

Rationale for Proposed Revisions to Cadmium Criteria for Ambient Water Quality

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RATIONALE FOR PROPOSED REVISIONS TO THE WATER QUALITY CRITERIA FOR CADMIUM

Introduction

Nevada state law (Nevada Revised Statutes [NRS] 445A.520) requires the state to establish water quality standards to protect beneficial uses of surface waters of the state. Additionally, Section 303 of the Clean Water Act and other Federal regulations (40 Code of Federal Regulations [CFR] Part 131) require that States and authorized tribes routinely review and, as appropriate, modify water quality standards that protect the designated uses of surface waters. Such standards also provide a basis for controlling discharges or releases of pollutants into a waterbody.

The U.S. Environmental Protection Agency (EPA) has, through Section 303 of the Clean Water Act, delegated authority to Nevada to establish water quality standards for all waterbodies or segments of waterbodies within the state. Additionally, the Clean Water Act requires that EPA periodically update water quality criteria. Criteria are an important component of the water quality standards, which consist of (1) designated beneficial uses, (2) numeric or narrative criteria that are protective these uses and (3) antidegradation provisions.

In March 2016, EPA published the final report updating the criterion to protect aquatic life from the toxic effects of cadmium, as "***Aquatic Life Ambient Water Quality Criteria Cadmium – 2016*** (EPA 2016). EPA had previously updated the criteria for cadmium in 2001. EPA based the 2016 update on data that have become available since 2001. EPA identified more than 100 new studies published prior to 2016 containing acute and chronic toxicity data for aquatic life exposed to dissolved cadmium. The 2016 update incorporates data for 75 new species and 49 new genera. EPA also updated the relationship of cadmium toxicity to total hardness using results from these studies.

In preparation for adopting the EPA's updated 2016 criteria, this rationale prepared by the Nevada Division of Environmental Protection (NDEP), Bureau of Water Quality Planning (BWQP) reviews and discusses the revisions proposed to update Nevada's water quality standards for cadmium. It is not until EPA approval and adoption of the revisions as part of the State water quality standards that the criteria values become regulatory.

Background

Water quality standards establish numeric criteria for cadmium to protect aquatic life from the toxic effects of exposure to dissolved cadmium. These criteria values represent the concentrations of cadmium that should not be exceeded in a waterbody, and are based on the results of toxicity testing on aquatic organisms. The toxicity of cadmium is moderated by the presence of calcium and magnesium ions, which together constitute the parameter known as hardness. Beginning with the 1980 criteria for cadmium, hardness has been incorporated into the equations for calculating the criteria (Table 1).

1980 Ambient Water Quality Criteria for Cadmium (EPA 1980)

In 1980, EPA first published numeric criteria to protect aquatic life from cadmium in freshwater and saltwater systems. Freshwater criteria were provided in units of micrograms per liter ($\mu\text{g/L}$) for chronic and acute exposure. These criteria were based on exposures under variable amounts of hardness. The 1980 document established numeric criteria for total recoverable cadmium in freshwater and saltwater aquatic systems. EPA noted that cadmium may be present at low concentrations (less than $0.01 \mu\text{g/L}$) in natural waters, but may be present at concentrations of several micrograms per liter or more in polluted waters and under acidic conditions.

An exponential equation was used to describe the observed relationship between hardness and the toxicity of cadmium in fresh water. EPA noted that hardness appeared to similarly affect both the acute and chronic toxicity of cadmium.

1984 Ambient Water Quality Criteria for Cadmium (EPA 1985)

The toxicity of cadmium in aquatic systems is highly dependent upon site-specific factors, including pH and hardness. By 1984, EPA recognized that using measurements obtained for “total recoverable” concentrations of cadmium was probably “...*too rigorous in some situations.*” EPA stated that “acid-soluble cadmium” “...*is probably the best measurement at the present.*” and gave several reasons for this assertion. Specifically, EPA noted that measures of acid-soluble cadmium were “compatible with all available data concerning toxicity of cadmium” and that “*measurement of acid-soluble cadmium should measure all forms of cadmium that are toxic to aquatic life.*”

