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Canadian Environmental Protection Act, 1999

Federal Environmental Quality Guidelines

Benzene, Toluene, Ethylbenzene, Xylene (BTEX)

Environment and Climate Change Canada

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Introduction

Federal Environmental Quality Guidelines (FEQGs) describe acceptable quality of the ambient environment. They are based solely on the toxicological effects or hazards of specific substances or groups of substances. FEQGs serve three functions: first they can be an aid to prevent pollution by providing targets for acceptable environmental quality; second, they can assist in evaluating the significance of concentrations of chemical substances currently found in the environment (monitoring of water, sediment, soil and biological tissue); and third, they can serve as performance measures of the effectiveness of risk management activities. The use of FEQGs is voluntary unless prescribed in permits or other regulatory tools. Thus FEQGs, which apply to the ambient environment, are not effluent limits or "never-to-be-exceeded" values but may be used to derive effluent limits. The development of FEQGs is the responsibility of the Minister of Environment under the *Canadian Environmental Protection Act, 1999* (CEPA) (Canada 1999). The intent is to develop FEQGs as an adjunct to risk assessment or risk management of priority chemicals identified in the Chemicals Management Plan (CMP) or other federal initiatives.

Where data permit, FEQGs are derived following Canadian Council of Ministers of the Environment (CCME) protocols. FEQGs are developed where there is a federal need for a guideline (for example, to support federal risk management or other monitoring activities) but where the CCME guidelines for the substance have not yet been developed or are not reasonably expected to be updated in the near future. For more information, please visit the Federal Environmental Quality Guidelines (FEQG) page.

This factsheet describes the Federal Water Quality Guidelines (FWQGs) for the protection of aquatic life from adverse effects of benzene, toluene, ethylbenzene and xylene (BTEX) (Table 1). These FWQGs apply to both freshwater and marine environments. There are no pre-existing FWQGs for BTEX. Interim CCME guidelines for benzene, toluene and ethylbenzene exist (CCME 1999a,b,c) but they were developed following the CCME protocol (CCME 1991) that is no longer in use. No FEQGs for BTEX are developed for biological tissue, sediment or soil compartments since BTEX are not expected to accumulate therein.

Table 1. Federal water quality guidelines for BTEX.

Aquatic Life	Short-term Benchmark (mg/L)	Long-term Guideline (mg/L)
Benzene	6.0	0.59
Toluene	3.0	0.03
Ethylbenzene	1.0	0.07
Xylene	1.0	0.07

The individual BTEX guidelines can then be applied to a water sample using a Hazard Index (HI) approach with the following equation:

$$Hazard\ Index = \sum_{i=1}^{n=4} \left(\frac{concentration_i}{guideline\ or\ benchmark_i}\right)$$

A HI ≥1 would indicate that total BTEX measured in a water sample are at a concentration that may pose a hazard to aquatic communities, and a total value of <1 would indicate the sample likely does not pose a hazard to aquatic communities.

Substance Identity

BTEX is a group of monoaromatic hydrocarbons, consisting of benzene (C_6H_6; CAS Registry Number 71-43-2), toluene (C_7H_8; CAS RN 108-88-3), ethylbenzene (C_8H_{10}; CAS RN 100-41-4) and xylene (C_8H_{10}; CAS RN 1330-20-7). Xylene has three isomers commonly used in commercial products (o-xylene CAS RN 95-47-6, m-xylene CAS RN 108-38-3 and p-xylene CAS RN 106-42-3). The xylene guidelines apply to all of its isomers as the toxicity dataset used to develop the guidelines included a composite of all of xylenes'

isomers. BTEX compounds are flammable, clear and colourless liquids, naturally found in crude oil and petroleum products (Health Canada 2014). BTEX are volatile organic compounds (VOCs) that evaporate quickly into the atmosphere due to their high vapour pressures (Health Canada 2014). Benzene has a unique listing on the List of Toxic Substances in Schedule 1 of CEPA while toluene, ethylene and xylene are also CEPA-toxic covered under the general Schedule 1 listing of VOCs that participate in photochemical reactions. .

Sources and Uses

In Canada, the sources of BTEX include both natural and anthropogenic. Natural sources of BTEX include petrogenic substances, including coal as well as emissions from volcanoes and forest fires (Health Canada 2007, 2014; NTP 2016). Anthropogenic sources of BTEX to the environment include emissions and/or releases from petrochemical plants, coal power plants, contaminated sites, landfills, industrial activities, petroleum refining and combustion of gasoline (ECCC, HC 2016). BTEX are used in, and produced by, oil and natural gas operations, and are present in crude oil, oil sands, bitumen, diluted bitumen (dilbit) and other gasoline products (CAREX Canada 2020a,b). BTEX have been measured in oil sands process water (OSPW) (Mahaffey and Dubé 2016). Benzene is used as a raw material in the production of other chemicals, including ethylbenzene to produce styrene, cumene to produce phenol and acetone, and cyclohexane to produce nylon and synthetic fibres (ATSDR 2007a; CAREX Canada 2020a; NTP 2016). It is also used in the manufacturing of products such as detergents, drugs, lubricants, rubbers and pesticides (ATSDR 2007a; CAREX Canada 2020a). Sources of benzene in surface water are typically from industrial effluents and atmospheric pollution (Health Canada 2009). Toluene is used in the synthesis of chemicals such as benzene and toluene diisocyanate. It is also used as a solvent in several products and processes, including adhesives, fingernail polish, lacquers, leather tanning, paint thinners, paints, printing and rubber (ATSDR 2017; Health Canada 2014). Ethylbenzene is primarily used in the production of styrene and polystyrene foam (Health Canada 2007, 2014). Ethylbenzene is also used as a solvent in consumer products, although this use is less prevalent than its use in styrene production (CAREX Canada 2020b; Health Canada 2007). Ethylbenzene can be found in consumer products such as adhesives, coatings dyes, perfumes, pharmaceuticals, plastics, rubber and varnishes (ATSDR 2007c; CAREX Canada 2020b; Health Canada 2007). Xylene is used primarily as a solvent in cleaning agents, paint thinners and varnishes (ATSDR 2007c; Health Canada 2014).

Ambient Concentrations

BTEX compounds are typically not routinely measured in water monitoring programs due to their short retention times in surface water. Monitoring of BTEX in surface water is usually only performed around industrial operations that are likely to have elevated concentrations from effluent emissions. Even in areas of high industrial activity, the majority of water samples are found to have BTEX concentrations below detection limits. The relative variability of individual BTEX compounds is expected to depend on the variations in physiochemical properties leading to difference in fate and partitioning as well as the variability of BTEX in the original source (that is, crude oil, bitumen etc.).

Table 2 provides information on the concentration of BTEX compounds in surface waters in the lower Athabasca Region of Alberta, a region where oil sand deposits naturally occur at and below the surface and where there is oil sands mining and in-situ oil sands development. The surface water monitoring data were collected between 2011 and 2017 from Alberta's Regional Aquatics Monitoring Program (RAMP) for the Athabasca region (RAMP 2021). For computation of mean and median BTEX concentrations, values below method detection limits (MDL) were treated as half the detection limit. In addition, ECCC, HC (2016) provides additional ambient data for ethylbenzene in Canadian surface waters.

Table 2. Surface water concentrations of BTEX in Athabasca Region, Alberta.

	Samples (n)	Non-Detects(n)	Med (µg/L)	Min (µg/L)	Max (µg/L)	MDL[1] (µg/L)
Benzene	1564	1411	0.05	<0.03	3.69	0.03- 0.5
Ethylbenzene	1564	1408	0.05	<0.05	4.63	0.05- 0.5
Toluene	1564	1395	0.05	<0.04	8.76	0.04- 0.5
m+p xylene[2]	1564	1398	0.05	<0.06	20.9	0.06- 0.5
o xylene[2]	1564	1395	0.05	<0.04	8.76	0.04- 0.5
Xylenes	578	424	0.355	<0.7	33.5	0.7

Source: Data from Regional Aquatics Monitoring Program (RAMP) (2021).
[1]MDL = method detection limit.
[2]m+p and o are xylene isomers.

Mode of Action

Similar to most petroleum derived compounds, the mode of toxic action of BTEX is believed to be non-specifically acting narcosis (Hsieh et al. 2006; Modrzyński et al. 2019; Posthuma et al. 2019). BTEX are included in the target lipid model training set with over 200 other narcotic chemicals (McGrath et al. 2018). Narcotic chemicals accumulate in tissues and exert effects through non-specific interference with cell membranes (Hsieh et al. 2006; Li et al. 2013). Since BTEX chemicals are typically released as mixtures, the effects of their cumulative narcotic toxic action can be accounted for by way of concentration addition. There is also some contradicting information regarding the potential for endocrine activity by BTEX, with some studies suggesting that BTEX have demonstrated endocrine activity (Kassotis et al. 2014; Robert et al. 2019) and others suggesting they lack endocrine activity (Mihaich and Borgert 2018). Most focus is on human health effects via exposure to air (Bolden et al. 2015) as opposed to aquatic life.

Fate, Behaviour and Partitioning in the Environment

BTEX are cycled through the air, water and soil, fed by industrial activity and from natural sources. BTEX are rapidly biodegraded in the environment and are non-persistent in the aquatic environment (CCME 1999 a,b,c; ECCC, HC 2016). Volatilization is the primary physical property of BTEX that determines the fate and persistence of these compounds in the environment. BTEX can stay in the atmosphere until they partition through photo-oxidation upon reaction with other substances in the air (Bandow et al. 1985). BTEX in surface water are likely to partition into the atmosphere through volatilization (ATSDR 2007a; Health Canada 2014). Benzene is the most soluble compound of the group but will not remain long in surface water due to its rapid volatilization half-life in surface water of ~5 hours (ATSDR 2007a). Toluene will remain in surface water for 5 hours to 16 days before it volatilizes into the atmosphere, while ethylbenzene and xylene half-lives vary in turbulent and static water from 3.1 hours to 4.1 days (Health Canada 2014).

