x	x

3.0 Literature Search

A literature search for relevant toxicity studies for the 14 VOCs of interest 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.

3.1 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.

3.2 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 LDW.

After searching ECOTOX, BIOSIS was searched to identify articles published in 2003 to 2005 for each of the 14 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.

3.3 DATABASE SEARCH RESULTS

Table 3-1 summarizes the results of the literature search. All no-effect concentrations (NOECs) and lowest observed effect concentrations (LOECs) found in the literature search are presented. Because a large number of the available values for some chemicals represented lethal concentrations for 50% of a test population (i.e., LC50 values), only the lowest LC50 for a given test organism is shown in Table 3-1.

In the course of the literature search, several papers were identified that established NOECs 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 3-1. One of the studies cited in these papers was used to develop the toxicity value for vinyl chloride. The original paper could not be obtained to review the data quality, but it was considered the most acceptable of the two available studies for vinyl chloride, as discussed in Section 4.3.13.

Table 3-1. Aquatic toxicity data obtained from the literature search

VOC	Reported Concentration (µg/L)	Effect Level	Endpoint	Test Duration	Test Organism	Reference
1,1,1-Trichloroethane	1,300	NOEC	mortality, reproduction	17d	*Daphnia magna* (water flea)	Thompson and Carmichael (1989)
	2,400	LOEC	mortality, reproduction	17d	*Daphnia magna* (water flea)	Thompson and Carmichael (1989)
	5,256	LC50	mortality	24h	*Artemia salina* (brine shrimp)	ECOTOX, reference #18365
	5,400	LC50	mortality	17d	*Daphnia magna* (water flea)	ECOTOX, reference #489
	7,500	LC50	mortality	48h	*Elminius modestus* (barnacle)	Pearson and McConnell (1975), as cited in de Rooij et al. (2004a)
	7,900	NOEC	growth	21d	*Daphnia magna* (water flea)	de Wolfe et al. (1986), as cited in de Rooij et al. (2004a)
	9,850	LC50	mortality	24h	*Eubranchipus* sp. (fairy shrimp)	ECOTOX, reference #13669
	31,200	LC50	mortality	96h	*Americamysis bahia* (opossum shrimp)	ECOTOX, reference #9607
	6,417,502	LC50	mortality	24h	*Brachionus calyciflorus* (rotifer)	ECOTOX, reference #13669
1,1,2-Trichloroethane	1,000	NOEC	mortality	48h	*Daphnia magna* (water flea)	LeBlanc (1980)
	10,000	NOEC	reproduction	3wk	*Artemia salina* (brine shrimp)	Adema and Vink (1981)
	15,000	EC50	reproduction	3wk	*Artemia salina* (brine shrimp)	Adema and Vink (1981)
	18,000	LC50	mortality	48h	*Daphnia magna* (water flea)	LeBlanc (1980)
	<31,000	NOEC	mortality	48h	*Chironomus thummi* (midge)	ECOTOX, reference #4072
	36,000	EC50	mortality, growth	16d	*Lymnaea stagnalis* (great pond snail)	ECOTOX, reference #15149
	41,000	LC50	mortality	3wk	*Chaetogammarus marinus* (amphipod)	ECOTOX, reference #15149
	42,000	LC50	mortality	7d	*Crangon crangon* (shrimp)	ECOTOX, reference #15149
	43,000	LC50	mortality	7d	*Palaemonetes varians* (shrimp)	ECOTOX, reference #15149
	43,000	LC50	mortality	96h	*Temora longicornis* (calanoid copepod)	ECOTOX, reference #15149
	65,000	LC50	mortality	14d	*Mytilus edulis* (blue mussel)	ECOTOX, reference #15149
	140,000	LC50	mortality	14d	*Dreissena polymorpha* (zebra mussel)	ECOTOX, reference #15149
	160,000	LC50	mortality	96h	*Ophryotrocha labronica* (polychaete)	ECOTOX, reference #5902
	170,000	LC50	mortality	7d	*Crepidula fornicata* (slipper limpet)	ECOTOX, reference #15149
1,1-Dichloroethane	202,000	LC50	mortality	14d	*Poecilia reticulate* (guppy)	Könemann (1981)

VOC	Reported Concentration (μg/L)	Effect Level	Endpoint	Test Duration	Test Organism	Reference
1,1-Dichloroethene	2,400	NOEC	mortality	48h	*Daphnia magna* (water flea)	LeBlanc (1980)
	11,600	LC50	mortality	48h	*Daphnia magna* (water flea)	Dill et al. (1980)
	79,000	LC50	mortality	48h	*Daphnia magna* (water flea)	LeBlanc (1980)
	224,000	LC50	mortality	96h	*Americamysis bahia* (opossum shrimp)	ECOTOX, reference #9607
1,2-Dichloroethane	6,927	LC50	mortality	72h	*Artemia salina* (brine shrimp)	Sanchez-Fortun et al. (1997)
	11,000	NOEC	reproduction	28d	*Daphnia magna* (water flea)	Richter et al. (1983)
	42,000	NOEC	growth	28d	*Daphnia magna* (water flea)	Richter et al. (1983)
	<68,000	NOEC	mortality	28d	*Daphnia magna* (water flea)	Richter et al. (1983)
	>100,000	LC50	mortality	96h	*Gammarus fasciatus* (scud)	ECOTOX, reference #6797
	>100,000	LC50	mortality	96h	*Pteronarcys californicus* (stonefly)	ECOTOX, reference #6797
	113,000	LC50	mortality	96h	*Americamysis bahia* (opossum shrimp)	ECOTOX, reference #9607
	186,000	LC50	mortality	48h	*Elminius modestus* (Australian barnacle)	ECOTOX, reference #13535
	220,000	LC50	mortality	48h	*Daphnia magna* (water flea)	Richter et al. (1983)
	900,000	LC50	mortality	96h	*Ophryotrocha labronica* (polychaete)	ECOTOX, reference # 5902
1,2-Dichloroethene (cis or trans)	6,785	LC50	mortality	72h	*Artemia salina* (brine shrimp)	Sanchez-Fortun et al. (1997)
	140,000	LC50	mortality	24-96h	*Lepomis macrochirus* (bluegill)	ECOTOX, reference #590
Acetone (2-Propanone)	10,000	LC50	mortality	24-48h	*Daphnia magna* (water flea)	Dowden and Bennett (1965)
	33,830	LC50	mortality	48h	*Anodonta imbecillis* (mussel)	Keller (1993)
	51,000	LC50	mortality	24h	*Brachionus calyciflorus* (rotifer)	ECOTOX, reference #17689
	100,000	LC50	mortality	12d	*Mercenaria mercenaria* (northern quahog)	ECOTOX, reference #2400
	>100,000	EC50	development	48h	*Crassostrea virginica* (American oyster)	ECOTOX, reference #2400
	>100,000	LC50	mortality	96h	*Gammarus pulex* (scud)	ECOTOX, reference #11951
	>100,000	LC50	mortality	96h	*Lumbriculus variegates* (oligochaete worm)	ECOTOX, reference #11951
	>100,000	LC50	mortality	96h	*Helisoma trivolvis* (ramshorn snail)	ECOTOX, reference #11951
	>100,000	LC50	mortality	96h	*Dugesia tigrina* (flatworm)	ECOTOX, reference #11951
	1,010,000[a]	LC50	mortality	192h	*Lithodes santolla* (southern king crab)	ECOTOX, reference #136

