Canadian Water Quality Guidelines for the Protection of Aquatic Life

ZINC (Dissolved) 2018

Zinc (Zn; CAS 7440-66-6) is an essential metal found widely in nature. Its predominant oxidation state in the natural environment is Zn^{2+}; the metallic form (Zn^0) is found only in highly reducing environments (Lindsay 1979). Zinc is able to form complexes with a variety of organic ligands and has a variety of salts (WHO 2001). Zinc metal is insoluble in water, but several of its salts are freely soluble (Budavari 1996; Lide 2006).

Production and Uses

Canada is one of the largest producers and exporters of zinc. Zinc generally occurs in association with copper and lead; therefore, mining and milling operations usually recover these metals as co-products (NRCan 2007). Zinc is used mainly to coat iron and steel products such as pipes, wire and sheet metal, to render them resistant to corrosion and rust (NRCan 2007). Additionally, many zinc compounds are used in dentistry, medicine, the rubber industry, paint, cosmetics and household products (ATSDR 2007).

Fate, Behaviour and Partitioning

Zinc can occur in both suspended and dissolved forms in natural aquatic environments but most is partitioned into suspended and bottom sediments (Eisler 1993). Several processes control zinc concentrations and mobility in water, and thus its bioavailability to aquatic organisms. Several abiotic variables influence the speciation of zinc, and thus the predominance among zinc forms: most importantly pH, alkalinity, redox potential (Eh), dissolved organic matter and salinity. The most common dissolved zinc species in natural waters under aerobic conditions are $ZnOH^+$, Zn^{2+} and $ZnCO_3$ (Florence 1977; Stumm and Morgan 1981). Of all chemical species found in aquatic

Table 1. Canadian Water Quality Guidelines (CWQGs) for the Protection of Aquatic Life for Dissolved Zinc for Specified Water Quality Conditions

	Short-term exposure ($\mu g \cdot L^{-1}$)	Long-term exposure ($\mu g \cdot L^{-1}$)
Fresh water	37[a]	7.0[b]
Marine	Not assessed	Not assessed

[a] The short-term benchmark is for **dissolved** zinc and is calculated using the following equation: **Benchmark = exp(0.833[ln(hardness mg·L⁻¹)] + 0.240[ln(DOC mg·L⁻¹)] + 0.526)**. The value in the table is for surface water of 50 mg $CaCO_3 \cdot L^{-1}$ hardness and 0.5 $mg \cdot L^{-1}$ dissolved organic carbon (DOC). The benchmark equation is valid between hardness 13.8 and 250.5 mg $CaCO_3 \cdot L^{-1}$ and DOC 0.3 and 17.3 $mg \cdot L^{-1}$.

[b] The long-term CWQG is for **dissolved** zinc and is calculated using the following equation: **CWQG = exp(0.947[ln(hardness mg·L⁻¹)] - 0.815[pH] + 0.398[ln(DOC mg·L⁻¹)] + 4.625)**. The value in the table is for surface water of 50 mg $CaCO_3 \cdot L^{-1}$ hardness, pH of 7.5 and 0.5 $mg \cdot L^{-1}$ DOC. The CWQG equation is valid between hardness 23.4 and 399 mg $CaCO_3 \cdot L^{-1}$, pH 6.5 and 8.13 and DOC 0.3 to 22.9 $mg \cdot L^{-1}$.

environments, the aqueous zinc ion (Zn^{2+}) is believed to be the most toxic (ANZECC 2000). Less soluble forms of zinc, such as zinc hydroxide ($Zn(OH)_2$) and zinc carbonate ($ZnCO_3$), are considered to be non-toxic (Cairns *et al.* 1971; Spear 1981). Changes in environmental conditions that influence zinc speciation can result in changes to zinc toxicity.

Table 3 lists concentrations of zinc found in Canadian surface waters.

Table 2. Acronyms Used

CWQG	Canadian Water Quality Guideline
DOC	dissolved organic carbon
EC_{50}	concentration expected to produce a certain effect in 50% of test organisms
IC_{50}	concentration inhibiting 50% of test organisms
LC_{50}	concentration lethal to 50% of test organisms
LOEC	lowest observed effect concentration
MATC	maximum acceptable toxicant concentration
MLR	multiple linear regression
NOEC	no observed effect concentration
SSD	species sensitivity distribution
TL_m	Median Tolerance Limit. Concentration at which there is 50% survival.
Zn^{2+}	aqueous zinc ion
$Zn(OH)_2$	zinc hydroxide
$ZnCO_3$	zinc carbonate

Effects on Aquatic Life

Zinc is an essential element for numerous biological functions. Environmental concentrations that are well below a species' optimal concentration range can disrupt homeostasis, and deficiencies have observable effects (Muyssen and Janssen 2002). At higher concentrations, however, zinc produces adverse chronic and acute effects on reproduction, biochemical and physiochemical reactions and behavioural effects in aquatic organisms (WHO 2001).

