

Appendix C: Water Quality Criteria for the Protection of Human Health and the Aquatic Biota
Criteria are in micrograms per liter (µg/l - parts per billion) unless indicated otherwise.

Compound	FR Cite/Source	CAS Number	Protection of Human Health			Protection of Aquatic Biota	
			Tox Class	Consumption of Water & Organisms	Consumption of Organisms Only	Maximum Allowable Concentration - Acute Criteria ^a	Average Allowable Concentration - Chronic Criteria ^a
<i>Toxic Metals</i>							
Antimony	65FR66443	7440360	TT	5.6 14	640 4,300	---	---
Arsenic	65FR31682	7440382	A	0.02 ^g	1.5 ^g	340 360	150 190
Cadmium ^{d, e.}	65FR31682	7440439	TT	---	---	1.03 1.74	0.15 0.62
Chromium (VI) ^{d.}	65FR31682	18540299	TT	---	---	16	11
Chromium (III) ^{d, e.}	EPA820/B-96-001	16065831	TT	---	---	322 311	42 101
Copper ^{d, e.}	65FR31682	7440508	TT	---	---	7.0 8.8	4.95 6.24
Cyanide	EPA820/B-96-001 68FR75510	57125	TT	140 700	140 220,000	22 ⁿ	5.2 ⁿ
Iron ^{c.}	EPA 440/5-86-001	7439896	TT	300 (added)	---	---	1,000
Lead ^{d, e.}	65FR31682	7439921	TT	---	---	30.1	1.17
Mercury	62FR42160 EPA 440/5-86-001	7439976	TT/BC	0.14	0.15	1.4 ^{d.f.} 2.4	0.012 (1986)
Methylmercury (added)	EPA823-R-01-001	22967926	---	---	0.3 mg/kg ^{l.}	---	---
Nickel ^{d, e.}	65FR31682	7440020	TT	610	4,600	260 786	29 87.4
Selenium	62FR42160 65FR31682 65FR66443	7782492	TT	170 (added)	4200 (added)	i. 20	5
Silver ^{d, e.}	65FR31682	7440224	TT	---	---	1.02 1.05	---

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Thallium	68FR75510	7440280	TT	0.24 - 1.7	0.47 - 6.3	---	---
Zinc ^{d, e}	65FR31682	7440666	TT	---	---	65.13 - 63.5	65.6 - 58.0
<i>Volatile Organic Compounds</i>							
Acrolein	74FR27535 74FR46587	107028	TT	6 - 320	9 - 780	3 (added)	3 (added)
Acrylonitrile	65FR66443	107131	C	0.051 ^h - 0.059	0.25 ^h - 0.66	---	---
Benzene	IRIS 01/19/00 65FR66443	71432	A	2.2 ^h - 1.2	51 ^h - 7.1	---	---
Bromoform	65FR66443	75252	C	4.3 ^h	140 ^h - 360	---	---
Carbon Tetrachloride	65FR66443	56235	C	0.23 ^h - 0.25	1.6 ^h - 4.4	---	---
Chlorodibromomethane	65FR66443	124481	C	0.40 ^h - 0.41	13 ^h - 3.4	---	---
Chloroform	62FR42160	67663	C	5.7	470	---	---
Dichlorobromomethane	65FR66443	75274	C	0.55 ^h - 0.27	17 ^h - 2.2	---	---
1,2-Dichloroethane	65FR66443	107062	C	0.38 ^h	37 ^h - 99	---	---
1,1-Dichloroethylene	68FR75510	75354	C	330 - 0.057	7,100 - 3.2	---	---
1,2-Dichloropropane (added)	65FR66443	78875	---	0.50 ^h	15 ^h	---	---
1,3-Dichloropropylene	68FR75510	542756	TT	0.34 - 10	21 - 1,700	---	---
Ethylbenzene	68FR75510	100414	TT	530 - 3,100	2,100 - 29,000	---	---
Methyl Bromide	65FR66443	74839	TT	47 ^h - 48	1,500 ^h - 4,000	---	---