VOC	Reported Concentration (µg/L)	Effect Level	Endpoint	Test Duration	Test Organism	Reference
Benzene	180	NOEC	mortality, growth, development	24d	*Cancer magister* (Dungeness crab)	Caldwell et al. (1976)
	1,100	100% mortality	mortality	24d	*Cancer magister* (Dungeness crab)	Caldwell et al. (1976)
	2,968	NOEC	reproduction	7d	*Ceriodaphnia dubia* (water flea)	Niederlehner et al. (1998)
	6,000	LC50	mortality	96h	*Gammarus* sp. (scud)	ECOTOX, reference #13419
	10,000	LC50	mortality	48h	*Ischnura elegans* (damselfly)	ECOTOX, reference #15788
	12,419	LC50	mortality	7d	*Ceriodaphnia dubia* (water flea)	Niederlehner et al. (1998)
	15,000	LC50	mortality	96h	*Daphnia pulex* (water flea)	ECOTOX, reference #15337
	16,796	LC50	mortality	96h	*Crangon franciscorum* (shrimp)	ECOTOX, reference #558
	21,000	LC50	mortality	48h	*Artemia salina* (brine shrimp)	ECOTOX, reference #2408
	27,000	LC50	mortality	96h	*Palaemonetes pugio* (shrimp)	ECOTOX, reference #420
	34,000	LC50	mortality	48h	*Cloeon dipterum* (mayfly)	ECOTOX, reference #15788
	48,000	LC50	mortality	48h	*Corixa* sp. (water boatman)	ECOTOX, reference #15788
	59,600	LC50	mortality	48h	*Daphnia magna* (water flea)	ECOTOX, reference #7069
	71,000	LC50	mortality	48h	*Culex pipiens* (northern house mosquito)	ECOTOX, reference #10574
	74,000	LC50	mortality	48h	*Dugesia lugubris* (vortex worm)	ECOTOX, reference #15788
	82,000	LC50	mortality	≤96h	*Diaptomus forbesi* (copepod)	ECOTOX, reference #7800
	100,000	LC50	mortality	48h	*Chironomus thummi* (midge)	ECOTOX, reference #15788
	111,800	100% mortality	mortality	1h	*Homarus americanus* (American lobster)	ECOTOX, reference #5353
	120,000	LC50	mortality	48h	*Asellus aquaticus* (aquatic sowbug)	ECOTOX, reference #15788
	130,000	LC50	mortality	48h	*Nemoura cinerea* (stonefly)	ECOTOX, reference #15788
	190,000	LC50	mortality	96h	*Katelysia opima* (marine bivalve)	ECOTOX, reference #9017
	200,000	LC50	mortality	48h	*Aedes aegypti* (yellow fever mosquito)	ECOTOX, reference #14863
	230,000	LC50	mortality	48h	*Lymnaea stagnalis* (great pond snail)	ECOTOX, reference #15788
	>320,000	LC50	mortality	48h	*Erpobdella octoculata* (leech)	ECOTOX, reference #15788
	>320,000	LC50	mortality	48h	*Tubificidae* (oligochaete)	ECOTOX, reference #15788
	356,000	LC50	mortality	48h	*Daphnia cucullata* (water flea)	ECOTOX, reference #2017
	377,000	LC50	mortality	48h	*Crassostrea gigas* (Pacific oyster)	ECOTOX, reference #8621
	550,000[a]	LC50	mortality	120h	*Lymnaea stagnalis* (great pond snail)	ECOTOX, reference #13419
Chlorobenzene	320	NOEC	reproduction	16d	*Daphnia magna* (water flea)	Hermens et al. (1984)
	<1,400	NOEC	mortality	10d	*Daphnia magna* (water flea)	Cowgill and Milazzo 1991
	2,500	EC50	reproduction	14d	*Daphnia magna* (water flea)	Calamari et al. (1983)
	3,890	NOEC	mortality	7-10d	*Ceriodaphnia dubia* (water flea)	ECOTOX, reference #212
	12,000	NOEC	reproduction	7-10d	*Ceriodaphnia dubia* (water flea)	ECOTOX, reference #212
	16,400	LC50	mortality	96h	*Americamysis bahia* (opossum shrimp)	ECOTOX, reference #9607