In fish, zinc interferes with gill uptake of calcium (Hogstrand *et al.* 1994; Spry and Wood 1985). Because calcium is also an essential element, this reduction in uptake causes calcium deficiency (Spry and Wood 1985). Zinc also disrupts calcium homeostasis in invertebrates (Muyssen *et al.* 2006) due to competition between zinc and calcium for the same uptake sites on the gill epithelium (Hogstrand *et al.* 1994; Hogstrand *et al.* 1998). Zinc also disturbs, to a lesser extent, sodium and chloride fluxes (Spry and Wood 1985).

At higher zinc concentrations, lethal toxicity of zinc to aquatic organisms is caused by the irreversible destruction of the gill epithelium, which causes tissue hypoxia, osmoregulatory failure, acidosis and low oxygen tensions in the arterial blood (Hiltibran 1971; Skidmore 1970; Skidmore and Tovell 1972).

In general, salmonids were found to be more sensitive than other types of fish in short-term studies.

Table 3. Range of Surface Water Zinc Concentrations Across Canada

Jurisdiction	Location	Concentration (µg Zn·L^{-1})	Reference
Great Lakes		0.087 to 0.277[a] (dissolved)	(Nriagu *et al.* 1996)
Manitoba	Ross Lake, Flin Flon Creek – downstream of Cu-Zn mine	41.4 to 1521	(Evans 2000)
Alberta, 2001 to 2003	Sites upstream and unaffected by mine activity	0.55 in 2002 to 0.13 in 2003[b]	(Wayland and Crosley 2006)
Alberta, 2005 to 2016	Athabasca region	<0.09 to 125 (dissolved) <0.1 to 139 (total)	(RAMP 2016)
Northwest Territories and British Columbia	Great Bear River (NWT) and Kicking Horse and Beaver Rivers (BC)	5.32 to 9.0	(Tri-Star Environmental Consulting 2006)
Nova Scotia	Streams	<5.0 to 11	(Reimann and De Caritat 1998)
Nova Scotia, 1970 to 2013	Brooks, lakes and ponds	<2 to 241	(Nova Scotia Environment 2015)
Ontario, 2014	Streams	<2 to 537	(Government of Ontario 2016)

[a] Average.
[b] Annual Median.

Toxicity-Modifying Factors

Water chemistry conditions influence how toxic zinc is to aquatic organisms by affecting its environmental fate, behaviour and bioavailability. Water hardness, dissolved organic carbon (DOC) and pH are the most important variables. Complete details of the assessment are available in the scientific criteria document (CCME 2018).

In general, increased hardness is protective (i.e., zinc is less toxic in harder waters), likely due to competitive interactions with Ca^{2+} and Mg^{2+} at binding sites. The effect of pH is not as clear. Authors report that toxicity to fish and algae increases with increasing pH in natural waters, but there are no consistent patterns for invertebrates (CCME 2018). Increased bioavailability of zinc is possible at high pH due to decreased binding by organic ligands. Dissolved organic matter is an important complexing agent for zinc; therefore, increased organic matter (measured as DOC) tends to have a protective effect. The toxicity modifying factors are described more fully in CCME (2018).

It is important to account for exposure and toxicity-modifying factors when deriving guidelines (CCME 2007). This can be done through single- or multi-factor equations, matrices or models. In this case, CCME used multiple linear regression (MLR) analysis to account for the simultaneous effects of water hardness, DOC and pH on zinc toxicity.

CCME derived empirical relationships for short-term and long-term exposure using forward stepwise MLR. The analysis identified which water chemistry variables explained a significant portion of variability in zinc toxicity. MLR analyses were conducted species by species. The best species model was selected based on how well it predicted toxicity, how well it explained variability in the dataset and, in the case of the long-term guideline, the protectiveness of the values calculated by the model.