Water solubilities for benzene, toluene, ethylbenzene and xylene are 1780 mg/L, 515 mg/L, 152 mg/L and 175-198 mg/L, respectively at 20°C (Headley et al. 2000). BTEX has low octanol/water partition coefficients, ranging from 1.56 to 2.69 for benzene, from 2.82 to 4.10 for toluene, 3.03 to 3.53 for ethylbenzene and from 2.73 to 3.48 for xylenes (Mackay et al. 2006; McGrath et al. 2018). Due to the low log K_{ow} values and bioaccumulation/bioconcentration factors (BAF/BCFs) reported elsewhere (ATSDR 2017; ATSDR 2007a,b,c; ECCC, HC 2016), bioaccumulation and hence biomagnification of BTEX in aquatic biota is expected to be minimal (Gossett et al. 1983). BTEX are subject to biodegradation in water and soil under aerobic conditions (ATSDR 2007a,b). BTEX compounds are mobile in water-saturated soil and are subject to leaching into groundwater, which in turn can discharge to surface waters, but are otherwise readily volatile in dry soil (ATSDR 2007a,b,c).

Aquatic Toxicity Data

The datasets presented in this document and used for the species sensitivity distributions (SSDs) and acute to chronic ratios (ACRs) are based on the collection and evaluation of aquatic toxicity data published up to January 2024. A detailed review of studies was performed by ECCC following the CCME (2007) guidance for data quality. Determinants of test acceptability included, but were not limited to, exposure duration, documentation of the control response, the use of suitable biological endpoints and the inclusion of appropriate statistical analyses of the data collected in the study. Due to the volatility of these compounds, special consideration was given to whether concentrations were analytically measured, if concentrations were maintained throughout the test duration, if test vessels were designed to contain the chemicals (for example, sealed, air space eliminated, flow-through system), and if standard procedures were followed. Studies were classified as either primary, secondary or unacceptable using CCME (2007) as guidance.

The Target Lipid Model (TLM) training set (McGrath et al. 2018) includes over 1000 endpoints from many studies including those for BTEX. The entire training set was not independently assessed here but many of the same BTEX papers were included in the SSD dataset and therefore were assessed by ECCC. Before inclusion into the TLM, studies were evaluated by the authors according to the Klimisch et al. (1997) scoring system and Organisation for Economic Co-operation and Development (OECD) (2000) guidelines, and only data deemed reliable were accepted (McGrath et al. 2018).

There is some uncertainty with the datasets since many lack important test details, especially for volatile chemicals like BTEX. Studies were deemed unacceptable for guideline derivation when the uncertainty surrounding maintaining test concentrations and appropriate test design was deemed too large. Toxicity data considered for developing the FWQGs are presented in the Appendix including reasoning for data quality classification. Endpoints for chronic exposure durations are scarce for all BTEX chemicals which is recognized as an uncertainty. Toxicity endpoints within and across chemicals typically span a narrow range, likely due to the chemicals sharing similar physical and chemical properties including a non-specific acting narcotic mode of action. Although the endpoints did not range widely, it appears that pelagic invertebrates, specifically cladoceran (that is, water fleas), and amphibians are most sensitive to BTEX.

Acceptable chronic amphibian data were available for two amphibian species (Black at al. 1982; Kennedy 2006) for benzene, toluene and xylene but no data were available for ethylbenzene or acute exposures. Both studies had comparable endpoints for *Lithobates pipiens* (leopard frog) for benzene and xylene which were more sensitive than the rest of the species in the datasets. Black et al. (1982) also tested the toxicity of benzene to *Ambystoma gracile* (northwestern salamander) and endpoints were aligned with *L. pipiens*. The amphibian and *Oncorhynchus mykiss* (rainbow trout) endpoints from Black et al. (1982) for toluene were considerably lower than the rest of the endpoints in the guideline dataset. Kennedy (2006) appears to support the *O. mykiss* value from Black et al. (1982) with similar endpoints values. However, there are no endpoints from Kennedy (2006) or other studies to compare against the toluene amphibian data. Black et al. (1982) was included in the development of the CCME interim guidelines (CCME 1999a,b) and was deemed to be acceptable based on data quality assessment for guideline development for BTEX in this document. Black et al. (1982) and Kennedy (2006) data were not included in the TLM for unknown reasons. However, over one thousand endpoints and 72 individual ACRs from over 200 chemicals are included in the TLM so it is uncertain how great an influence including these endpoints would make to the TLM estimates. Additional research on the toxicity to amphibians from BTEX is needed, specifically chronic exposure including full-life cycle reproductive tests to consider potential endocrine effects (Robert et al. 2019).

Federal Water Quality Guideline Derivation

Federal Water Quality Guidelines (FWQGs) are preferably developed using the CCME (2007) protocol, however they can be developed following other methods when data requirements are not met. In the case of BTEX, there were sufficient acute toxicity data to develop Type A benchmarks but insufficient chronic toxicity data to develop Type A or B long-term guidelines (CCME 2007). Therefore, for the long-term guidelines, an ACR was used to extrapolate endpoints from short-term to long-term and then used with available long-term data to meet the minimum data requirements. ACR approaches have been used in guideline development (ECCC 2024, Warne et al. 2018), risk assessment (Okonski et al. 2021) and the

Target-Lipid model itself (McGrath et al. 2018). When data are not robust it represents an opportunity to develop chronic EQGs. The most sensitive and preferred endpoint (or geometric mean) was then selected for each species following CCME (2007). A geometric mean was calculated where multiple comparable endpoints were available for the same species, effect, life stage and exposure duration. Where no algae or aquatic plant endpoints were available for acute exposures, typically defined as less than or equal to 24 hours, median endpoints for 48-hours were included in the acute datasets instead as per CCME (2007). Some EC10 endpoints were calculated by ECCC using the USEPA toxicity relationship analysis program (TRAP v. 1.3) (USEPA 2015) and are identified in the Appendix under "additional notes".

Species Sensitivity Distributions

The R package (R version 4.03) 'ssdtools' (ssdtools version 1.0.6) as well as the corresponding user friendly web application 'shinyssdtools' (shinyssdtools version 0.1.1) were used to create SSDs from the datasets (Dalgarno 2018; Thorley and Schwarz 2018). The package fits several cumulative distribution functions (CDFs) (log-normal, log-logistic, gamma, log-Gumbel, Weibull, log-normal mixture) to the data using maximum likelihood estimation (MLE) as the regression method. The package then uses Akaike information criterion (AICc) to weight each model, representing how well each fit the data relative to the others. The best predictive model is that with the lowest AICc (indicated by the model with a delta value of 0). The distributions that successfully fit the data with delta values <7 are averaged based on the respective weights. HC_p estimates with 95% confidence intervals are calculated using parametric bootstrapping (10000 iterations). The hazard concentration at 5% (herein referred to as HC_5) output is then used as the benchmark or guideline value if deemed protective. The full R script and results are available in the Appendix. See Fox et al. (2020) and Thorley and Schwarz (2018) for more information on the approach.

Target Lipid Model

Since BTEX are considered nonpolar narcotics and the datasets were not robust, the target lipid model (TLM) was used as an additional line of evidence to support and, in some cases, establish the acute benchmarks and long-term guidelines developed for BTEX. The TLM is a quantitative structure-activity relationship (QSAR) developed for nonpolar narcotics based on the premise of critical body burden theory (McCarty et al. 1991, 1992; Di Toro et al. 2000; McGrath et al. 2018). The model predicts no-effect concentrations in water based on a chemical's K_{OW}, represented by the lower confidence level HC_5 (herein referred to the TLM-based HC_5) which was found to be protective of 95% of species in the model dataset (McGrath et al. 2018). A geometric mean of the log K_{ow} values summarized in Mackay (2006) and the estimated (EPI Suite Ver 4.11) values reported in McGrath et al. (2018) for each substance were used for TLM equations in this document (see TLM calculations in the Appendix). The following TLM equation derives chronic HC_5 values for Type I narcotic chemicals (with log K_{OW} <6.5) (McGrath et al. 2018):

Equation 1:

$$Chronic\ Log(HC_5) = E[m] log K_{OW} + \mathrm{E}[\log(\mathrm{C}_\mathrm{L}^*)] + \Delta\mathrm{c} - \mathrm{E}[\log(\mathrm{ACR})]$$

$$- \mathrm{K_Z} \sqrt{\mathrm{V[m]} \log(K_{OW})^2 + V[\log(C_L^*)] + V[\log(ACR)] + 2 \log(K_{OW})\, [Cov(m, \log(C_L^*)]}$$

where, the universal narcosis slope is E[m] = -0.940 with a variance of V[m]=0.000225, the log mean value of 79 critical target lipid body burdens (CTLBBs) is $E[\log(C^*_L)]$=1.85 with a variance of $V[\log(C^*_L)]$=0.135, ACR= 5.22, log mean acute to chronic ratio (ACR) is E[log(ACR)]=0.718 with a variance of V[log(ACR)]=0.149, the covariance between slope and log CTLBB $Cov(m,\log(C^*_L))$= -0.0079, and the 95% confidence sample size-dependent extrapolation factor k_Z=2.396 (McGrath et al 2018).