VOC	Reported Concentration (µg/L)	Effect Level	Endpoint	Test Duration	Test Organism	Reference
Tetrachloroethene	331	NOEC	reproduction	7d	*Ceriodaphnia dubia* (water flea)	Niederlehner et al. (1998)
	332	LC50	mortality	72h	*Artemia salina* (brine shrimp)	Sanchez-Fortun et al. (1997)
	400	NOEC	reproduction	21d	*Daphnia magna* (water flea)	ECOTOX, reference #56345
	829	LC50	mortality	7d	*Ceriodaphnia dubia* (water flea)	Niederlehner et al. (1998)
	900	EC50	growth	7d	*Dugesia japonica* (flatworm)	ECOTOX, reference #12513
	1,300	LC50	mortality	96h	*Palaemonetes pugio* (grass shrimp)	ECOTOX, reference #14563
	1,300	LC50	mortality	96h	*Nereis arenaceodentata* (polychaete)	ECOTOX, reference #14563
	1,400	LC50	mortality	7d	*Dugesia japonica* (flatworm)	ECOTOX, reference #12513
	1,800	LC50	mortality	3h	*Moina macrocopa* (water flea)	ECOTOX, reference #12513
	3,500	LC50	mortality	48h	*Elminius modestus* (Australian barnacle)	ECOTOX, reference #19535
	3,600	LC50	mortality	96h	*Tallaperia maria* (stonefly)	ECOTOX, reference #14563
	7,000	LC50	mortality	48h	*Tanytarsus dissimilis* (midge)	ECOTOX, reference #16044
	9,100	LC50	mortality	96h	*Gammarus annulata* (scud)	ECOTOX, reference #14563
	9,100	LC50	mortality	48h	*Daphnia magna* (water flea)	ECOTOX, reference #15981
	10,200	LC50	mortality	96h	*Americamysis bahia* (opossum shrimp)	ECOTOX, reference #9607
	13,200	LC50	mortality	96h	*Acartia tonsa* (calanoid copepod)	ECOTOX, reference #14563
	17,400	LC50	mortality	96h	*Crangon septemspinosa* (bay shrimp)	ECOTOX, reference #14563
	21,600	NOEC	mortality	96h	*Gammarus minus* (scud)	ECOTOX, reference #14563
	93,400	LC50	mortality	96h	*Physa heterostropha* (pond snail)	ECOTOX, reference #14563
Toluene (methylbenzene)	737	NOEC	reproduction	7d	*Ceriodaphnia dubia* (water flea)	Niederlehner et al. (1998)
	1,000	NOEC	reproduction	21d	*Daphnia magna* (water flea)	ECOTOX, reference #847
	5,600	NOEC	mortality	48h	*Chironomus thummi*	ECOTOX, reference #4072
	9,500	LC50	mortality	96h	*Palaemonetes pugio* (daggerblade shrimp)	Tatem et al. 1978
	14,700	LC50	mortality	96h	*Eualus* sp. (shrimp)	Korn et al. (1979)
	23,500	LC50	mortality	8d	*Hemigrapsus nudus* (shore crab)	ECOTOX, reference #12879
	24,200	LC50	mortality	96h	*Nitocra spinipes* (harpacticoid copepod)	ECOTOX, reference #7800
	28,000	LC50	mortality	96h	*Cancer magister* (Dungeness crab)	ECOTOX, reference #5035
	33,000	LC50	mortality	24h	*Artemia* sp. (brine shrimp)	ECOTOX, reference #2408
	38,900	NOEC	mortality	96h	*Physa heterostropha* (pond snail)	ECOTOX, reference #14396
	58,000	LC50	mortality	96h	*Gammarus minus* (scud)	ECOTOX, reference #14396
	113,000	LC50	mortality	24h	*Brachionus sp.* (rotifer)	ECOTOX, reference #9385
	172,000	LC50	mortality	48h	*Crassostrea gigas* (Pacific oyster)	ECOTOX, reference #8621
	225,000	LC50	mortality	96h	*Katelysia opima* (marine bivalve)	ECOTOX, reference #9017
	447,000	LC50	mortality	96h	*Diaptomus forbesi* (calanoid copepod)	ECOTOX, reference #11282
	1,047,000	EC50	development	48h	*Crassostrea gigas* (Pacific oyster)	ECOTOX, reference #8621
	1,100,000	LC50	mortality	96h	*Melanoides tuberculata* (snail)	ECOTOX, reference #18198

VOC	Reported Concentration (µg/L)	Effect Level	Endpoint	Test Duration	Test Organism	Reference
Trichloroethene	1,700	LC50	mortality	7d	*Platyhelminthes* sp. (flatworm)	Yoshioka et al. (1986)
	2,200	NOEC	mortality	48h	*Daphnia magna* (water flea)	LeBlanc (1980)
	2,300	LC50	mortality	3h	*Daphnia* sp. (water flea)	Yoshioka et al. (1986)
	2,300	NOEC	reproduction	21d	*Daphnia magna* (water flea)	ECOTOX, reference #56378
	7,095	NOEC	reproduction	7d	*Ceriodaphnia dubia* (water flea)	Niederlehner et al. (1998)
	8,000	LOEC	reproduction	21d	*Daphnia magna* (water flea)	ECOTOX, reference #56378
	14,000	LC50	mortality	96h	*Mysidopsis bahia* (mysid shrimp)	Ward et al. 1986
	16,951	LC50	mortality	7d	*Ceriodaphnia dubia* (water flea)	Niederlehner et al. (1998)
	18,000	LC50	mortality	48h	*Daphnia magna* (water flea)	LeBlanc (1980)
	20,000	LC50	mortality	48h	*Elminius modestus* (Australian barnacle)	ECOTOX, reference #19535
	24,000	LC50	mortality	48h	*Gammarus pulex* (scud)	ECOTOX, reference #15788
	30,000	LC50	mortality	48h	*Asellus aquaticus* (aquatic sowbug)	ECOTOX, reference #15788
	39,000	LC50	mortality	48h	*Daphnia pulex* (water flea)	ECOTOX, reference #2017
	42,000	LC50	mortality	48h	*Cloeon dipterum* (mayfly)	ECOTOX, reference #15788
	48,000	LC50	mortality	48h	*Aedes aegypti* (yellow fever mosquito)	ECOTOX, reference #14863
	49,000	LC50	mortality	48h	*Ischnura elegans* (damselfly)	ECOTOX, reference #15788
	55,000	LC50	mortality	48h	*Culex pipiens* (northern house mosquito)	ECOTOX, reference #10574
	56,000	LC50	mortality	24-48h	*Lymnaea stagnalis* (great pond snail)	ECOTOX, reference #10574
	56,000	LC50	mortality	48h	*Daphnia cucullata* (water flea)	ECOTOX, reference #2017
	64,000	LC50	mortality	48h	*Chironomus* (midge)	ECOTOX, reference #15788
	70,000	LC50	mortality	48h	*Nemoura cinerea* (stonefly)	ECOTOX, reference #15788
	75,000	LC50	mortality	48h	*Hydra oligactix* (hydra)	ECOTOX, reference #10574
	75,000	LC50	mortality	48h	*Erpobdella octoculata* (leech)	ECOTOX, reference #15788
	132,000	LC50	mortality	48h	*Tubificidae* (oligochaete)	ECOTOX, reference #15788
Vinyl chloride (chloroethene)	128,000	NOEC	mortality	96h	*Brachydanio rerio* (zebrafish)	Groeneveld et al. (1993), as cited in de Rooij et al. (2004b)
	388,000	100% mortality	mortality	10d	*Esox lucius* (northern pike)	Brown et al. (1977)