For the short-term benchmark, hardness and DOC were both significant factors. For the long-term Canadian Water Quality Guideline (CWQG), hardness, pH and DOC all explained a significant portion of the variation and were used to derive the CWQG equation.

CCME's short-term benchmark equation is based on a pooled *Daphnia magna* and *D. pulex* model containing variables for hardness and DOC. The long-term CWQG equation is based on an *Oncorhynchus mykiss* model containing variables for hardness, pH and DOC. Accordingly, the CWQG and short-term benchmark for freshwater exposure to zinc are presented as multi-variable equations that are a function of water hardness, DOC and pH and allow users to derive guidelines and benchmarks based on the water chemistry of the site under consideration.

Water Quality Guideline Derivation

For the derivation of the short-term guideline, effect concentrations were normalized to a hardness of 50 $mg \cdot L^{-1}$ as $CaCO_3$ and a DOC concentration of 0.5 $mg \cdot L^{-1}$ using the pooled *Daphnia* MLR equation. For the derivation of the long-term guideline, effect concentrations were normalized to a hardness of 50 $mg \cdot L^{-1}$ as $CaCO_3$ and a DOC concentration of 0.5 $mg \cdot L^{-1}$ and pH of 7.5 using the *O. mykiss* MLR. Total zinc concentrations were converted to dissolved using a conversion factor for laboratory toxicity data of 0.978 for the short-term guideline and 0.986 for the long-term guideline (USEPA 1996) and plotted (see Figures 1 and 2). For details and references regarding the data included in the SSDs, see the scientific criteria document for the CWQG for zinc and its spreadsheet appendix (CCME 2018).

Short-term Freshwater Benchmark Concentration

CCME derives short-term benchmark concentrations using severe effects data (such as lethality) for defined short-term exposure periods. These benchmarks are estimators of severe effects to the aquatic ecosystem and are intended to give guidance on the impacts of severe but transient situations, such as spill events and infrequent releases of short-lived or non-persistent substances. Short-term benchmark concentrations *do not* provide guidance for protective levels of a substance in the aquatic environment, as they are levels that *do not* protect against adverse effects.

The minimum data requirements for the Type A guideline approach were met and CCME used a total of 81 data points to derive the benchmark concentration (Table 4). Each species was ranked according to sensitivity.

Table 4. Endpoints Used to Determine the Short-term Freshwater Benchmark Concentration for Dissolved Zinc[a]