The species geometric average of 65 definitive ACRs is 5.22 and is used in the TLM equation above. The TLM equation for acute effect concentrations in water (that is, acute HC_5 values) for Type I narcotic chemicals (with log K_{OW} <6.5) is the same as Equation 1 but with the ACR terms removed (McGrath et al. 2018):

Equation 2:

$$Acute\ Log(HC_5) = E[m] log K_{OW} + \mathrm{E}[\log(\mathrm{C}_\mathrm{L}^*)] + \Delta \mathrm{c}$$

$$- \mathrm{K_Z} \sqrt{\mathrm{V[m]} \log(K_{OW})^2 + V[\log(C_L^*)] + 2 \log(K_{OW}) [Cov(m, \log(C_L^*)]}$$

The TLM has been published in several peer-reviewed journal articles and includes data for a large number of species and narcotics. The model has been validated for mono-aromatic hydrocarbons like BTEX and BTEX toxicity data are included in the training set. The TLM represents an opportunity to derive guidelines for nonpolar narcotics with limited data and was used to develop an aquatic biota tissue guideline for siloxane D4 (ECCC 2022).

To be conservative, the lower value determined among the two methods (that is, TLM and SSD) for each unique toxicity dataset was set as the guideline value. The BTEX datasets were compiled with mostly freshwater species but some marine species were also included as indicated. This is aligned with the TLM which also includes species from both environments since nonpolar narcotics are not expected to vary in toxicity in the two environments. In addition, the SSD datasets do not show clustering of marine species which would indicate a difference in toxicity. Preliminary SSDs were created with only freshwater species and there was either no difference or very minimal difference in final HC_5 values when compared to SSDs created with marine species included. Therefore, in order to use as much data as possible and because there was no evidence to suggest a difference in toxicity, both freshwater and marine species were included in guideline derivation. The BTEX FWQGs can be applied to both freshwater and marine environments.

Acute to Chronic Ratios

Acute SSDs were created for all four BTEX chemicals using acute toxicity data. Since insufficient data existed for full chronic SSDs, the chronic data were supplemented with transformed acute data using an ACR. Paired acute and chronic endpoints from the same study were used to determine ACRs and then a geometric mean was taken of all available ACRs to be used for all BTEX chemicals.

For benzene, paired acute and chronic endpoints from the same study were available for two species: *Ceriodaphnia dubia* (water flea, invertebrate) and *Pimephales promelas* (fathead minnow, fish). An ACR of 3.4, was derived by dividing the *C. dubia* acute lethal endpoint (48-h LC50=17.3 mg/L) by the chronic maximum acceptable toxicity concentration (7-d MATC=5.14 mg/L) for reproduction, both obtained from Niederlehner et al. (1998). The second ACR, 1.5, was derived by dividing the *P. promelas* acute lethal endpoint (96 h LC50=15.59 mg/L) by the chronic 25% effect concertation (7-d EC25=10.6 mg/L) for biomass, both obtained from Marchini et al. (1992).

There were paired acute and chronic endpoints for toluene from the same study for three species: *C. dubia*, *P. promelas* and *Oncorhynchus kisutch* (coho salmon, fish). An ACR of 2.6, was derived by dividing the *C. dubia* acute lethal endpoint (48-h LC50=3.78 mg/L) by the chronic maximum acceptable toxicity concentration (7-d MATC= 1.43 mg/L) for reproduction, both obtained from Niederlehner et al. (1998). The acute lethal endpoint (96 h LC50=17.03 mg/L) was divided by the chronic 25% effect concertation (7-d EC25=6.53 mg/L) for biomass, both obtained for *P. promelas* from Marchini et al. (1992), resulting in an ACR of 2.6. The acute lethal endpoint (96-h LC50=6.3) was divided by the chronic maximum acceptable toxicity concentration (40-d MATC=2.28 mg/L), both obtained for *O. kisutch* from Moles (1981), resulting in an ACR of 2.8.

There were no paired acute and chronic endpoints for ethylbenzene or xylene. Therefore, a geometric mean was taken of the calculated ACRs of 3.4, 1.5, 2.6, 2.7 and 2.8 resulting in an average ACR of 2.5 to be used for all BTEX chemicals for transforming acute data for chronic SSDs.

Benzene

Short-term Benchmark

A total of 13 endpoints for 13 species (5 fish, 6 invertebrates, 2 aquatic plants/algae) from 9 studies were included in the SSD dataset and are summarized in Table 3. Three marine species and 10 freshwater species were included in the SSD dataset. *O. mykiss* (fish) was the most sensitive species in the dataset with a median effect concentration of 5.9 mg/L. *Artemia* sp. (invertebrate) was the least sensitive species in the dataset with a median effect concentration of 127.3 mg/L. Figure 1 shows the acute SSD for benzene, with a resulting HC_5 of 6 (4.2 to10) mg/L. The TLM-based acute HC_5 of 9.45 mg/L was calculated using Equation 2 and 2.10 for log K_{OW} (Appendix). The SSD- (6 mg/L) and TLM-based (9.45 mg/L) acute HC_5s are in good agreement, being within a factor of 2 of each other.

Table 3. Benzene acute toxicity data.

Family	Species	Duration	Endpoint	Effect Concentration (mg/L)	Reference
Fish	*Oncorhynchus mykiss*	96-h	LC50	5.9	Galassi et al. 1988
Fish (marine)	*Solea solea* L.	96-h	LC50	9.03	Furay and Smith 1995
Invertebrate	*Ceriodaphnia dubia*	48-h	LC50	10.15	Rose et al. 1998
Fish (marine)	*Platichthys flesus* L.	96-h	LC50	10.69	Furay and Smith 1995
Invertebrate	*Hyalella curvispina*	96-h	LC50	12.5	Marzio and Saenz 2006
Invertebrate	*Daphnia spinulata*	48-h	LC50	13.28	Marzio and Saenz 2006
Invertebrate	*Daphnia pulex*	96-h	LC50	15	Trucco et al. 1983
Fish	*Pimephales promelas*	96-h	LC50	15.59	Marchini et al. 1992
Algae	*Raphidocelis subcapitata*	48-h	EC50 (Growth inhibition)	15.77	Tsai and Chen 2007
Invertebrate	*Daphnia magna*	24-h	LC50	18	Galassi et al. 1988
Fish	*Poecilia reticulata*	96-h	LC50	28.6	Galassi et al. 1988
Invertebrate (marine)	*Artemia* sp.	24-h	LC50	127.3	Abernethy et al. 1986
Algae	*Ankistrodesmus falcatus*	4-h	EC50 (Primary productivity)	310	Wong et al. 1984

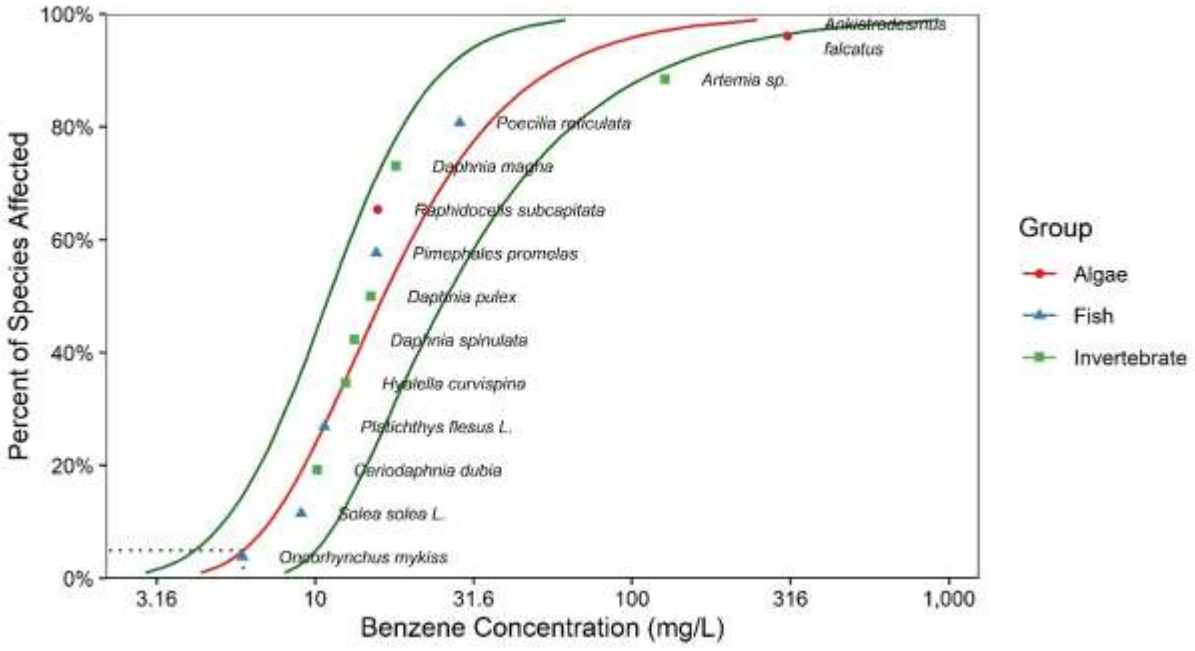

Figure 1. Acute SSD for benzene. The HC_5 (dotted line) is 6.0 mg/L.

Long-term Guideline

Very few chronic data were available and the dataset did not meet CCME requirements for long-term Type A guideline development, lacking at least two fish and two invertebrate endpoints from acceptable studies. Combining the chronic data and the transformed acute data using the ACR of 2.5, an SSD was derived following the procedures described previously. Table 4 includes chronic data for 6 species and transformed acute data for 10 species. Figure 2 shows the chronic SSD for benzene, with a resulting HC_5 of 0.59 (0.22 to 2.0) mg/L. Equation 1 was used to derive a TLM-based HC_5 of 0.67 mg/L. The SSD- and TLM-based HC_5s are in good agreement and well within a factor of two.