VOC	Reported Concentration (µg/L)	Effect Level	Endpoint	Test Duration	Test Organism	Reference
Xylene	1,168	NOEC	reproduction	7d	*Ceriodaphnia dubia* (water flea)	Niederlehner et al. (1998)
	2,973	LC50	mortality	7d	*Ceriodaphnia dubia* (water flea)	Niederlehner et al. (1998)
	7,400	LC50	mortality	24-96h	*Palaemonetes pugio* (grass shrimp)	ECOTOX, reference #19953
	20,000	NOEC	reproduction	2d	*Brachionus calyciflorus* (rotifer)	ECOTOX, reference #3963
	53,000	LC50	mortality	120h	*Gammarus fossarum* (scud)	ECOTOX, reference #13419
	87,582	LC50	mortality	24h	*Eubranchipus* sp. (fairy shrimp)	ECOTOX, reference #13669
	99,500	LC50	mortality	24h	*Diaptomus forbesi* (calanoid copepod)	ECOTOX, reference #11282
	150,000	LC50	mortality	24h	*Daphnia magna* (water flea)	ECOTOX, reference #5718
	190,000	LC50	mortality	96h	*Katelysia opima* (marine bivalve)	ECOTOX, reference #9017
	190,000	LC50	mortality	120h	*Asellus aquaticus* (aquatic sowbug)	ECOTOX, reference #13419
	194,273	LC50	mortality	24h	*Artemia salina* (brine shrimp)	ECOTOX, reference #13669
	350,000	LC50	mortality	96h	*Amphimelania holandri* (snail)	ECOTOX, reference #13419

[a] Additional higher concentrations were reported in ECOTOX

EC50 – effects concentration for 50% of a test population

LC50 – lethal concentration for 50% of a test population

LOEC – lowest-observed-effect concentration

NOEC – no-observed-effect concentration

4.0 Selection of Toxicity Data

This section describes how specific studies were selected to provide toxicity data for the 14 VOCs of interest.

4.1 STUDY SELECTION

The studies identified in the literature search (Table 3-1) 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 LOECs were available. Instead, many studies typically reported LC50s and NOECs 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 LOEC and the highest NOEC below that LOEC 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 (see Section 4.3). The following general rules were followed:

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

In many cases, the available toxicity data were uncertain because LOECs were rarely reported, NOECs 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 NOECs, LOECs, and LC50s are reported. The concentrations of individual VOCs detected in porewater samples collected from any of the piezometers will be compared to the selected toxicity values (Section 4.3) to evaluate the need for deployment of peepers at those piezometer locations. The concentrations of individual VOCs detected in porewater samples collected from any of the peepers will also be compared to the selected toxicity values to assess risks to

[1] The actual effect threshold is uncertain for a NOEC without a corresponding LOEC.

benthic invertebrates associated with exposure to VOCs in porewater. Depending on the degree of uncertainty in the selected toxicity values, LDWG will consider, in consultation with EPA and Ecology, whether the application of uncertainty factors is appropriate.

4.2 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 EPA's AWQC, and on Suter and Tsao (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 hrs for daphnids, and no less than 96 hrs 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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[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 hrs 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., DO, pH, temp, salinity) should be reported
- dissolved oxygen (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 NOEC and LOEC
- the chemical source and purity should be noted

4.3 SELECTED STUDIES AND TOXICITY DATA

This section presents the toxicity data selected based on the study acceptability guidelines discussed in Sections 4.1 and 4.2. Sufficient data were found to derive toxicity data for 12 of the 14 VOCs using this approach. For the remaining two VOCs, 1,1-dichloroethane and vinyl chloride, no invertebrate studies were found and only one or two fish studies were found (Table 3-1). Therefore, toxicity data for these two VOCs were obtained by calculating acute and chronic values using the narcosis model from DiToro et al. (2000).

Selected toxicity data derived from the literature for the 12 VOCs with sufficient data are summarized in Table 4-1, and toxicity data for 1,1-dichloroethane and vinyl chloride derived from the narcosis model are presented in Table 4-2. Test conditions in studies used to derive toxicity data for VOCs with sufficient toxicity test information from the literature are documented in Table 4-3, and the rationale for the selection of the toxicity study for each VOC is presented in Sections 4.3.1 to 4.3.12. Section 4.3.13 describes the approach used to derive toxicity data for 1,1-dichloroethane and vinyl chloride using the narcosis model.