Species sensitivity distribution rank	Species	Endpoint	Normalized effect concentration (µg dissolved Zn·L^{-1})
1	*Daphnia magna* (water flea)	96-h LC_{50}	22.7
2	*Ceriodaphnia dubia* (water flea)	48-h LC_{50}	34.0
3	*Pseudokirchneriella subcapitata* (green algae)	4-h EC_{50} (growth)	36.2
4	*Ceriodaphnia reticulata* (water flea)	48-h LC_{50}	67.2
5	*Chlorella pyrenoidosa* (green algae)	24-h EC_{50} (growth)	76.3
6	*Oncorhynchus mykiss* (rainbow trout)	5-d LC_{50}	84.9
7	*Daphnia pulex* (water flea)	48-h LC_{50}	94.6
8	*Oncorhynchus tshawytscha* (Chinook salmon)	96-h LC_{50}	99.6
9	*Oncorhynchus clarkii virginalis* (Rio Grande cutthroat trout)	96-h LC_{50}	120
10	*Cottus bairdi* (mottled sculpin)	96-h LC_{50}	121
11	*Salvelinus confluentus* (bull trout)	5-d LC_{50}	123
12	*Morone saxatilis* (striped bass)	96-h LC_{50}	141
13	*Salmo trutta* (sea trout)	96-h LC_{50}	147
14	*Daphnia ambigua* (cladoceran)	48-h LC_{50}	150
15	*Rhinichthys chrysogaster* (longfin dace)	96-h LC_{50}	152
16	*Thymallus arcticus* (Arctic grayling)	96-h LC_{50}	171
17	*Lampsilis rafinesqueana* (Neosho mucket)	48-h EC_{50} (survival)	175
18	*Pimephales promelas* (fathead minnow)	96-h TLM	194
19	*Daphnia longispina* (cladoceran)	48-h EC_{50} (immobility)	210
20	*Daphnia carinata* (cladoceran)	48-h LC_{50}	224
21	*Oncorhynchus clarkii pleuriticus* (Colorado River cutthroat trout)	96-h LC_{50}	245
22	*Simocephalus vetulus* (cladoceran)	48-h EC_{50} (immobility)	246
23	*Daphnia galeata* (cladoceran)	48-h EC_{50} (immobility)	262
24	*Simocephalus exspinosus* (cladoceran)	48-h EC_{50} (immobility)	307
25	*Prosopium williamsoni* (mountain whitefish)	96-h LC_{50}	327
26	*Oncorhynchus clarkii stomias* (greenback cutthroat trout)	96-h LC_{50}	328
27	*Acroperus elongatus* (cladoceran)	48-h EC_{50} (immobility)	423
28	*Chydorus ovalis* (cladoceran)	48-h EC_{50} (immobility)	426
29	*Ceriodaphnia pulchella* (cladoceran)	48-h EC_{50} (immobility)	443
30	*Lampsilis siliquoidea* (fatmucket)	96-h EC_{50} (survival)	470
31	*Chydorus sphaericus* (cladoceran)	48-h EC_{50} (immobility)	516
32	*Ptychocheilus lucius* (Colorado pikeminnow)	96-h LC_{50}	533
33	*Bufo boreas* (boreal toad)	96-h LC_{50}	535
34	*Oncorhynchus nerka* (sockeye salmon)	115-h LC_{50}	717
35	*Oncorhynchus kisutch* (coho salmon)	96-h LC_{50}	834
36	*Culicoides furens* (midge)	96-h LC_{50}	888
37	*Chironomus plumosus* (midge)	96-h LC_{50}	999
38	*Physa heterostropha* (snail)	96-h LC_{50}	1 021
39	*Moina macrocopa* (cladoceran)	48-h LC_{50}	1 144
40	*Tubifex tubifex* (worm)	96-h LC_{50}	1 145
41	*Xyrauchen texanus* (razorback sucker)	96-h LC_{50}	1 286
42	*Physa gyrina* (snail)	96-h LC_{50}	1 356
43	*Rhinichthys cataractae* (longnose dace)	96-h LC_{50}	1 382

Species sensitivity distribution rank	Species	Endpoint	Normalized effect concentration (µg dissolved Zn·L^{-1})
44	*Brachionus havanaensis* (rotifer)	24-h LC_{50}	1 428
45	*Gila elegans* (bonytail)	96-h LC_{50}	1 505
46	*Lymnaea luteola* (snail)	96-h LC_{50}	1 542
47	*Salvelinus fontinalis* (brook trout)	96-h LC_{50}	1 713
48	*Platygobio gracilis* (flathead chub)	96-h LC_{50}	1 809
49	*Hydra viridissima* (green hydra)	96-h LC_{50}	2 003
50	*Lirceus alabamae* (isopode)	96-h LC_{50}	2 077
51	*Cyprinus carpio* (carp)	96-h LC_{50}	2 496
52	*Spirodela polyrrhiza* (greater duckweed)	4-d IC_{50} (growth)	2 505
53	*Azolla pinnata* (mosquito fern)	4-d IC_{50} (growth)	2 540
54	*Catostomus commersoni* (white sucker)	96-h LC_{50}	2 688
55	*Lepomis macrochirus* (bluegill)	96-h LC_{50}	3 155
56	*Catostomus latipinnis* (flannelmouth sucker)	24-h LC_{50}	3 604
57	*Corbicula fluminea* (bivalve)	96-h LC_{50}	3 696
58	*Brachydanio rerio* (zebrafish)	96-h LC_{50}	3 761
59	*Caecidotea bicrenata* (isopode)	96-h LC_{50}	3 897
60	*Gambusia holbrooki* (eastern mosquitofish)	96-h LC_{50}	4 192
61	*Rana hexadactyla* (green pond frog)	96-h LC_{50}	4 404
62	*Hydra vulgaris* (pink hydra)	96-h LC_{50}	4 928
63	*Bufo melanostictus* (Asian toad)	96-h LC_{50}	4 945
64	*Morone americana* (white perch)	48-h TLm	5 253
65	*Ptychocheilus oregonensis* (northern pikeminnow)	96-h LC_{50}	5 420
66	*Hydra oligactis* (coelenterate)	72-h LC_{50}	5 928
67	*Lumbriculus variegatus* (oligochaete)	96-h LC_{50}	7 293
68	*Anguilla rostrata* (American eel)	96-h TLm	7 542
69	*Notemigonus crysoleucas* (golden shiner)	24-h LC_{50}	7 666
70	*Baetis tricaudatus* (mayfly)	96-h LC_{50}	8 429
71	*Fundulus diaphanus* (banded killifish)	96-h TLm	9 987
72	*Lepomis gibbosus* (pumpkinseed)	96-h TLm	10 455
73	*Aeolosoma headleyi* (annelid)	48-h LC_{50}	11 076
74	*Xenopus laevis* (African clawed frog)	4-d LC_{50}	18 947
75	*Lepidostoma* sp. (caddisfly)	96-h LC_{50}	35 215
76	*Carassius auratus* (goldfish)	24-h LC_{50}	39 517
77	*Rhithrogena hageni* (mayfly)	96-h LC_{50}	40 479
78	*Drunella doddsi* (mayfly)	96-h LC_{50}	46 625
79	*Chloroperlidae* (stonefly)	96-h LC_{50}	49 058
80	*Cinygmula* sp. (mayfly)	96-h LC_{50}	49 058
81	*Ephemerella* sp. (mayfly)	96-h LC_{50}	49 058