The two amphibians (*L. pipiens* and *A. gracile*) showed higher sensitivity compared to the rest of the dataset (as discussed previously) falling just below both the SSD HC_5 and TLM estimate. The available fish, invertebrate and algae endpoints are above both HC_5 estimates, as well as all acute endpoints in the acute dataset. The *L. pipiens* (leopard frog) Rocky Mountain population is designated as endangered and the Western Boreal/Prairie population is designated as a population of concern under Schedule 1 of the *Species at Risk Act* (SARA SC 2002, c.29). The *L. pipiens* eastern population and *A. gracile* are not at risk. Since the *L. pipiens* LC10 of 0.55 mg/L, and another *L. pipiens* LC20 (subchronic) value of 0.4 mg/L (Kennedy 2006) not in the SSD dataset are below the SSD HC_5 of 0.59 mg/L, the CCME protection clause (CCME 2007) should be considered. The protection clause states that if an acceptable no-effect or low-effect level endpoint for a species at risk in Canada is lower than the proposed long-term guideline then that endpoint becomes the recommended guideline. However, some uncertainties exist regarding the reliability of Black et al. (1982) endpoints and therefore uncertainty with basing the guideline entirely on the study. Because of this uncertainty and since the SSD-based HC_5 is negligibly higher than the lowest SSD endpoint, the SSD estimate of 0.59 mg/L was adopted as the long-term guideline for benzene.

Table 4. Benzene chronic toxicity data.

Family	Species	Exposure type (duration)	Endpoint (effect) [b]	Effect Concentration (mg/L)	Transformed Effect Concentration (mg/L)[a]	Chronic SSD dataset (mg/L)	Reference
Amphibian	*Lithobates pipiens*	Chronic (9-d)	LC10	0.55	-	0.55	Black et al. 1982
Amphibian	*Ambystoma gracile*	Chronic (9-d)	LC10	0.56	-	0.56	Black et al. 1982
Fish	*Oncorhynchus mykiss*	Acute (96-h)	LC50	5.9	2.36	2.36	Galassi et al. 1988
Fish (marine)	*Solea solea* L.	Acute (96-h)	LC50	9.03	3.61	3.61	Furay and Smith 1995
Fish (marine)	*Platichthys flesus* L.	Acute (96-h)	LC50	10.69	4.28	4.28	Furay and Smith 1995
Invertebrate	*Hyalella curvispina*	Acute (96-h)	LC50	12.5	5.00	5.00	Marzio and Saenz 2006
Invertebrate	*Ceriodaphnia dubia*	Chronic (7-d)	MATC[c] (Reprod.)	5.14	-	5.14	Niederlehner et al. 1998
Invertebrate	*Daphnia spinulata*	Acute (48-h)	LC50	13.28	5.31	5.31	Marzio and Saenz 2006
Invertebrate	*Daphnia pulex*	Acute (96-h)	LC50	15	6.00	6.00	Trucco et al. 1983
Invertebrate	*Daphnia magna*	Acute (24-h)	LC50	18	7.20	7.20	Galassi et al. 1988
Fish	*Pimephales promelas*	Chronic (7-d)	IC25 (Biomass)	10.57	-	10.57	Marchini et al. 1992
Fish	*Poecilia reticulata*	Acute (96-h)	LC50	28.6	11.44	11.44	Galassi et al. 1988
Algae	*Raphidocelis subcapitata*	Chronic (72-h)	EC50 (Growth)	29	-	29	Galassi et al. 1988
Invertebrate (marine)	*Artemia* sp.	Acute (24-h)	LC50	127.3	37.89	50.93	Abernethy et al. 1986
Algae	*Ankistrodesmus falcatus*	Acute (4-h)	EC50 (Primary production)	310	124	124	Wong et al. 1984
Algae	*Scenedesmus quadricauda*	Chronic (96-h)	EC50 (Growth)	157	-	157	Marzio and Saenz 2006

[a]Acute effect concentrations were transformed using an ACR of 2.5. Chronic concentrations were left untransformed.
[b]When the endpoint effect is not lethality (that is, LCx), the effect is noted in brackets.
[c]Calculated by ECCC by taking the geometric mean of the NOEC (2.97 mg/L) and LOEC (8.9 mg/L) from study.

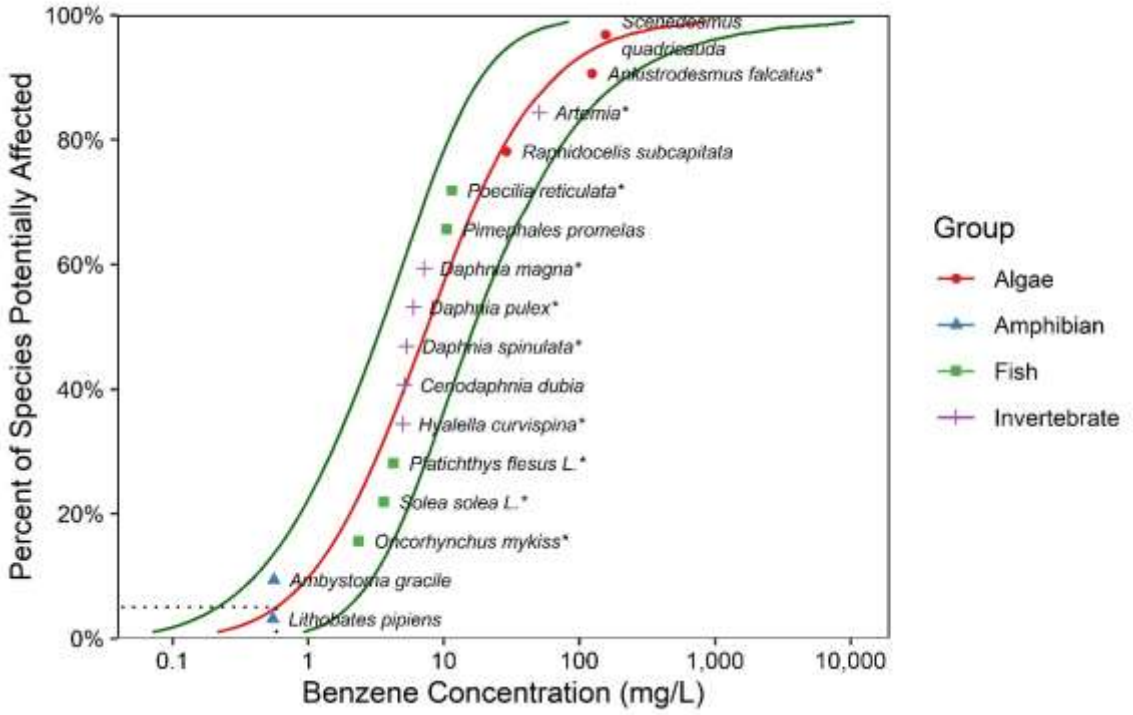

Figure 2. Chronic SSD for benzene including transformed acute data (indicated by *). The HC_5 (dotted line) is 0.59 mg/L.

Table 5. Summary of the TLM- and SSD-based HC_5 estimates for both acute and chronic exposures for benzene. **Underlined** values are the lower values and are adopted as the benchmark and FEQG.

	Acute TLM estimate (mg/L)	Acute SSD HC_5 (mg/L)	Chronic TLM estimate (mg/L)	Chronic SSD HC_5 (with ACR) (mg/L)
Benzene	9.45	**6.0**	0.67	**0.59**

Toluene

Short-term Benchmark

A total of 14 endpoints for 14 species (5 fish, 7 invertebrates, 2 aquatic plants/algae) from 11 studies were included in the SSD dataset and are summarized in Table 6. *Ceriodaphnia dubia* (invertebrate) was the most sensitive species in the dataset with a median effect concentration of 3.78 mg/L. *Scenedesmus subspicatus* (algae) was the least sensitive species in the dataset with a median effect concentration of 125 mg/L. Two marine species and 12 freshwater species were included in the SSD dataset. Figure 3 shows the acute SSD for toluene with a resulting HC_5 of 3.0 (1.7 to 6.9) mg/L. The TLM-based acute HC_5 of 3.2 mg/L was calculated using Equation 2 and 2.63 for log K_{OW} (Appendix). The SSD- (3.0 mg/L) and TLM-based (3.2 mg/L) acute HC_5 are in good agreement, being well within a factor of 2 of each other.

Table 6. Toluene acute toxicity dataset.