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Methylene Chloride	65FR66443	75092	C	4.6 ^h 4.7	590 ^h 1,600	---	---
Monochlorobenzene	68FR75510	108907	TT	130 680	1,600 21,000	---	---
1,1,2,2-Tetrachloroethane	65FR66443	79345	C/BC	0.17 ^h	4.0 ^h 11	---	---
Tetrachloroethylene	65FR66443	127184	C	0.69 0.8	3.3 8.85	---	---
Toluene	68FR75510	108883	TT	1,300 6,800	15,000 200,000	---	---
1,2-Trans-Dichloroethylene (added)	68FR75510	156605	---	140	10,000	---	---
1,1,2-Trichloroethane	65FR66443	79005	C	0.59 ^h 0.60	16 ^h 42	---	---
Trichloroethylene	65FR66443	79016	C	2.5 2.7	30 81	---	---
<i>Acid Organic Compounds</i>							
Vinyl Chloride	68FR75510	75014	C	0.025 2	2.4 525	---	---
2-Chlorophenol (added)	65FR66443	95578	---	81 ^h	150 ^h	---	---
2,4-Dichlorophenol	65FR66443	120832	TT	77 ^h 93	290 ^h 790	---	---
2,4-Dimethylphenol (added)	65FR66443	105679	---	380 ^h	850 ^h	---	---
2,4 Dinitrophenol	65FR66443	51285	TT	69 ^h 70	5,300 ^h 14,000	---	---
2-Methyl-4,6-Dinitrophenol	65FR66443	534521	TT	13 13.4	280 765	---	---
Pentachlorophenol	65FR31682 65FR66443	87865	C/BC	0.27 ^h 0.28	3.0 ^h 8.2	exp(1.005-(pH)-4.86) 19 ^k	exp(1.005-(pH)-5.13) 15 ^k
Phenol	74FR27535	108952	TT	10,000 21,000 ^h	860,000 4.6x10 ⁶	---	---
Nonylphenol (added)	EPA-822-F05-003	84852153	C/BC	28	6.6		

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			Tox Class	Consumption of Water & Organisms	Consumption of Organisms Only	Maximum Allowable Concentration - Acute Criteria ^a	Average Allowable Concentration - Chronic Criteria ^a
2,4,6-Trichlorophenol	65FR66443	88062	C/BC	1.4 ^h 2.4	2.4 ^h 6.5	---	---
<i>Base Neutral Compounds</i>							
Acenaphthene (added)	65FR66443	83329	---	670 ^h	990 ^h	---	---
Anthracene	65FR66443	120127	TT/BC	8,300 ^h 9,600	40,000 ^h 110,000	---	---
Benzidine	65FR66443	92875	A	0.000086 ^h 0.00012	0.00020 ^h 0.00054	---	---
Benzo(a)Anthracene	65FR66443	56553	C/BC	0.0038 ^h 0.0028	0.018 ^h 0.031	---	---
Benzo(a)Pyrene	65FR66443	50328	C/BC	0.0038 ^h 0.0028	0.018 ^h 0.031	---	---
Benzo(b)Fluoranthene	65FR66443	205992	C/BC	0.0038 ^h 0.0028	0.018 ^h 0.031	---	---
Benzo(k)Fluoranthene	65FR66443	207089	C/CB	0.0038 ^h 0.0028	0.018 ^h 0.031	---	---
Bis(2-Ethylhexyl)Phthalate	65FR66443	117817	C/BC	1.2 ^h 1.8	2.2 ^h 5.9	---	---
Butylbenzyl Phthalate ^w	IRIS 02/01/93	85687	C/BC	1,500 ^h	1,900 ^h		
Chloroethyl ether (Bis-2)	65FR66443	111444	C	0.031 ^h	0.53 ^h 1.4	---	---
Chloroisopropyl ether(Bis-2)	65FR66443	108601	TT	1,400 ^h	65,000 ^h 170,000	---	---
Chrysene	65FR66443	218019	C/BC	0.0038 ^h 0.0028	0.018 ^h 0.031	---	---
Dibenzo(a,h)Anthracene	65FR66443	53703	C/BC	0.0038 ^h 0.0028	0.018 ^h 0.031	---	---
1,2-Dichlorobenzene	68FR75510	95501	TT/BC	420 2,700	1,300 17,000	---	---
1,3-Dichlorobenzene	65FR66443	541731	TT/BC	320 400	960 2,600	---	---
1,4-Dichlorobenzene	68FR75510	106467	TT/BC	63 400	190 2,600	---	---
3,3'-Dichlorobenzidine	65FR66443	91941	C/BC	0.021 ^h 0.04	0.028 ^h 0.077	---	---