[a]Normalized for hardness and dissolved organic carbon—see text for details.

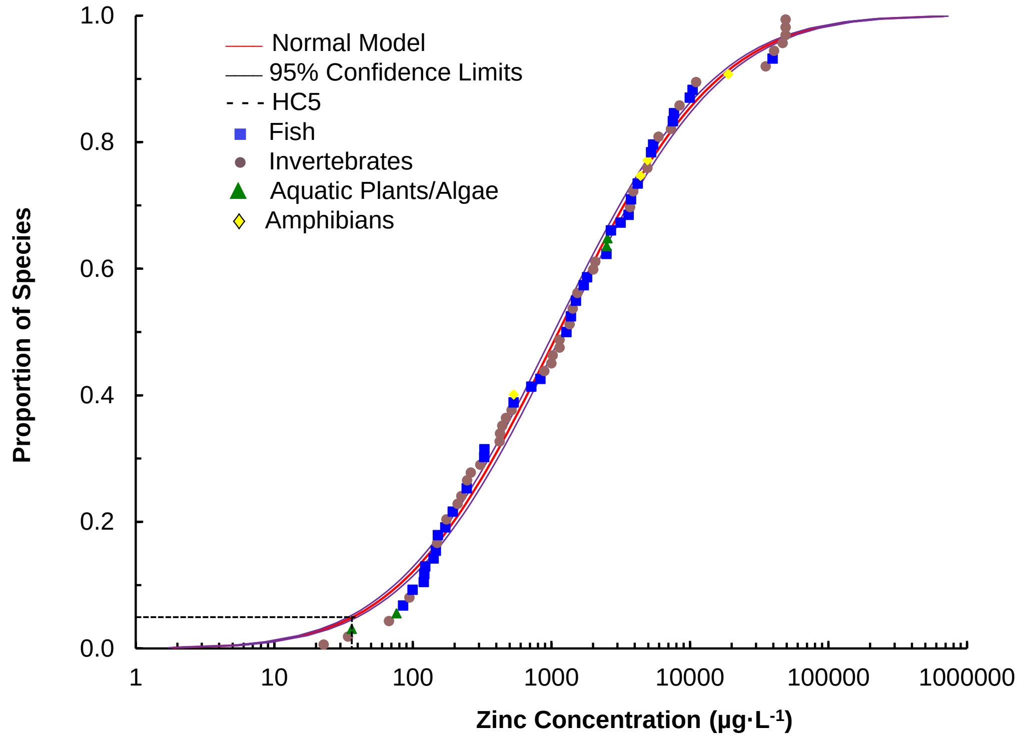

Figure 1. Short-term species sensitivity distribution (SSD) for dissolved zinc in fresh water. Derived by fitting the log-normal model to the short-term LC/EC$_{50}$ values of 81 aquatic species. Data were normalized to hardness and dissolved organic carbon, and converted to dissolved concentrations as described on page 4. The fifth percentile on the short-term SSD is 37 µg·L^{-1}.

Because water hardness and DOC were significant toxicity-modifying factors in the short-term analysis, CCME expresses the short-term benchmark as an equation into which the local water hardness and DOC must be entered in order to produce an appropriate site-specific benchmark concentration. Full details of the derivation are provided in CCME (2018). See Table 5 for examples.