Family	Species	Duration	Endpoint	Effect Concentration (mg/L)	Reference
Invertebrate	*Ceriodaphnia dubia*	48-h	LC50	3.78	Niederlehner et al. 1998
Invertebrate	*Hyalella curvispina*	48-h	LC50	5.53	Marzio and Saenz 2006
Invertebrate	*Daphnia spinulata*	48-h	LC50	5.53	Marzio and Saenz 2006
Fish	*Oncorhynchus mykiss*	96-h	LC50	5.8	Galassi et al. 1988
Fish	*Oncorhynchus kisutch*	96-h	LC50	6.3	Moles et al. 1981
Invertebrate	*Daphnia magna*	24-h	LC50	7	Galassi et al. 1988
Fish	*Pimephales promelas*	96-h	LC50	17.03	Marchini et al. 1992
Fish	*Carassius auratus*	96-h	LC50	22.8	Brenniman et al. 1976
Invertebrate (marine)	*Homarus americanus*	48-h	LC50	26.1	Philibert et al. 2021
Algae	*Raphidocelis subcapitata*	48-h	EC50 (Growth inhibition)	26.3	Hsieh et al. 2006
Fish	*Poecilia reticulata*	96-h	LC50	28.2	Galassi et al. 1988
Invertebrate (marine)	*Artemia* sp.	24-h	LC50	59.06	Abernethy et al. 1986
Invertebrate	*Chironomus plumosus*	48-h	LC50	64.9	Li et al. 2013
Algae	*Scenedesmus subspicatus*	48-h	EC50 (Growth inhibition)	125	Kuhn and Pattard 1990

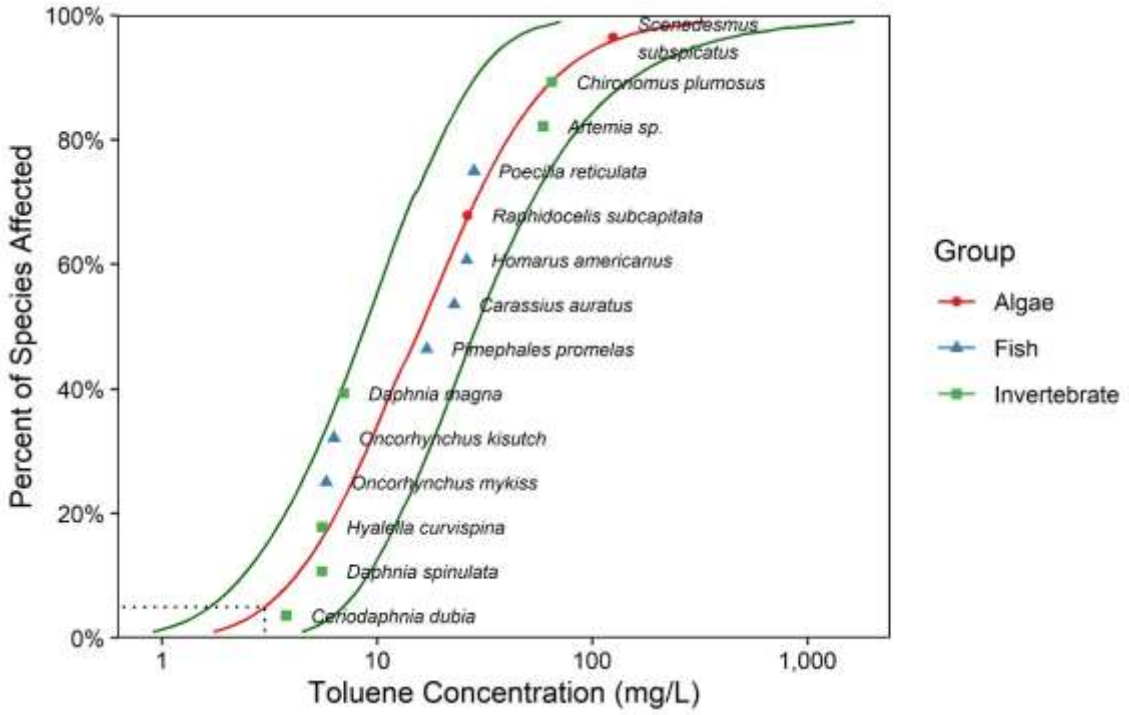

Figure 3. Acute SSD for toluene. The HC_5 (dotted line) is 3.0 mg/L.

Long-term Guideline

Limited chronic data were available and the dataset did not meet CCME requirements for guideline development, lacking at least two invertebrate endpoints from acceptable studies. Combining the few chronic data and the transformed acute data using the ACR of 2.5, an SSD was derived following the procedures described previously. Table 7 includes chronic data for 8 species and transformed acute data for 9 species. Figure 4 shows the chronic SSD for toluene, with a resulting HC_5 of 0.03 (0.002 to0.55) mg/L.

The TLM-based chronic HC_5 of 0.22 mg/L was calculated using Equation 1. The SSD-based HC_5 (0.03 mg/L) is ~7-fold lower than the TLM-based HC_5 (0.22 mg/L). SSD endpoints for two species (*L. pipiens* and *O. mykiss*) fall below the SSD HC_5 and three species (additionally, *A. gracile*) fall below the TLM HC_5. Both *L. pipiens* (Rocky Mountain and the Western Boreal/Prairie) and *O. mykiss* populations (Athabasca River) are listed under Schedule 1 of the *Species at Risk Act* (SARA S.C.2002,c.29) and therefore the CCME protection clause (CCME 2007) should be considered. However, as was the case with benzene, there are some uncertainties with this dataset due to the lack of robust chronic data and because the three most sensitive species are far lower than the rest of the dataset. The lowest effect concentration of 0.005 mg/L is over 40-fold lower than the estimated HC_5 by the TLM (0.22 mg/L) and 6-fold lower than the SSD HC_5 (0.03 mg/L). Therefore, in order to balance the desire to be conservative and to acknowledge the uncertainties with and the reliability of the available data, the SSD estimate of 0.03 mg/L was adopted as the long-term guideline for toluene. Additional consideration, such as examining other lines of evidence to assess risk, development of site-specific guidelines or the application of the CCME (2007) protection clause, may be warranted in sites where endangered amphibians and/or rainbow trout are present.

Table 7. Toluene chronic toxicity data.

Family	Species	Exposure type (duration)	Endpoint (effect) [b]	Effect Concentration (mg/L)	Transformed Effect Concentration (mg/L) [a]	Chronic SSD dataset (mg/L)	Reference
Fish	*Oncorhynchus mykiss*	Chronic (27-d)	LC20	0.005	-	0.005	Kennedy 2006
Amphibian	*Lithobates pipiens*	Chronic (9-d)	LC10	0.006	-	0.006	Black et al. 1982
Amphibian	*Ambystoma gracile*	Chronic (9-d)	LC10	0.06	-	0.06	Black et al. 1982
Invertebrate	*Ceriodaphnia dubia*	Chronic (7-d)	MATC[c] (Reproduction)	1.43	-	1.43	Niederlehner et al. 1998
Invertebrate	*Daphnia spinulata*	Acute (48-h)	LC50	5.53	2.09	2.09	Marzio and Saenz 2006
Invertebrate	*Hyalella curvispina*	Acute (96 -h)	LC50	5.53	2.09	2.09	Marzio and Saenz 2006
Fish	*Oncorhynchus kisutch*	Chronic (40-d)	MATC [c] (Weight)	2.28	-	2.28	Moles et al. 1981
Invertebrate	*Daphnia magna*	Acute (24-h)	EC50 (Immobilization)	7	2.64	2.64	Galassi et al. 1988
Fish	*Pimephales promelas*	Chronic (7-d)	IC25 (Biomass)	6.53	-	6.53	Marchini et al. 1992
Fish	*Carassius auratus*	Acute (96 -h)	LC50	22.8	8.77	8.77	Brenniman et al. 1976
Algae	*Raphidocelis subcapitata*	Chronic (8-d)	EC50 (Growth)	9.4	-	9.4	Herman et al. 1990
Fish	*Homarus americanus*	Acute (48- h)	LC50	26.1	10.0	10.0	Philibert et al. 2021
Fish	*Poecilia reticulata*	Acute (96-h)	LC50	28.2	10.8	10.8	Galassi et al. 1988
Invertebrate (marine)	*Artemia* sp.	Acute (24-h)	LC50	59.06	22.29	22.29	Abernethy et al. 1986
Invertebrate	*Chironomus plumosus*	Acute (48- h)	LC50	64.9	24.5	24.5	Li et al. 2013
Algae	*Scenedesmus quadricauda*	Chronic (96-h)	EC50 (Growth)	25.8	-	25.8	Marzio and Saenz 2006
Algae	*Scenedesmus subspicatus*	Acute (48-h)	EC50 (Growth)	125	50	50	Kuhn and Pattard 1990

[a]Acute effect concentrations for fish and invertebrates were transformed using the ACR of 2.5 and chronic concentrations were left untransformed.
[b]When the endpoint effect is not lethality (that is, LCx), the effect is noted in brackets.
[c]Calculated by ECCC by taking the geometric mean of the NOEC and LOEC.

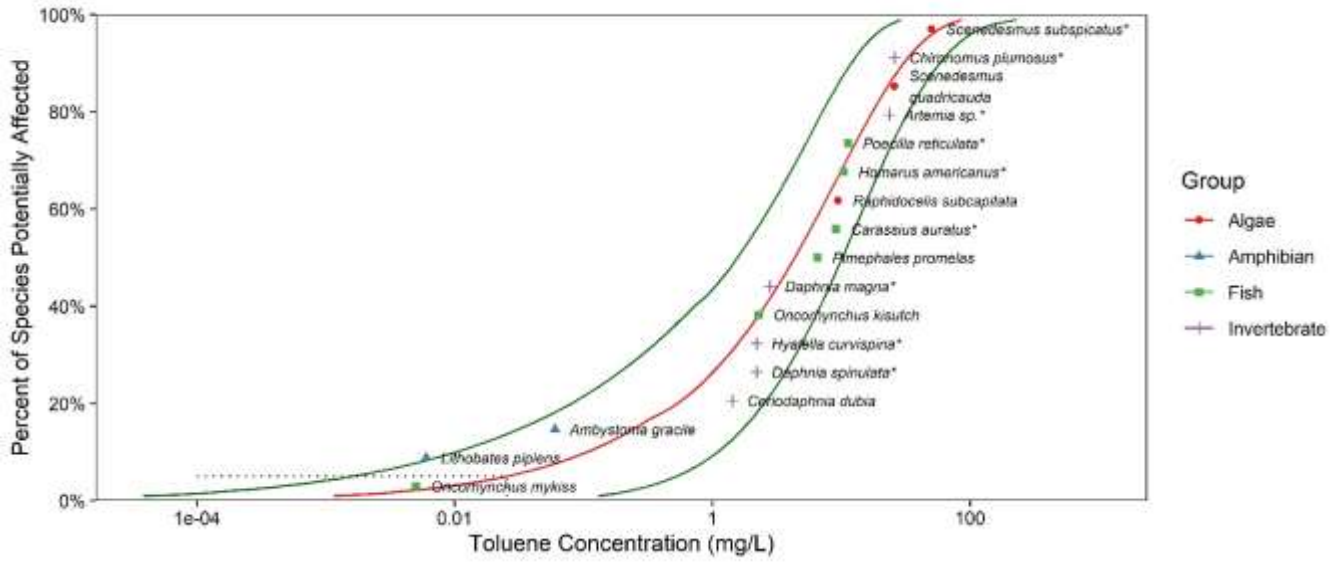

Figure 4. Toluene chronic SSD including transformed acute data (indicated by *). The HC_5 is 0.03 mg/L.