Table 4-1. Summary of selected toxicity values derived from the literature search

VOC	Effect Level	Test Duration	Test Organism	NOEC (µg/L)	LC50 (µg/L)
1,1,1-Trichloroethane	NOEC	17d	*Daphnia magna* (water flea)	1,300	2,400[a]
	LOEC	17d	*Daphnia magna* (water flea)		
1,1,2-Trichloroethane	NOEC	48h	*Daphnia magna* (water flea)	1,000	15,000
	LC50	48h	*Artemia salina* (brine shrimp)		
1,1-Dichloroethene	NOEC	48h	*Daphnia magna* (water flea)	2,400	11,600
	LC50	48h	*Daphnia magna* (water flea)		
1,2-Dichloroethane	LC50	72h	*Artemia salina* (brine shrimp)	na	6,927
1,2-Dichloroethene (cis or trans)	LC50	72h	*Artemia salina* (brine shrimp)	na	6,785
Acetone (2-Propanone)	LC50	48h	*Mytilus* sp. (mussel)	na	33,830
Benzene	NOEC	24d	*Cancer magister* (Dungeness crab)	180	1,100[b]
	100% mortality	24d	*Cancer magister* (Dungeness crab)		
Chlorobenzene	NOEC	10d	*Daphnia magna* (water flea)	<1,400	2,500[c]
	EC50	14d	*Daphnia magna* (water flea)		
Tetrachloroethene	NOEC	7d	*Ceriodaphnia dubia* (water flea)	331	332
	LC50	72h	*Artemia salina* (brine shrimp)		
Toluene (Methylbenzene)	NOEC	7d	*Ceriodaphnia dubia* (water flea)	737	14,700
	LC50	96h	*Eualus* spp. (shrimp)		
Trichloroethene	NOEC	48h	*Daphnia magna* (water flea)	2,200	14,000
	LC50	96h	*Mysidopsis bahia* (mysid shrimp)		
Xylene	NOEC	7d	*Ceriodaphnia dubia* (water flea)	1,168	2,973
	LC50	7d	*Ceriodaphnia dubia* (water flea)		

[a] Value is a LOEC (lowest-observed-effect concentration)

[b] Value is a LC100 (lethal concentration for 100% of a test population)

[c] Value is a EC50 (effects concentration for 50% of a test population)

LC50 – lethal concentration for 50% of a test population

NOEC – no-observed-effect concentration

Table 4-2. Toxicity values derived from the DiToro et al. (2000) narcosis model

VOC	Predicted Final Chronic Value (µg/L)	Predicted Final Acute Value (µg/L)
Equations from DiToro et al. (2000)	$\log(FCV) = \log[6.94] + \Delta C_\ell - 0.945 \log(K_{OW})$	$FAV = FCV \times 5.09$
1,1-Dichloroethane	7,800[a]	39,600[a]
Vinyl chloride	12,800[b]	65,300[b]

[a] Predicted using a K_{OW} of 1.80 from EPA (1985) and ΔC_ℓ of -0.244 from DiToro et al. (2000).

[b] Predicted using a K_{OW} of 1.36 from NIOSH (1986) and ΔC_ℓ of -0.244 from DiToro et al. (2000).

ΔC_ℓ – chemical class correction factor (DiToro et al. 2000)

FAV – final acute value

FCV – final chronic value

Table 4-3. Summary of conditions in selected toxicity tests

Test Species, Age	Test Duration	Test Methods [a]	Control Used?	Statistical Comparison to Control?	DO Conc.	Measured or Nominal Conc?	Organisms Fed?	Reported Effect and Conc. (µg/L)	Reference
1,1,1 Trichloroethane									
Daphnia magna (water flea), <24 h	17 d	static renewal, covered beakers	yes	yes	7.8 to 11.1 mg/L	nominal	yes	NOEC (mortality and reproduction) = 1,300 LOEC (mortality and reproduction) = 2,400	Thompson and Carmichael (1989)
1,1,2 Trichloroethane									
Daphnia magna (water flea), <24 h	48 h	static, covered beakers	yes	nr	>6.5 mg/L	measured at initiation and termination of test	no	NOEC (mortality) = 1,000	LeBlanc (1980)
Artemia salina (brine shrimp), larva	3 wk	static, artificial seawater	yes	nr	≥70% saturation	nominal	nr	LC50 = 15,000	Adema and Fink (1981)
1,1-Dichloroethene									
Daphnia magna (water flea), <24 h	48 h	static covered beakers	yes	nr	>6.5 mg/L	measured at initiation and termination of test	no	NOEC (mortality) = 2,400 µg/L	LeBlanc (1980)
Daphnia magna (water flea), <24 h	48 h	static	yes	nr	nr	nominal	no	LC50 = 11,600	Dill et al. (1980)
1,2-Dichloroethane									
Artemia salina (brine shrimp) 3 d old	72 h	plastic petri dishes, unknown if covered, 35 ppt salinity	yes	yes	nr	nominal	No	LC50 = 6,227 µg/L	Sanchez-Fortun et al. (1997)