Equation 1.

$$\text{Short-term benchmark} = \exp(0.833[\ln(\text{hardness})] + 0.240[\ln(\text{DOC})] + 0.526)$$

—where the benchmark is expressed in dissolved zinc concentration (µg·L^{-1}), hardness is measured as $CaCO_3$ equivalents in mg·L^{-1} and DOC is measured in mg·L^{-1}.

Table 5. Example Short-term Benchmark Concentrations (µg·L^{-1}) for Dissolved Zinc in Fresh Water at Various Levels of Water Hardness and DOC[a]

DOC (mg·L^{-1})	Hardness (mg·L^{-1})							
	15	**25**	**50**	**75**	**100**	**150**	**200**	**250.5 [a]**
0.5	14	21	37	52	66	93	118	143
2.0	19	29	52	73	93	130	165	199
5.0	24	36	65	91	115	162	206	248
10.0	28	43	77	107	136	191	243	293
17.3 [a]	32	49	87	122	155	218	277	334 (maximum)

[a] The short-term benchmark equation is valid between hardness 13.8 and 250.5 mg $CaCO_3$·L^{-1} and from DOC 0.3 to 17.3 mg·L^{-1}.

Long-term Freshwater Quality Guideline

Long-term exposure guidelines identify waterborne concentrations intended to protect all forms of aquatic life for indefinite exposure periods. The minimum data requirements for the Type A guideline approach were met and a total of 29 data points were used to derive the guideline (Table 6). Each species for which appropriate long-term toxicity data were available was ranked according to sensitivity.

Table 6. Endpoints Used to Determine the Long-term Freshwater CWQG for Dissolved Zinc

Species sensitivity distribution rank	Species	Endpoint	Normalized effect concentration [a] (µg dissolved Zn·L^{-1})
1	*Chironomus riparius* (chironomid)	11-w LOEC (development)	9.89
2	*Ceriodaphnia dubia* (water flea)	7-d MATC (reproduction)	11.3
3	*Pseudokirchneriella subcapitata* (green algae)	72-h EC_{10} (growth rate)	13.8
4	*Daphnia magna* (cladoceran)	21-d EC_{10} (reproduction)	15.0
5	*Potamopyrgus jenkinsi* (snail)	12-w MATC (growth)	19.1
6	*Jordanella floridae* (flagfish)	100-d MATC (growth)	27.9
7	*Cottus bairdi* (mottled sculpin)	30-d EC_{10} (mortality)	31.5
8	*Brachionus havanaensis* (rotifer)	18-d EC_{10} (population growth inhibition)	36.5
9	*Phoxinus phoxinus* (Eurasian minnow)	150-d LC_{10} (mortality)	51.0
10	*Dreissena polymorpha* (zebra mussel)	10-w LC_{10} (mortality)	51.1
11	*Pimephales promelas* (fathead minnow)	7-d IC_{10} (growth)	68.2
12	*Brachionus calyciflorus* (rotifer)	48-h EC_{10} (intrinsic rate of population increase)	73.0
13	*Oncorhynchus mykiss* (rainbow trout)	30-d LC_{10} (mortality)	101
14	*Lampsilis siliquoidea* (fatmucket)	28-d IC_{10} (length)	104
15	*Bufo boreas* (boreal toad)	4-w MATC (development)	108
16	*Lymnaea stagnalis* (snail)	28-d EC_{10} (growth)	113
17	*Salmo trutta* (brown trout)	58-d MATC (weight)	130
18	*Prosopium williamsoni* (mountain whitefish)	90-d IC_{10} (biomass)	133
19	*Salvelinus fontinalis* (brook trout)	24-w IC_{10} (egg fragility)	161
20	*Oncorhynchus clarkii pleuriticus* (cutthroat trout)	30-d MATC (biomass)	169
21	*Chlorella* sp. (green algae)	48-h IC_{50} (growth rate)	225
22	*Physa gyrina* (snail)	30-d NOEC/L (mortality)	344
23	*Lemna minor* (duckweed)	7-d EC_{10} (growth)	400

Species sensitivity distribution rank	Species	Endpoint	Normalized effect concentration [a] (µg dissolved Zn·L⁻¹)
24	*Lyngbya* sp. (cyanobacteria)	18-d EC_{10} (growth rate)	415
25	*Cyclotella meneghiniana* (diatom)	5-d EC_{10} (growth rate)	477
26	*Ceratophyllum demersum* (hornwort)	15-d LOEC (chlorophyll content and biomass)	1 116
27	*Chlamydomonas* sp. (green algae)	10-d EC_{10} (growth rate)	1 428
28	*Scenedesmus quadricauda* (green algae)	5-d EC_{10} (growth rate)	1 628
29	*Rhithrogena hageni* (mayfly)	10-d EC_{10} (mortality)	1 696

[a]Normalized for hardness and dissolved organic carbon—see text for details.