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			Tox Class	Consumption of Water & Organisms	Consumption of Organisms Only	Maximum Allowable Concentration - Acute Criteria ^a	Average Allowable Concentration - Chronic Criteria ^a
Diethyl Phthalate	65FR66443	84662	TT	17,000 ^h 23,000	44,000 ^h 120,000	---	---
Dimethyl Phthalate	65FR66443	131113	TT	270,000 343,000	1,100,000 2,900,000	---	---
Di-n-butyl Phthalate	65FR66443	84742	TT/BC	2,000 2,700	4,500 12,000	---	---
2,4-Dinitrotoluene	65FR66443	121142	C	0.11	3.4 9.10	---	---
1,2-Diphenylhydrazine	65FR66443	122667	C	0.036 ^h 0.040	0.2 ^h 0 0.54	---	---
Fluoranthene	65FR66443	206440	TT/BC	130 ^h 300	140 ^h 370	---	---
Fluorene	65FR66443	86737	TT/BC	1,100 ^h 1,300	5,300 ^h 14,000	---	---
Hexachlorobenzene	65FR66443	118741	C/BC	0.00028 0.00075	0.00029 0.00077	---	---
Hexachlorobutadiene	65FR66443	87683	C/BC	0.44 ^h	18 ^h 50	---	---
Hexachlorocyclopentadiene	68FR75510	77474	TT/BC	40 240	1,100 17,000	---	---
Hexachloroethane	65FR66443	67721	C/BC	1.4 ^h 1.9	3.3 ^h 8.9	---	---
Indeno(1,2,3-cd)Pyrene	65FR66443	193395	C/BC	0.0038 ^h 0.0028	0.018 ^h 0.031	---	---
Isophorone	65FR66443	78591	TT	35 ^h 8.4	960 ^h 600	---	---
Nitrobenzene	65FR66443	98953	TT	17 ^h	690 ^h 1,900	---	---
N-Nitrosodimethylamine	65FR66443	62759	C	0.00069 ^h	3.0 ^h 8.1	---	---
N-Nitrosodi-n-Propylamine	65FR66443	621647	---	0.0050 ^h	0.51 ^h	---	---
N-Nitrosodiphenylamine	65FR66443	86306	C	3.3 ^h 5.0	6.0 ^h 16	---	---
Pyrene	68FR75510	129000	TT/BC	830 ^h 960	4,000 ^h 11,000	---	---
1,2,4-Trichlorobenzene (added)	68FR75510	120821	---	35	70	---	---

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			Tox Class	Consumption of Water & Organisms	Consumption of Organisms Only	Maximum Allowable Concentration - Acute Criteria ^a	Average Allowable Concentration - Chronic Criteria ^a
<i>Pesticides/PCBs</i>							
Aldrin	65FR31682 65FR66443	309002	C/BC	0.000049 ^h 0.00013	0.000050 ^h 0.00014	(added) 3.0 ^b	---
Carbaryl	EPA-820-R-12-007	63252	TT			2.1	2.1
Chlordane	65FR31682 65FR66443	57749	C/BC	0.00080 ^h 0.00057	0.00081 ^h 0.00059	2.4 ^b	.004 ^b
Chlorpyrifos ^c	EPA 440/5-86-001	2921882	---	---	---	0.083	0.041
4,4'-DDT	65FR31682 65FR66443	50293	C/BC	0.00022 ^h 0.00059	0.00022 ^h 0.00059	1.1 ^b	0.001 ^b
4,4'-DDE	65FR66443	72559	C/BC	0.00022 ^h 0.00059	0.00022 ^h 0.00059	---	---
4,4'-DDD	65FR66443	72548	C/BC	0.00031 ^h 0.00083	0.00031 ^h 0.00084	---	---
Demeton ^c	EPA 440/5-86-001	8065483	---	---	---	---	0.1
Diazinon	EPA-822-R-05-006	333415	TT			0.17	0.17
Dieldrin	65FR31682 65FR66443	60571	C	0.000052 ^h 0.00014	0.000054 ^h 0.00014	0.24	0.056
alpha-Endosulfan	65FR31682 65FR66443	959988	TT	62 ^h 0.93	89 ^h 2.0	0.22 ^b	0.056 ^b
beta-Endosulfan	65FR31682	33213659	TT	62 ^h 0.93	89 ^h 2.0	0.22 ^b	0.056 ^b