Test Species, Age	Test Duration	Test Methods [a]	Control Used?	Statistical Comparison to Control?	DO Conc.	Measured or Nominal Conc?	Organisms Fed?	Reported Effect and Conc. (µg/L)	Reference
1,2-Dichlorethene (cis- or trans-)									
Artemia salina (brine shrimp) 3 d old	72 h	plastic petri dishes, unknown if covered, 35 ppt salinity	yes	yes	nr	nominal	no	LC50 = 6,785 µg/L	Sanchez-Fortun et al. (1997)
Acetone (2-propanone)									
Mytilus sp (mussels), juvenile	48 h	static	yes	nr	nr	nominal	no	LC50 = 33,830	Keller (1993)
Benzene									
Cancer magister (Dungeness crab), a few hours	50 d	flow-through, methods to minimize volatization not reported	yes	yes	nr	Concentration of 180 µg/L nominal; higher concetrations measured	yes	NOEC (mortality, growth, and development) = 180 LC100 = 1,100	Caldwell et al. (1976)
Chlorobenzene									
Daphnia magna (water flea), <12 h	10 d	static renewal, covered test vessels	yes	yes	8.0 ± 1.5 mg/L	nominal	yes	NOEC (mortality) = <1,400	Cowgill and Milazzo (1991)
Daphnia magna (water flea), 12 h	14 d	static renewal, closed bottles	yes	yes	nr	nominal	yes	EC50 = 2,500	Calamari et al. (1983)
Tetrachloroethene									
Ceriodaphnia dubia (water flea); age not reported	7 d	static, covered vessels	yes	yes	>7 mg/L	measured	yes	NOEC (reproduction) = 331	Niederlehner et al. (1998)
Artemia salina (brine shrimp larvae) 3 days old	72 h	plastic petri dishes, unknown if covered, 35 ppt salinity	yes	yes	nr	nominal	no	LC50 = 332	Sanchez-Fortun et al. (1997)

Test Species, Age	Test Duration	Test Methods [a]	Control Used?	Statistical Comparison to Control?	DO Conc.	Measured or Nominal Conc?	Organisms Fed?	Reported Effect and Conc. (µg/L)	Reference
Toluene (methylbenzene)									
Ceriodaphnia dubia (water flea); age not reported	7 d	static, covered vessels	yes	yes	>7 mg/L	measured	yes	NOEC (reproduction) = 737	Niederlehner et al. (1998)
Eualus spp. (shrimp), adult	96 h	static	yes	nr	≥80% saturation	measured at initiation and termination of test	no	LC50 = 14,700	Korn et al. (1979)
Trichloroethene									
Daphnia magna (water flea), <24 h	48 h	static, covered beakers	yes	nr	>6.5 mg/L	measured at initiation and termination of test	no	NOEC (mortality) = 2,200	LeBlanc (1980)
Mysidopsis bahia (mysid shrimp), 3 d	96 h	static, covered chambers	yes	nr	nr	measured at initiation and termination of test	yes	LC50 = 14,000	Ward et al. (1986)
Xylene									
Ceriodaphnia dubia (water flea; age not reported)	7 d	static, covered vessels	yes	yes	>7 mg/L	measured	yes	NOEC (reproduction) = 1,168 LC50 = 2,973	Niederlehner at al. (1998)

nr – not reported

na – not availableEC50 – effects concentration for 50% of a test population; LC50 – lethal concentration for 50% of a test population

LOEC – lowest-observed-effect concentration; NOEC – no-observed-effect concentration

[a] Including steps taken to minimize volatilization

4.3.1 1,1,1-Trichloroethane

The lowest toxicity values presented in Table 3-1 for 1,1,1-trichloroethene are from Thompson and Carmichael (1989). This study was reviewed in detail and found to be acceptable. In this study, *Daphnia magna* (<24 hr old) were exposed to test solutions of 1,1,1-trichloroethane that were renewed every two days. To reduce losses of the chemical through volatilization, polystyrene beakers with gas-tight screwcaps were used as test vessels. As a consequence of the small vessels, each held only one daphnid, rather than the groups of ten animals recommended in the OECD (1984) guideline. Test organisms were fed daily with cultured algae. Six nominal concentrations of 1,1,1-trichloroethane ranging from 1,800 to 32,000 µg/L were used, plus a negative control. Mean measured concentrations in solutions containing 1,1,1-trichloroethane ranged from 1,300 to 23,000 µg/L. Control solutions contained less than 200 µg/L of 1,1,1-trichloroethane. The test vessels were examined daily for mortality of the parent daphnids and, from Day 7, for the presence of offspring. The temperature was maintained at 20 (±1)°C, and DO concentrations ranged from 7.8 to 11.1 mg/L during the test.

At 1,300 µg/L, no effects were observed on mortality or number of offspring. At the next highest concentration, 2,400 µg/L, both mortality and number of offspring were significantly different from the negative control. Therefore, these concentrations were selected as the toxicity values for 1,1,1-trichloroethane (Table 4-1).

4.3.2 1,1,2-Trichloroethane

The lowest toxicity value presented in Table 3-1 for 1,1,2-trichloroethane is from Adema and Vink (1981). This study was reviewed in detail and found to be acceptable. In this test, *Artemia salina* (3 days old) were exposed to 1,1,2-trichloroethane for 3 weeks. Information on whether the test conditions were static, static-renewal, or flow-through was not available. Artificial seawater was used in the test, although the study did not report the salinity of the seawater. Test vessels were covered to prevent loss of the chemical through volatilization. A negative control was used and DO concentrations were greater than 70% of saturation during the exposure period. The EC50 of 15,000 µg/L from this study was selected as a toxicity value for 1,1,2-trichloroethane.

The only NOEC below the selected effect concentration for 1,1,2-trichloroethane was from the same study by LeBlanc (1980). The NOEC for mortality from this study (1,000 µg/L) was selected for 1,1,2 trichloroethane (Table 4-1).

4.3.3 1,1-Dichloroethene

The lowest toxicity value presented in Table 3-1 for 1,1-dichloroethene is from Dill et al. (1980). The study was reviewed, and test parameters were considered acceptable, although the study did not report whether test vessels were covered to minimize volatilization. In this study, *Daphnia magna* (<24 hr old) were exposed to

1,1-dichloroethene for 48 hours in a static environment. A range of chemical concentrations were tested in addition to a negative control. The LC50 reported in this study was 11,600 µg/L, and was selected as a toxicity value for 1,1-dichloroethene (Table 4-1).

The lowest NOEC presented in Table 3-1 for 1,1-dichloroethene is from LeBlanc (1980). This study was reviewed in detail and found to be acceptable. Test procedures were based on EPA protocols [EPA (1975), as cited in LeBlanc (1980)]. *Daphnia magna* (< 24 hr old) were exposed to 1,1-dichloroethene for 48 hrs in a static test conducted at a temperature of 22 (±1)°C. Test vessels were covered to prevent loss of the chemical through volatilization. At least five nominal concentrations were tested[4], plus a negative control. At the initiation of the test, the DO concentration was greater than 60% saturation, and DO concentrations did not fall below 6.5 mg/L during the exposure period. Therefore, the NOEC of 2,400 µg/L from this study was selected for 1,1-dichloroethene (Table 4-1).