Table 8. Summary of the TLM and SSD HC_5 estimates for both acute and chronic exposures for toluene. **Underlined** values are the lower values and are adopted as the benchmark and FEQG.

	Acute TLM estimate (mg/L)	Acute SSD HC_5 (mg/L)	Chronic TLM estimate (mg/L)	Chronic SSD HC_5 (with ACR) (mg/L)
Toluene	3.2	**3.0**	0.22	**0.03**

Ethylbenzene

Short-term Benchmark

A total of 12 endpoints for 12 species (3 fish, 7 invertebrates, 2 aquatic plants/algae) from 7 studies were included in the SSD dataset and are summarized in Table 9. *Daphnia magna* (invertebrate) was the most sensitive species in the dataset with a median effect concentration of 2.12 mg/L. *Chironomus plumosus* (invertebrate) was the least sensitive species in the dataset with a median effect concentration of 37.8 mg/L. Three marine species and nine freshwater species were included in the dataset. Figure 5 shows the acute SSD for ethylbenzene with a resulting HC_5 of 1.9 (1.2 to 3.5) mg/L. The TLM-based acute HC_5 was calculated using Equation 2 and 3.19 for log K_{OW} (Appendix). This resulted in a TLM-based HC_5 of 1.0 mg/L.

Table 9. Acute toxicity dataset for ethylbenzene.

Family	Species	Duration	Endpoint	Effect Concentration (mg/L)	Reference
Invertebrate	*Daphnia magna*	48-h	LC50	2.12	Abernethy et al. 1986
Invertebrate (marine)	*Mysidopsis bahia*	96-h	LC50	2.6	Masten et al. 1994
Invertebrate	*Ceriodaphnia dubia*	48-h	LC50	3.18	Niederlehner et al. 1998
Fish	*Oncorhynchus mykiss*	96-h	LC50	4.2	Galassi et al. 1988
Invertebrate	*Daphnia spinulata*	48-h	LC50	4.25	Marzio et al. 2006
Invertebrate	*Hyalella curvispina*	96-h	LC50	4.25	Marzio et al. 2006
Fish (marine)	*Menidia menidia*	96-h	LC50	5.1	Masten et al. 1994
Algae	*Skeletonema costatum*	24-h	EC50 (Growth)	8	Masten et al. 1994
Fish	*Poecilia reticulata*	96-h	LC50	9.6	Galassi et al. 1988
Algae	*Raphidocelis subcapitata*	24-h	EC50 (Growth)	13.4	Masten et al. 1994
Invertebrate (marine)	*Artemia* sp.	24-h	LC50	15.39	Abernethy et al. 1986
Invertebrate	*Chironomus plumosus*	48-h	LC50	37.8	Li et al. 2015

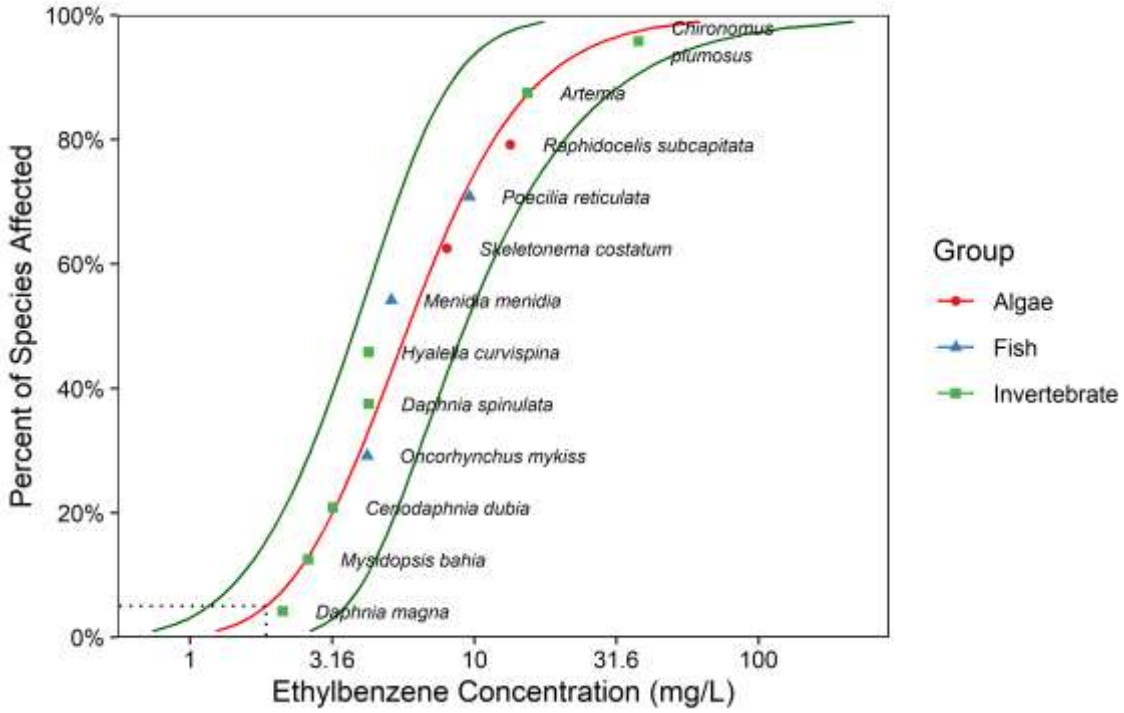

Figure 5. Acute SSD for ethylbenzene. The HC_5 (dotted line) is 1.9 mg/L.

Long-term Guideline

Very few chronic data were available and the dataset did not meet CCME requirements for guideline development, missing data for fish and at least one other invertebrate. Combining the limited chronic data and the transformed acute data using the ACR of 2.5, an SSD was derived following the procedures described previously. Table 10 includes chronic data for 4 species and transformed acute data for 9 species. Figure 6 shows the chronic SSD for ethylbenzene, with a resulting HC_5 of 0.37 (0.1 to 1.2) mg/L. Equation 1 was used to derive a TLM-based HC_5 which resulted in a value of 0.07 mg/L. All available chronic and acute data were above the TLM-based estimate however one endpoint, the 21-day MATC (reproduction) of 0.2 mg/L for *D. magna* (Kennedy 2006) did fall below the SSD HC_5. *Daphnia magna* is not a species at risk in Canada and the endpoint is for reproduction, not mortality, and therefore the CCME (2007) protection clause is not invoked. The TLM estimate is lower than the SSD HC_5, and therefore the TLM-based HC_5 estimate of 0.07 mg/L was adopted as the guideline for ethylbenzene.

Table 10. Chronic toxicity dataset for ethylbenzene.

Family	Species	Exposure type (duration)	Endpoint (effect) [b]	Effect Concentration (mg/L)	Transformed Effect Concentration (mg/L) [a]	Chronic SSD dataset (mg/L)	Reference
Invertebrate	*Daphnia magna*	Chronic (21-d)	MATC (Reproduction)	0.2	-	0.2	Kennedy 2006
Invertebrate	*Mysidopsis bahia*	Acute (96-h)	LC50	2.6	1.0	1.0	Masten et al. 1994
Invertebrate	*Ceriodaphnia dubia*	Acute (48-h)	LC50	3.18	1.27	1.27	Niederlehner et al. 1998
Fish	*Oncorhynchus mykiss*	Acute (96-h)	LC50	4.2	1.7	1.7	Galassi et al. 1988
Invertebrate	*Daphnia spinulata*	Acute (48-h)	LC50	4.25	1.70	1.70	Marzio et al. 2006
Invertebrate	*Hyalella curvispina*	Acute (96-h)	LC50	4.25	1.70	1.70	Marzio et al. 2006
Fish	*Menidia menidia*	Acute (96-h)	LC50	5.1	2.0	2.0	Masten et al. 1994
Algae	*Raphidocelis subcapitata*	Chronic (96-h)	EC50 (Growth inhibition)	3.6	-	3.6	Masten et al. 1994
Fish	*Poecilia reticulata*	Acute (96-h)	LC50	9.6	3.8	3.8	Galassi et al. 1988
Algae	*Skeletonema costatum*	Chronic (72-h)	EC50 (Growth inhibition)	4.9	-	4.9	Masten et al. 1994
Invertebrate	*Artemia* sp.	Acute (24-h)	LC50	15.39	6.156	6.156	Abernethy et al. 1986
Algae	*Scenedesmus quadricauda*	Chronic (96-h)	EC50 (Growth inhibition)	8.49	-	8.49	Marzio et al. 2006
Invertebrate	*Chironomus plumosus*	Acute (48-h)	LC50	37.8	15.1	15.1	Li et al. 2015