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	65FR66443						
Endosulfan Sulfate	65FR66443	1031078	TT	62 ^h 0.93	89 ^h 2.0	---	---
Endrin	65FR31682 68FR75510	72208	TT	0.59 0.76	0.060 0.81	0.086 0.18	0.036 0.0023
Endrin Aldehyde	65FR66443	7421934	TT	0.29 ^h 0.76	0.30 ^h 0.81	---	---
Heptachlor	65FR31682 65FR66443	76448	C	0.000079 ^h 0.00021	0.000079 ^h 0.00021	0.52 ^b	0.0038 ^b
Heptachlor Epoxide	65FR31682 65FR66443	1024573	C	0.000039 ^h 0.00010	0.000039 ^h 0.00011	0.52 ^b	0.0038 ^b
Benzene hexachloride-alpha	65FR66443	319846	C/BC	0.0026 ^h 0.0039	0.0049 ^h 0.013	---	---
Benzene hexachloride-beta	65FR66443	319857	C/BC	0.0091 ^h 0.014	0.017 ^h 0.046	---	---
Benzene hexachloride-gamma (Lindane)	65FR31682 68FR75510	58899	TT/BC	0.98 0.019	1.8 0.063	0.95 2.0	--- 0.8 (remove)
Malathion ^c	EPA 440/5-86-001	121755	---	---	---	---	0.1
Parathion ^c	EPA 440/5-86-001	56382	---	---	---	0.065	0.013
Total PCB's ^m	65FR31682 65FR66443	53469219	C/BC	0.000064 ^h 0.000044	0.000064 ^h 0.000045	---	0.014 ^b
PCB-1242	65FR31682 65FR66443	53469219	C/BC	0.000064 0.000044	0.000064 0.000045	---	0.014 ^b

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PCB-1254	65FR31682 65FR66443	11097691	C/BC	0.000064 0.000044	0.000064 0.000045	---	0.014 ^b
PCB-1221	65FR31682 65FR66443	11104282	C/BC	0.000064 0.000044	0.000064 0.000045	---	0.014 ^b
PCB-1232	65FR31682 65FR66443	11141165	C/BC	0.000064 0.000044	0.000064 0.000045	---	0.014 ^b
PCB-1248	65FR31682 65FR66443	12672296	C/BC	0.000064 0.000044	0.000064 0.000045	---	0.014 ^b
PCB-1260	65FR31682 65FR66443	11096825	C/BC	0.000064 0.000044	0.000064 0.000045	---	0.014 ^b
PCB-1016	65FR31682 65FR66443	12674112	C/BC	0.000064 0.000044	0.000064 0.000045	---	0.014 ^b
Dioxin (2,3,7,8-TCDD)	65FR66443	1746016	C/BC	5.0x10 ⁻⁹ -0.13x10 ^{-z}	5.1x10 ⁻⁹ -0.14x10 ^{-z}	---	---
Toxaphene	65FR31682 65FR66443	8001352	C/BC	0.00028 ^h 0.00073	0.00028 ^h 0.00075	0.73	0.0002
<i>Other Substances</i>							
Ammonia ^c	EPA822-R-99-014 EPA 822-R-13-001	7664417	---	---	---	see EPA April 2013 water quality criteria document for Ammonia	
Asbestos	57FR60848	1332214	A	7 million fibers/L	---	---	---
Barium ^c (added)	EPA 440/5-86-001	7440393	---	1,000 (added)	---	---	---
Chlorine ^c	EPA 440/5-86-	7782505	---	---	---	19	11