4.3.4 1,2-Dichloroethane

The lowest toxicity value presented in Table 3-1 for 1,2-dichloroethane is an LC50 study using *Artemia salina* (Sanchez-Fortun et al. (1997). This study was reviewed in detail and found to be acceptable, although the study did not state whether the Petri dishes were covered, and did not provide raw toxicity data. In this study, *Artemia* shrimp larvae were added to synthetic seawater at a salinity of 35 parts per thousand (ppt) in plastic Petri dishes containing the appropriate volume of 1,2-dichloroethane. Controls containing untreated synthetic seawater were also tested. The Petri dishes were incubated at 25°C. Larvae were evaluated for mortality after 72 hours. The LC50 was 6,927 µg/L. This LC50 was selected because it is the lowest toxicity value from an acceptable study (Table 4-1).

No NOECs are available that are less the LC50 reported for *Artemia,* although NOECs are available for mortality, growth, and reproduction endpoints with *Daphnia magna* (Richter et al. 1983). Richter et al. (1983) reported NOECs ranging from 11,000 to <68,000 µg/L and an LC50 of 220,000 µg/L. However, because the LC50 value for *Artemia* was below these NOECs, it was selected for 1,2-dichloroethane.

4.3.5 1,2-Dichloroethene

The lowest toxicity value presented in Table 3-1 for 1,2-dichloroethene is also derived from a study testing toxicity to *Artemia salina* (Sanchez-Fortun et al. (1997). This study was reviewed in detail and found to be acceptable, having been conducted as described above for the study with 1,2-dichloroethane (Section 4.3.5). The reported LC50 was 6,785 µg/L. The only other toxicity data available for this chemical is an

[4] Toxicity tests were conducted for multiple chemicals, and the authors did not specify the number of concentrations tested for each chemical or provide the raw toxicity data. Therefore, LOECs could not be determined from the study.

LC50 of 140,000 g/L from a bluegill study (Table 3-1). Therefore, the lower LC50 for *Artemia* was selected as the toxicity value for 1,2-dichloroethene (Table 4-1).

4.3.6 Acetone (2-Propanone)

The lowest toxicity value presented in Table 3-1 for acetone (2-propanone) is from a study by Dowden and Bennett (1965). This study presented very few details regarding test methods, so it was not considered acceptable.

The second lowest toxicity value in Table 3-1 is from a study by Keller (1993) using juvenile *Anodonta imbecilis* mussels. The study design was considered acceptable, although information on DO content, methods to control volatilization, raw toxicity data, and whether effect concentrations were statistically different from the negative controls were not presented. The tests were conducted for 48 hrs under static conditions at a temperature of 22 (1±)°C, and organisms were not fed during the test period. Five nominal test concentrations were used, plus a negative control. The LC50 concentration of 33,830 µg/L was selected for acetone (Table 4-1).

No studies were available from the literature that reported a NOEC for acetone.

4.3.7 Benzene

The lowest toxicity values presented in Table 3-1 for benzene are from Caldwell et al. (1976). The study design was considered acceptable. The toxicity test was conducted with larval stages of the Dungeness crab, *Cancer magister*. Larvae were exposed to benzene solutions at three concentrations (180, 1,100, and 7,000 µg/L), plus a negative control, within a few hours after larvae were hatched. The test was conducted using flow-through conditions at 13°C. 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 LC100 and NOEC, respectively, for benzene (Table 4-1).

4.3.8 Chlorobenzene

The lowest toxicity value presented in Table 3-1 for chlorobenzene is from Calamari et al. (1983). The study was reviewed, and test parameters were considered acceptable. In this study, *Daphnia magna* were exposed to chlorobenzene for 14 days in a static renewal environment. Test bottles were closed to prevent loss of the chemical through volatilization. A range of chemical concentrations were tested in addition to a negative control, and reproductive parameters were observed in three broods of daphnids. DO concentrations were not reported, but the paper stated that DO did not fluctuate by more than 10% both inside the sample bottle and among different bottles. Raw toxicity data were not reported. The concentration at which the reproductive rate was reduced by 50% (EC50) was 2,500 µg/L.

The lowest NOEC presented in Table 3-1 for chlorobenzene is from Hermens et al. (1984). A review of this study revealed that the authors did not indicate whether a negative control was used, so this study was not preferred even though no effects were reported. Instead, the NOEC for *Daphnia magna*, the same test species in Hermens et al. (1984), was selected from the Cowgill and Milazzo (1991) study. All aspects of this study were considered acceptable. In this study, *Daphnia magna* were exposed to chlorobenzene for 10 days in a renewed static environment. Test vessels were covered to prevent loss of the chemical through volatilization. Five nominal concentrations were tested in addition to a negative control, and no mortality was observed. DO concentrations during the test were 8.0 ± 1.5 mg/L. No effect on mortality was observed at a chlorobenzene concentration of <1,400 µg/L. Therefore, the EC50 of 2,500 µg/L and the NOEC of <1,400 µg/L were selected toxicity values for chlorobenzene (Table 4-1).

4.3.9 Tetrachloroethene

The lowest toxicity value presented in Table 3-1 for tetrachloroethene is from an LC50 study using *Artemia salina* (Sanchez-Fortun et al. 1997). This study was conducted as described previously for 1,2-dichloroethane (Section 4.3.5). The methods were considered acceptable; the LC50 was 332 µg/L.