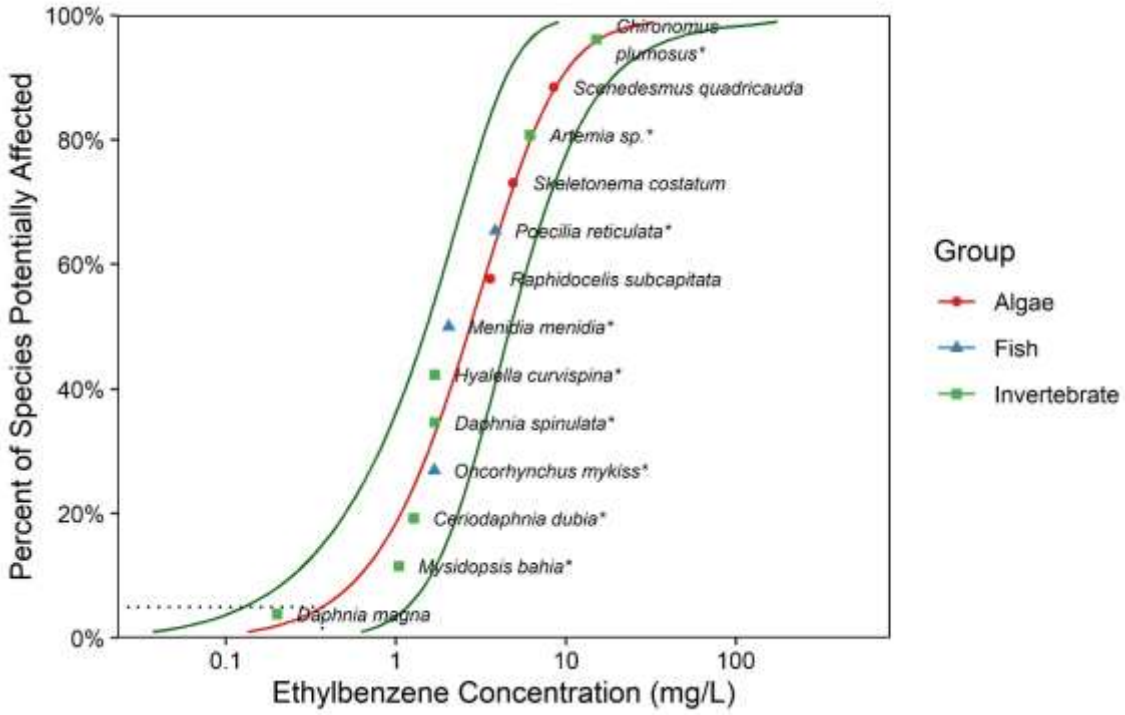

Figure 6. Ethylbenzene chronic SSD including transformed acute data (*). The HC_5 (dotted line) is 0.37 mg/L.

Table 11. Summary of the TLM and SSD HC_5 estimates for both acute and chronic exposures for ethylbenzene. **Underlined** values are the lower values and are adopted as the benchmark and FEQG.

	Acute TLM estimate (mg/L)	**Acute SSD HC_5 (mg/L)**	**Chronic TLM estimate (mg/L)**	**Chronic SSD HC_5 (with ACR) (mg/L)**
Ethylbenzene	**1.0**	1.9	**0.07**	0.37

Xylene

Short-term Benchmark

A total of 23 endpoints for 12 species (6 fish and 6 invertebrates) from 7 studies were included in the SSD dataset and are summarized in Table 12. Some studies measured the three isomers (o-, m- and p-) separately while others measured them as a total. The available data do not suggest that one isomer is more toxic than the others, which is also supported by the narcotic mode of action. In addition, sufficient data were not available to create separate SSDs for all three isomers. Therefore, all isomers were grouped together in the same dataset. Where comparable endpoints exist for the same species, a geometric mean was calculated. For example, a geometric mean of endpoints for o-, m- and p- isomers were taken in several instances and used in the SSD. *Ceriodaphnia dubia* (invertebrate) was the most sensitive species in the dataset with a median effect concentration of 2.44 mg/L. *Chironomus plumosus* (invertebrate) was the least sensitive species in the dataset with a median effect concentration of 42 mg/L. One marine species and 11 freshwater species were included in the dataset. Figure 7 shows the acute SSD for xylene with a resulting HC_5 of 2.3 (1.1 to 5.5)

mg/L. The TLM-based acute HC_5 was calculated using Equation 2 and 3.21 for log K_{OW} (Appendix). This results in a TLM-based HC_5 of 1.0 mg/L.

Table 12. Acute toxicity dataset for xylene.

Family	Species	Duration	Endpoint	Effect Concentration (mg/L)	Isomer	Reference
Invertebrate	*Ceriodaphnia dubia*	48-h	LC50	2.44	o-Xylene	Rose et al. 1998
Invertebrate	*Daphnia magna*	48-h	LC50	3.82	p-Xylene	Holcombe et al. 1987
Invertebrate	*Daphnia spinulata*	48-h	LC50	4.86	Geomean of o-, m-, p- xylene	Marzio and Saenz 2006
Invertebrate	*Hyalella curvispina*	96-h	LC50	4.86	Geomean of o-, m-, p- xylene	Marzio and Saenz 2006
Fish	*Oncorhynchus mykiss*	96-h	LC50	5.50	Geomean of o-, m-, p- xylene	Galassi et al. 1988
Fish	*Poecilia reticulata*	96-h	LC50	11.09	Geomean of o-, m-, p- xylene	Galassi et al. 1988
Fish	*Catostomus commersoni*	96-h	LC50	16.10	o-Xylene	Holcombe et al. 1987
Fish	*Lepomis macrochirus*	96-h	LC50	16.10	p-Xylene	Holcombe et al. 1987
Fish	*Pimephales promelas*	96-h	LC50	16.10	Total xylenes	Holcombe et al. 1987
Fish	*Carassius auratus*	96-h	LC50	16.94	Total xylenes	Brenniman et al. 1976
Invertebrate (marine)	*Artemia* sp.	24-h	LC50	22.42	Geomean of o-, m-, p- xylene	Abernethy et al. 1986
Invertebrate	*Chironomus plumosus*	48-h	LC50	42.0	Total xylenes	Li et al. 2013

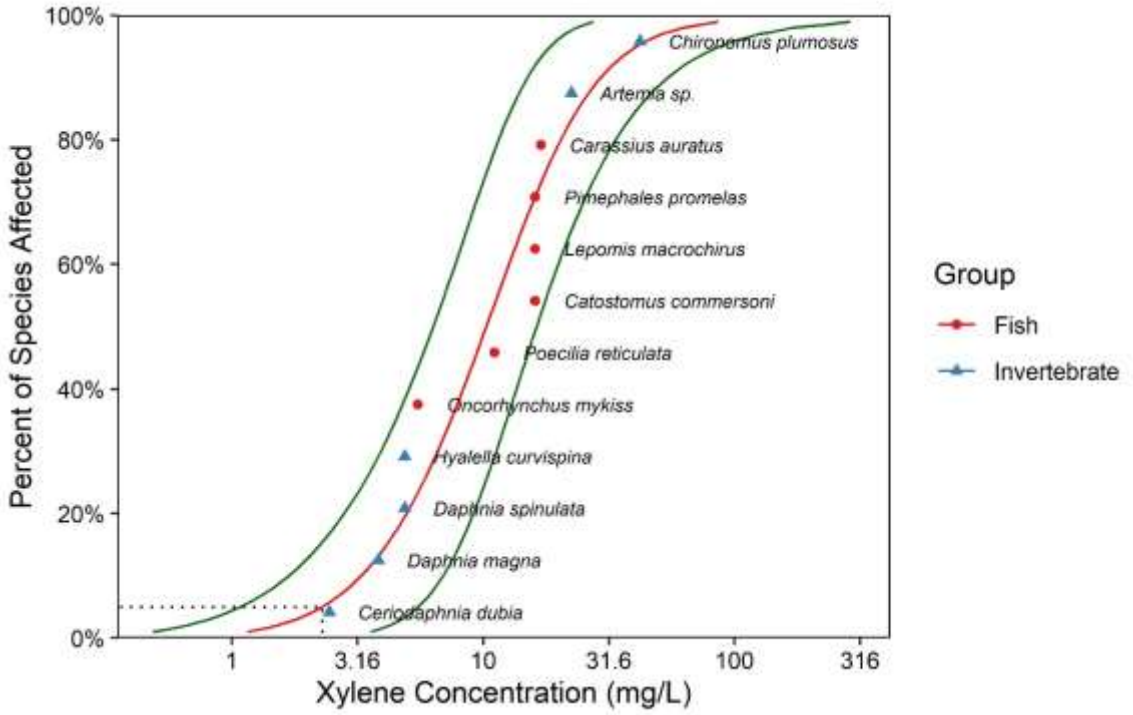

Figure 7. Acute SSD for xylene. The HC_5 (dotted line) is 2.3 mg/L.

Long-term Guideline

Very few chronic data were available and the chronic dataset did not meet CCME requirements for guideline development, missing at least two fish and two invertebrate species. Combining the chronic data and the transformed acute data using the ACR of 2.5, an SSD was derived following the procedures described previously. Table 13 includes chronic data for 4 species and transformed acute data for 11 species. Figure 8 shows the chronic SSD for xylene, with a resulting HC_5 of 0.61 (0.22 to 1.8) mg/L. Equation 1 was used to derive a TLM-based HC_5 which resulted in a value of 0.07 mg/L. All available chronic and acute data are above the TLM-based estimate however one endpoint, the 6-day LC20 (embryo-larval mortality) of 0.31 mg/L for *L. pipiens* (amphibian) (Kennedy 2006) does fall below the SSD HC_5. Therefore, as was done for benzene and toluene, the protection clause (CCME 2007) was considered. However, the lowest value (0.31 mg/L) is still 4.5 fold higher than the TLM estimate which, to be conservative and consistent, was adopted as the guideline value for xylene.

Table 13. Chronic toxicity dataset for xylene.