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	001						
Chloride ^c (added)	53FR19028	16887006	---	---	---	860,000 (added)	230,000 (added)

GENERAL NOTES:

This Appendix has been updated to reflect USEPA recommendations as of October 2012. These recommendations were published in “National Recommended Water Quality Criteria,” and can be found at <http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm>

The most significant changes from previous versions of Appendix C are to Human Health criteria and reflect EPA’s new methodology for deriving human health criteria (Methodology for Deriving Ambient Water Quality for the Protection of Human Health” (2000), EPA-822-B-00-004, October, 2000) as published in 65 FR 66443. Additional notes and information concerning these criteria can be found in the documents referenced here. Equations used to calculate hardness-dependent metal criteria have been updated (Appendix E) and factors for converting total recoverable-based to dissolved-based criteria for metals (Appendix D) have been added to reflect current recommendations of USEPA.

“FR Cite/Source” citations have been added to all criteria. This citation refers to the EPA publication from which the criteria are derived. The “Gold Book” is Quality Criteria for Water: 1986. EPA 440/5-86-001.

Chemical Abstracts Service (CAS) registry numbers have been added to Appendix C. CAS numbers provide a unique identification for each chemical.

Tox Class - designated toxicity class for substance: A=Class A carcinogen (known human carcinogen); C=Carcinogenic (probable or possible human carcinogen); TT=Threshold Toxicant (not a known or probable carcinogen); BC=High potential to bioconcentrate or bioaccumulate;

Carcinogenic - for those toxic substances which are identified as carcinogens (A or C) the criteria have been established at a risk level of 10^{-6} assuming a lifetime exposure to a 70 Kg male consuming 17.5 grams per day of fish and shell-fish products and ingesting 2.0 liters of water per day.

Threshold Toxicants - for those toxic substances which are identified as non-carcinogens (TT) the criteria are best estimates of concentrations which are not expected to produce adverse effects in human health assuming a lifetime exposure to a 70 Kg male consuming 17.5 grams per day of fish and shell-fish products and ingesting 2.0 liters of water per day.

Footnotes:

- a. Maximum Allowable Concentration (MAC) = the highest concentration of a pollutant to which aquatic life can be exposed for a short period of time (1-hour average) **once every three years** without deleterious effects. Average Allowable Concentration (AAC) - the highest concentration of a pollutant to which aquatic life can be exposed for an extended period of time (4 days) **once every three years** without deleterious effects. $\mu\text{g/l}$ = micrograms per liter. The MAC is the equivalent to the Federal Criteria Maximum Concentration (CMC) and the AAC is equivalent to the Federal Criteria Continuous Concentration (CCC).
- b. The aquatic life criteria for this compound were developed in 1980 using 1980 EPA guidelines for criteria development. The MAC (CMC) or acute value shown is a final acute value (FAV) which by the 1980 guidelines is an instantaneous value.
- c. Compound is not listed in EPA's Section 304(a) Criteria for Priority Toxic Pollutants as published in the December 22, 1992, pages 60911-60917, of the Federal Register but is included in Appendix C of the Vermont Water Quality Standards because the pollutant can be deleterious to aquatic life and criteria have been developed for the protection of aquatic organisms.