The lowest NOEC presented in Table 3-1 for tetrachloroethene is from Niederlehner at al. (1998). All components of the study described in the paper were found to be acceptable, although the age of the organisms at the start of the experiment was not discussed by the authors. Test procedures were based on a standard, short term, chronic test method developed for EPA's Whole Effluent Testing Program [EPA (1994), as cited in Niederlehner at al. (1998)]. *Ceriodaphnia dubia* were exposed to tetrachloroethene for 7 days in a static environment. Test vessels were covered to prevent loss of the chemical through volatilization. Five nominal concentrations were tested in addition to a negative control, and behavior, mortality, and reproduction endpoints were evaluated. DO concentrations were monitored on 24-hour old solutions and did not fall below 7 mg/L during the exposure period. The 7-day LC50 was 829 µg/L, and the NOEC for reproduction was 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 toxicity value (Table 4-1). The NOEC from the *Ceriodaphnia dubia* study was also selected as the toxicity value (Table 4-1). It should be noted that a similar NOEC for *Daphnia magna* reproduction of 400 µg/L was also presented in Table 4-1. The similarity of the *Artemia* LC50 values to these two NOECs indicates that *Artemia* may be more sensitive than daphnids.

4.3.10 Toluene (Methylbenzene)

The lowest toxicity value for toluene (methylbenzene) is from Tatem et al. (1978). The study was reviewed, but the test methods were not considered acceptable because there was no discussion of the use of a control test.

The next lowest toxicity value for toluene was an LC50 of 14,700 µg/L from a study in which adult shrimp (*Eualus* spp.) were exposed for 96 hours in a static environment

Korn et al. (1979). A positive control was used, and DO concentrations were never less than 80% saturation during the test. However, this study did not discuss methods used to reduce evaporative losses, and comparison of measured concentrations at both test initiation and termination showed that toluenedeclined substantially during the test, thus indicating that the LC50 may be an overestimate (i.e., the actual LC50 may be lower). However, because this reported LC50 is the lowest concentration at which an effect was reported, it was selected as the toxicity value.

The lowest NOEC for toluene presented in Table 3-1 is from Niederlehner et al. (1998). The study was reviewed and found to be acceptable. Test procedures were based on a standard, short term, chronic test method developed for EPA's Whole Effluent Testing Program [(EPA 1994), as cited in Niederlehner at al. (1998)]. *Ceriodaphnia dubia* were exposed to toluene for 7 days in a static environment. Test vessels were covered to prevent loss of the chemical through volatilization. Five nominal concentrations were tested in addition to a negative control, and behavior, mortality, and reproduction endpoints were evaluated. DO concentrations were monitored on 24-hour old solutions and did not fall below 7 mg/L. A NOEC of 737 µg/L was reported for the reproductive endpoint. This NOEC and the LC50 value of 2,500 g/L were selected for toluene (Table 4-1).

4.3.11 Trichloroethene

The lowest toxicity value presented in Table 3-1 for trichloroethene is from Yoshioka et al (1986). This study was a 7-d LC50 test in which heads were removed from flatworms, with endpoints of abnormal head regeneration and mortality. This study was considered unacceptable because the test does not represent a relevant environmental stressor.

The next lowest toxicity value where effects were observed was from Yoshioka et al. (1986). This study was not considered acceptable, because 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 LOEC 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 Ward et al. (1986), and was considered acceptable. In this study, *Mysidopsis bahia* (mysid shrimp) were exposed to trichloroethene for 96 hours in a static environment. Test chambers were covered to prevent loss of the chemical through volatilization. A range of chemical concentrations were tested in addition to a negative control. Chemical concentrations were measured at the initiation and termination of the test. DO concentrations were not reported. The LC50 of 14,000 µg/L was selected as a toxicity value.

The lowest NOEC presented in Table 3-1 for trichloroethene is from LeBlanc (1980). There were two additional NOECs below the LC50 from Ward et al. (1986); these NOECs were for different endpoints and species. LeBlanc (1980) was reviewed and found to be acceptable. Test procedures were based on EPA protocols [EPA (1975), as cited in LeBlanc (1980)]. *Daphnia magna* (< 24 hr old) were exposed to trichloroethene for 48 hrs in a static test conducted at a temperature of 22 (±1)°C. Test vessels were covered to prevent loss of the chemical through volatilization. At least five nominal concentrations were tested[5], plus a negative control. At the initiation of the test, the DO concentration was greater than 60% saturation, and DO concentrations did not fall below 6.5 mg/ 4- L during the exposure period. The NOEC from this study was 2,200 µg/L. Therefore, the LC50 from Ward et al. (1986) and the NOEC from LeBlanc (1980) were selected as the toxicity values for trichloroethene (Table 1).

4.3.12 Xylene

The lowest toxicity values for xylene in Table 3-1 were obtained from a study with *Ceriodaphnia dubia* (Niederlehner et al. 1998). This study was considered acceptable. Test procedures were based on a standard, short term, chronic test method developed for EPA's Whole Effluent Testing Program (EPA 1994), as cited in Niederlehner at al. (1998)]. *Ceriodaphnia dubia* were exposed to xylene for 7 days in a static environment. Test vessels were covered to prevent loss of the chemical through volatilization. Five nominal concentrations were tested in addition to a negative control, although raw toxicity data were not provided. Behavior, mortality, and reproductive endpoints were evaluated. DO concentrations were monitored on 24-hour old solutions and did not fall below 7 mg/L during the exposure period. The 7-day LC50 was 2,973 µg/L, and the NOEC for reproduction was 1,168 µg/L; these concentrations were selected as the toxicity value for xylene (Table 4-1).

4.3.13 1,1-Dichloroethane and vinyl chloride based on the narcosis model

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 assoiated 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 final acute values (FAVs) and final chronic values (FCVs) for 1,1-dichloroethane and vinyl chloride, and the literature K_{OW} values used to calculate those values, are presented in Table 4-2. Chronic values were obtained 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.

[5] Toxicity tests were conducted for multiple chemicals, and the authors did not specify the number of concentrations tested for each chemical or provide the raw toxicity data. Therefore, the LOECs could not be determined from the study.

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