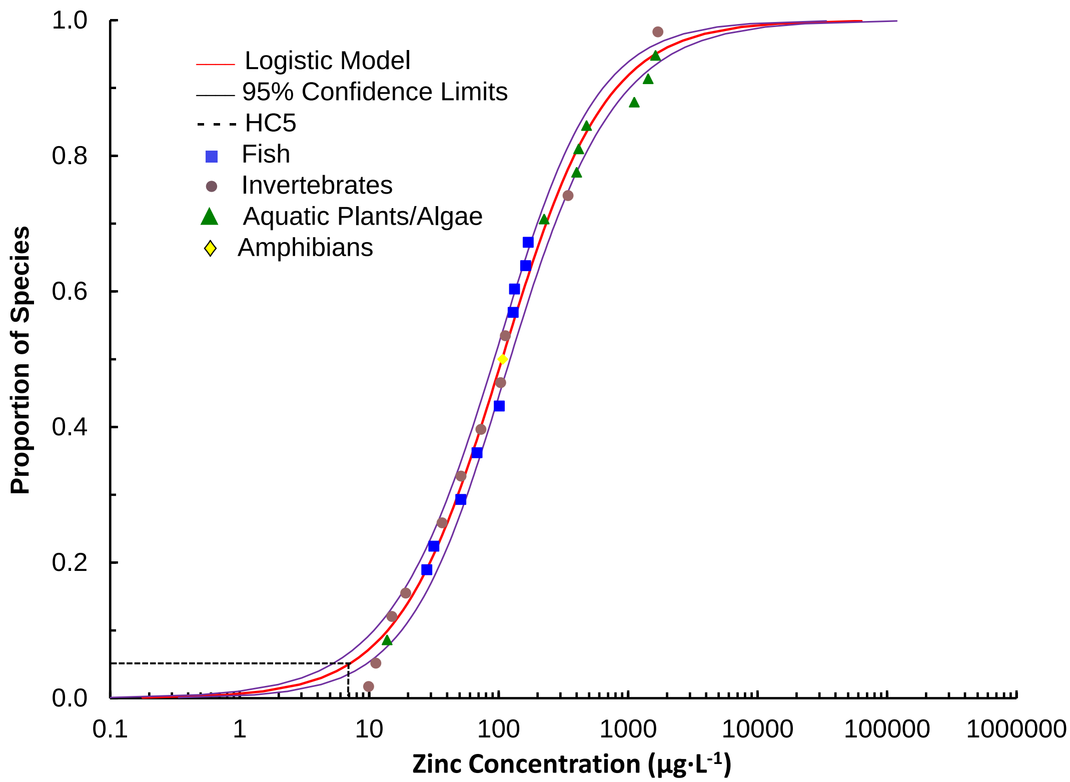

Figure 2. Long-term species sensitivity distribution (SSD) for dissolved zinc in fresh water, derived by fitting the logistic model to the long-term endpoints of 29 aquatic species. Data were normalized to hardness, dissolved organic carbon and pH, and converted to dissolved concentrations as described on page 4. The fifth percentile on the long-term SSD is 7.0 µg·L⁻¹.

No data points fell below the fifth percentile value on the long-term SSD curve. CCME assessed the CWQG for zinc for protectiveness and found it achieved the intended level of protection as per CCME 2007 and 2018).

Because the analysis of the long-term data found that water hardness, pH and DOC were significant toxicity-modifying factors, the CWQG is expressed as an equation into which the local water hardness, pH and DOC must be entered in order to produce an appropriate site-specific CWQG.

Equation 2.

$$CWQG = \exp(0.947[\ln(\text{hardness})] - 0.815[\text{pH}] + 0.398[\ln(\text{DOC})] + 4.625)$$

—where the CWQG is expressed in dissolved zinc concentration ($\mu g \cdot L^{-1}$), hardness is measured as $CaCO_3$ equivalents in $mg \cdot L^{-1}$, pH is in standard units and DOC is in $mg \cdot L^{-1}$.