Family	Species	Exposure type (duration)	Endpoint (effect) [b]	Effect Concentration (mg/L)	Transformed Effect Concentration (mg/L) [a]	Chronic SSD dataset (mg/L)	Reference
Amphibian	*Lithobates pipiens*	Sub-chronic (6-d)	LC20	0.31	-	0.31	Kennedy 2006
Invertebrate	*Ceriodaphnia dubia*	Acute (48-h)	LC50	2.44	0.98	0.98	Rose et al. 1998
Invertebrate	*Daphnia magna*	Acute (48-h)	LC50	3.82	1.53	1.53	Holcombe et al. 1987
Invertebrate	*Daphnia spinulata*	Acute (48-h)	LC50	4.86	1.95	1.95	Marzio and Saenz 2006
Invertebrate	*Hyalella curvispina*	Acute (96-h)	LC50	4.86	1.95	1.95	Marzio and Saenz 2006
Fish	*Oncorhynchus mykiss*	Chronic (23-d)	LC10	3.22	-	3.22	Black et al. 1982
Algae	*Selenastrum capriconutum*	Chronic (8-d)	EC50 (Growth inhibition)	4.16	-	4.16	Herman et al. 1990
Fish	*Poecilia reticulata*	Acute (96-h)	LC50	11.09	4.43	4.43	Galassi et al. 1988
Fish	*Catostomus commersoni*	Acute (96-h)	LC50	16.10	6.44	6.44	Holcombe et al. 1987
Fish	*Lepomis macrochirus*	Acute (96-h)	LC50	16.10	6.44	6.44	Holcombe et al. 1987
Fish	*Pimephales promelas*	Acute (96-h)	LC50	16.10	6.44	6.44	Holcombe et al. 1987
Fish	*Carassius auratus*	Acute (96-h)	LC50	16.94	6.78	6.78	Brenniman et al. 1976
Invertebrate	*Artemia* sp.	Acute (24-h)	LC50	22.42	8.97	8.97	Abernethy et al. 1986
Algae	*Scenedesmus quadricauda*	Chronic (96-h)	EC50 (Growth inhibition)	12.51	-	12.51	Marzio and Saenz 2006
Invertebrate	*Chironomus plumosus*	Acute (48-h)	LC50	42.0	16.8	16.8	Li et al. 2013

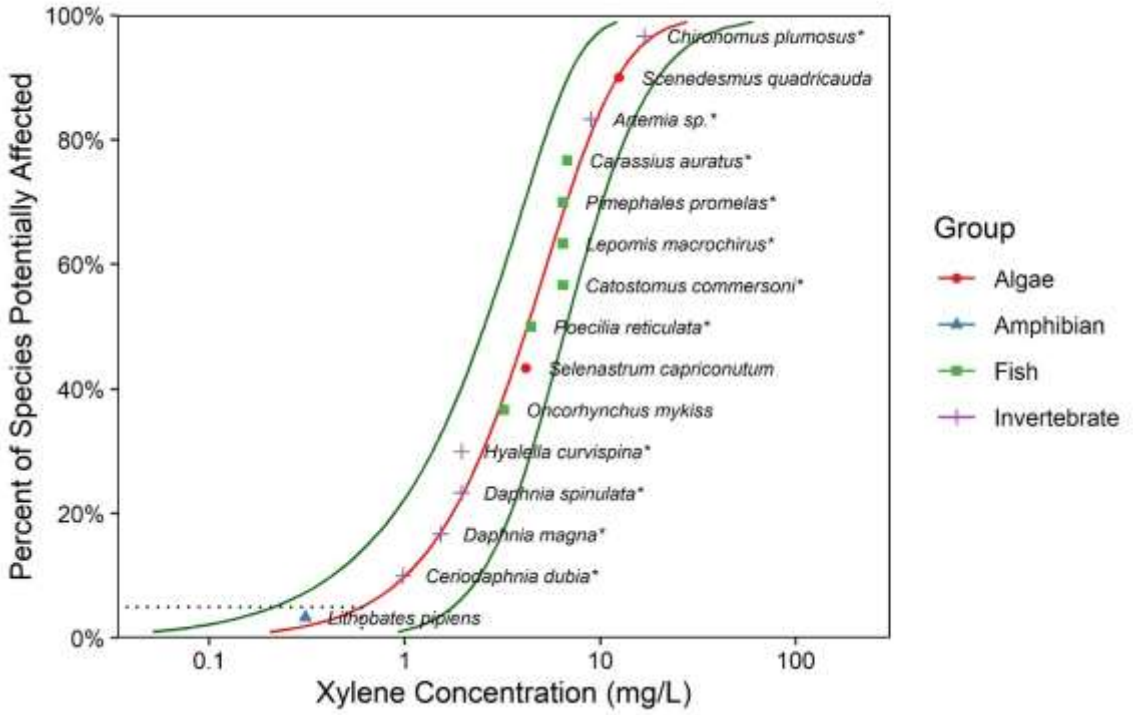

Figure 8. Xylene chronic SSD including transformed acute data (*). The HC_5 (dotted line) is 0.61 mg/L. Figure 9.

Table 14. Summary of the TLM and SSD HC_5 estimates for both acute and chronic exposures for xylene. **Underlined** values are the lower values and are adopted as the benchmark and FEQG.

	Acute TLM estimate (mg/L)	**Acute SSD HC_5 (mg/L)**	**Chronic TLM estimate (mg/L)**	**Chronic SSD HC_5 (with ACR) (mg/L)**
Xylene	**1.0**	2.3	**0.07**	0.61

Federal Water Quality Guidelines

A short-term benchmark concentration and the long-term FWQG provide guidance for both acute and chronic exposures, respectively. The short-term exposure value is intended to protect most species, not individuals, against lethality during severe but transient events such as spills or inappropriate use/disposal of the substance in question. Long-term guidelines are intended to protect the most sensitive species and life stages indefinitely. Although BTEX are not persistent, aquatic life may be chronically exposed to a substance because of gradual release from soils/sediments, gradual entry through groundwater/runoff, municipal discharges and effluents from industrial processes. The short-term benchmark concentrations and FWQGs for BTEX are tools for the assessment and interpretation of BTEX monitoring data in water.

CCME Type A or Type B guidelines could not be derived for BTEX because all required chronic toxicity data were not available. However, appropriate data were available to calculate an ACR to fulfill minimum data requirements to derive SSDs. Since BTEX are all considered nonpolar narcotics, the TLM was used to corroborate the SSD-based guideline or derive the FEQGs when the estimate was more conservative.

The final short-term benchmarks and long-term guidelines for BTEX compounds are the lower of the SSD- and TLM-based estimates. The federal short-term benchmarks and long-term guidelines for BTEX compounds were rounded to two significant figures and are presented in Table 1. These FWQGs apply to both freshwater and marine environments.

Hazard Index Approach: Applying to a mixture

The individual BTEX guidelines (long-term) and benchmarks (short-term) can be applied to a water sample using a Hazard Index (HI) approach with the following equation:

$$Hazard\ Index = \sum_{i=1}^{n=4}(\frac{concentration_i}{guideline\ or\ benchmark_i})$$

Which expands to;

$$Short-term\ Hazard\ Index = \sum_{i=1}^{n=4}(\frac{Concentration_{Benzene}}{Benchmark_{Benzene}} + \frac{Concentration_{Toluene}}{Benchmark_{Toluene}} + \frac{Concentration_{Ethylbenzene}}{Benchmark_{Ethylbenzene}} + \frac{Concentration_{Xylene}}{Benchmark_{Xylene}})$$

$$Long-term\ Hazard\ Index = \sum_{i=1}^{n=4}(\frac{Concentration_{Benzene}}{FWQG_{Benzene}} + \frac{Concentration_{Toluene}}{FWQG_{Toluene}} + \frac{Concentration_{Ethylbenzene}}{FWQG_{Ethylbenzene}} + \frac{Concentration_{Xylene}}{FWQG_{Xylene}})$$

As the above are ratios, the units (that is, mg/L) must be the same for the numerator and denominator. A final HI ≥1 would indicate that total BTEX measured in a water sample are at a concentration that may pose a hazard to aquatic communities, and a total value of <1 would indicate the sample likely does not pose a hazard to aquatic communities. This approach is included in the cumulative risk assessment framework published by the Pest Management Regulatory Agency (PRMA) (Health Canada Pest Management Regulatory Agency 2017).

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List of Acronyms and Abbreviations

ACR – acute to chronic ratio
AICc – Akaike information criterion corrected for small sample size
BTEX – benzene, toluene, ethylbenzene and xylene
CAS RN – chemical abstracts service registry number
CEPA – Canadian Environmental Protection Act
CCME – Canadian Council of Ministers of Environment
CMP – Chemicals Management Plan
ECx - effect concentration %
ECCC – Environment and Climate Change Canada
FEQG – Federal Environmental Quality Guideline
FWQG – Federal Water Quality Guideline
GoC – Government of Canada
HC_5 – hazard concentration at the 5^{th} percentile of an SSD plot
HC_p – hazard concentration at a given percentile (p)
ICx – inhibitory concentration
K_{OW} – water partition coefficient
LCx– lethal concentration
LCL – lower confidence limit
LOEC – Lowest observable effect concentration
MATC – Maximum acceptable toxicant concentration
NOEC – no observed effect concentration
MDL – method detection limit
MLE – maximum likelihood estimation
OSPW – oil sands process waters
QSAR – Quantitative structure-activity relationship
RAMP – Regional Aquatics Monitoring Program
SARA – Species at Risk Act
SSD – species sensitivity distribution
TLM – target lipid model
UCL – upper confidence limit
VOC – volatile organic chemical