- d. Criteria for this metal are expressed in terms of dissolved metal in the water column. Dissolved metal concentrations in the water column can be determined analytically or can be estimated from total metal concentrations using the conversion factors in Appendix D.
- e. Aquatic life criteria for this metal is expressed as a function of total hardness (mg/l as CaCO₃) in the water column and as a function of the pollutant's water effect ratio, WER, as defined in §131.36(c). Unless otherwise determined by the Secretary, in a manner consistent with the most current USEPA guidance, the WER shall be 1.0. The specific value given here corresponds to a hardness of 50 mg/l. Criteria values for other hardness may be calculated from the equations shown in Appendix E.
- f. This criterion was derived from data for inorganic mercury (II) but is applied here to total mercury.
- g. Vermont promulgated numerical criteria for arsenic based on freshwater fish species bioconcentration factors (BCF). A BCF of 4 was used to calculate human health protection criteria.
- h. This criterion has been revised to reflect The Environmental Protection Agency's q1* or RfD, as contained in the Integrated Risk Information System (IRIS) as of May 17, 2002. The fish tissue bioconcentration factor (BCF) from the 1980 Ambient Water Quality Criteria document was retained in each case.
- i. The $MAC = 1/[(f1/MAC1) + (f2/MAC2)]$ where f1 and f2 are the fractions of total selenium that are treated as selenite and selenate, respectively, and MAC1 and MAC2 are 185.9 g/l and 12.82 g/l, respectively. This value for selenium is expressed in terms of total recoverable metal in the water column. It can be expressed in terms of dissolved metal by using the conversion factor (0.996- MAC or 0.922- AAC).
- j. This human health criterion is the same as originally published in the Red Book which predates the 1980 methodology and did not utilize the fish ingestion BCF approach. This same criterion value is now published in the Gold Book.
- k. Freshwater aquatic life values for pentachlorophenol are expressed as a function of pH, and are calculated as follows: $MAC = \exp(1.005(pH)-4.869)$; $AAC = \exp(1.005(pH)-5.134)$. Values displayed in table correspond to a pH of 7.8.
- l. This fish tissue residue criterion for methylmercury is used for the purpose of determination of attainment pursuant to these Standards. Fish consumption advisory guidance for mercury in fish taken from the waters of Vermont is developed by the Vermont Department of Health and is available on their website.
- m. These criteria apply to total PCB's (e.g. the sum of all congener or all isomer or homolog or Arochlor analyses).
- n. These criteria expressed as ug free cyanide (as CN)/l.

Appendix D: Conversion factors for estimating dissolved metals from total values. To convert total metal values to dissolved metal, multiply total metal values/concentrations by the conversion factor listed (or calculated) in the table below. Alternative methods for translating total to dissolved values following USEPA guidance (“The Metals Translator: Guidance for Calculating a Total Recoverable Metals Permit Limit from a Dissolved Criterion”; EPA 823-B-96-007) may be considered on a case-by-case basis.

Metal	Conversion Factor for MAC	Conversion Factor for AAC
Arsenic	1.0	
Cadmium	$1.136672 - [(\ln \text{hardness})(0.041838)]$	$1.101672[(\ln \text{hardness})(0.041838)]$
Chromium III	0.316	0.860
Chromium VI	0.982	0.962
Copper	0.96	0.96
Lead	$1.46204 - [(\ln \text{hardness})(0.145712)]$	$1.46203 - [(\ln \text{hardness})(0.145712)]$
Mercury	0.85	0.85
Nickel	0.998	0.997
Selenium	---	---
Silver	0.85	---
Zinc	0.978	0.986

Appendix E: Parameters for Calculating Freshwater **Total** Metals Criteria that are Hardness-Dependent. MAC and AAC values are calculated using the equations below the table and inserting the metal-specific values shown in the table.

Metal	m_A	b_A	m_C	b_C
Cadmium	1.0166 1.128	-3.924 -3.828	0.7409 0.7852	-4.719 -3.49
Chromium III	0.8190	3.7256 3.688	0.8190	0.6848 1.561
Copper	0.9422	-1.700 -1.464	0.8545 0.9422	-1.702 -1.465
Lead	1.273	-1.460	1.273	-4.705
Nickel	0.8460	2.255 3.3610	0.8460	0.0584 1.1645
Silver	1.72	-6.59 -6.52	---	---
Zinc	0.8473	0.884 0.8604	0.8473	0.884 0.7614

Hardness-dependent metals criteria can be calculated from the following equations:

$$\text{MAC (dissolved)} = \exp\{m_A [\ln (\text{hardness})] + b_A\} \text{ (Conversion Factor from Appendix D)}$$

$$\text{AAC (dissolved)} = \exp\{m_C [\ln (\text{hardness})] + b_C\} \text{ (Conversion Factor from Appendix D)}$$