Table 7. Example CWQG Concentrations ($\mu g \cdot L^{-1}$) for Dissolved Zinc in Fresh Water at Various Levels of Water Hardness, pH and DOC [a]

pH 6.5[a]						
DOC	**Hardness (mg $CaCO_3 \cdot L^{-1}$)**					
($mg \cdot L^{-1}$)	**25**	**50**	**75**	**100**	**200**	**399[a]**
0.5	8.2	16	23	30	59	113
2.0	14	27	40	53	102	195
5.0	20	39	58	76	146	281
10.0	27	52	76	100	193	371
22.9[a]	37	72	106	139	268	516 (maximum)
pH 7.0						
DOC	**Hardness (mg $CaCO_3 \cdot L^{-1}$)**					
($mg \cdot L^{-1}$)	**25**	**50**	**75**	**100**	**200**	**399[a]**
0.5	5.4	10	15	20	39	75
2.0	9.4	18	27	35	68	130
5.0	14	26	38	50	97	187
10.0	18	35	51	67	128	247
22.9[a]	25	48	70	93	178	343
pH 7.5						
DOC	**Hardness (mg $CaCO_3 \cdot L^{-1}$)**					
($mg \cdot L^{-1}$)	**25**	**50**	**75**	**100**	**200**	**399[a]**
0.5	3.6	7.0	10	13	26	50
2.0	6.3	12	18	23	45	87
5.0	9.0	17	26	34	65	125
10.0	12	23	34	44	85	164
22.9[a]	17	32	47	62	119	228
pH 8.0						
DOC	**Hardness (mg $CaCO_3 \cdot L^{-1}$)**					
($mg \cdot L^{-1}$)	**25**	**50**	**75**	**100**	**200**	**399[a]**
0.5	2.4	4.6	6.8	8.9	17	33
2.0	4.2	8.1	12	16	30	58
5.0	6.0	12	17	22	43	83
10.0	7.9	15	22	29	57	109
22.9[a]	11	21	31	41	79	152

[a] The CWQG equation is valid between hardness 23.4 and 399 mg $CaCO_3 \cdot L^{-1}$, pH 6.5 and 8.13 and DOC of 0.3 to 22.9 $mg \cdot L^{-1}$.

Marine Water Quality Guideline

CCME did not derive a marine water quality guideline for zinc at this time and hence no marine value is recommended. It is not appropriate to apply the zinc freshwater guideline to marine or estuarine environments.

Considerations in Guideline Application

The freshwater benchmark and CWQG equations must be used in order to obtain a site-specific benchmark and CWQG, respectively, based on the DOC, pH and hardness of the water body of interest. Where guideline users have only water sample concentrations expressed as total zinc, CCME recommends first comparing these samples to the dissolved guideline. Should an exceedance occur, re-sample for a dissolved concentration for direct comparison to the CWQG.

Extrapolations should not be made above the conditions used to develop the relationships for toxicity-modifying factors. Extrapolations should not be made above the upper hardness or DOC limits or, for the long-term guideline, below the lower pH limit. Where users want a more stringent WQG for waters below the DOC and hardness limits or above the pH limit, they should extrapolate with caution and contact their local authority for advice. For the short-term benchmark, those conditions are hardness values between 13.8 and 250.5 mg $CaCO_3 \cdot L^{-1}$ and DOC concentrations of 0.3 to 17.3 $mg \cdot L^{-1}$. For the long-term guideline, these conditions are hardness values between 23.4 and 399 $mg \cdot L^{-1}$, DOC concentrations of 0.3 and 22.9 $mg \cdot L^{-1}$, and pH of 6.5 to 8.13. Where values for DOC, hardness or pH are lacking, CCME recommends using values that provide the most conservative guideline estimate to ensure protectiveness.

Natural background levels of zinc are very site specific and high and low concentrations may lead to locally adapted ecological communities that may respond differently to anthropogenic releases of zinc compared with non-adapted communities. This aspect cannot be incorporated into a nationally-applicable guideline value. Therefore, CCME (2007) recommends "that, where the site-specific natural background concentration of a substance exceeds the national guideline value derived primarily from laboratory toxicity data, the natural background concentrations should be taken as the site-specific guideline value, unless another appropriate site-specific guideline value is derived according to recommended methods."

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