Other ions in solution affect the toxicity of cadmium to aquatic organisms. Once again, hardness was used as a surrogate for the ions that affect the results of toxicity tests on cadmium. In all cases, the calculated criteria concentrations (acute and chronic exposures) were greater than those presented in the 1980 criteria document, across a range of hardness values. However, despite advocating use of “acid-soluble” cadmium, the EPA document concluded that:

“EPA believes that a measurement such as “acid-soluble” would provide a more scientifically correct basis upon which to establish criteria for metals. The criteria were developed on this basis. However, at this time, no EPA approved methods for such a measurement are available to implement the criteria through the regulatory programs of the Agency and the States. The Agency is considering development and approval of methods for a measurement such as “acid-soluble.” Until available, however, EPA recommends applying the criteria using the total recoverable method.”

Table 1. History of EPA's Recommended Ambient Water Quality Criteria for Protection of Aquatic Life from Cadmium

Year	Acute		Chronic		Form
	Equation	Duration	Equation	Duration	
1980	$e^{(1.05(\ln \text{hardness}) - 3.73)}$	Any time	$e^{(1.05(\ln \text{hardness}) - 8.53)}$	24-hr avg	Total recoverable
1985	$e^{(1.128(\ln \text{hardness}) - 3.828)}$	1-hr avg	$e^{(0.7852(\ln \text{hardness}) - 3.490)}$	4-day avg	Total recoverable
1996	$e^{(1.128(\ln \text{hardness}) - 3.6867)}$	1-hr avg	$e^{(0.7852(\ln \text{hardness}) - 2.715)}$	4-day avg	Total recoverable
2001	$1.136672 - ((\ln \text{hardness}) * (0.041838)) * e^{(1.0166 * (\ln \text{hardness}) - 3.924)}$	1-hr avg	$1.101672 - ((\ln \text{hardness}) * (0.041838)) * e^{(0.7409 * (\ln \text{hardness}) - 4.719)}$	4-day avg	Dissolved
2016	$1.136672 - ((\ln \text{hardness}) * (0.041838)) * e^{(0.9789 * (\ln \text{hardness}) - 3.866)}$	1-hr avg	$1.101672 - ((\ln \text{hardness}) * (0.041838)) * e^{(0.7977 * (\ln \text{hardness}) - 3.909)}$	4-day avg	Dissolved

1980. Ambient Water Quality Criteria for Cadmium. EPA 440/5-80-025. October.

1985. Ambient Water Quality Criteria for Cadmium -1984. EPA 440/5-84-032. January.

1996. 1995 Updates: Water Quality Criteria Documents for the Protection of Aquatic Life in Ambient Water. EPA-820-B-96-001. September.

2001. 2001 Update of Ambient Water Quality Criteria for Cadmium. EPA-822-R-01-001. April.

2016. Aquatic Life Ambient Water Quality Criteria Cadmium - 2016. EPA-820-R-16-002. March.

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1995 Ambient Water Quality Criteria for Cadmium (EPA 1996)

In 1995, EPA provided updates to ambient criteria for a suite of toxic chemicals, including cadmium, for protection of aquatic life. This update continued use of data for “total recoverable” cadmium in the equations. Toxicity remained related to hardness, using the slope derived in the 1985 criteria calculations. Values of both the acute and chronic criteria were higher than those calculated in 1985. Exposure durations remained as a four-day average for chronic criteria and a one-hour average for acute criteria, with a frequency of not more than once every three years.

2001 Ambient Water Quality Criteria for Cadmium (EPA 2001)

The criteria recommended by EPA in 2001 used, for the first time, formulas based on data for concentrations of dissolved cadmium. This modification required the addition of a “conversion factor” to adapt the equations for use with data for dissolved cadmium (see EPA 2001). The 2001 criteria calculations continued to use hardness as a surrogate for the ions that affect the results of toxicity tests on cadmium. However, EPA emphasized that the hardness adjustment is more of an estimation than a precise measurement. EPA reiterated that *“When evaluating time-variable ambient concentrations generally, 1-hour average concentration are considered to be appropriate for comparison with the acute criterion, and 4-day averages with the chronic criterion. The allowable frequency for exceeding a criterion is set at once every three years, on the average.”*

The 2001 criteria values were based on dissolved cadmium and were considerably lower than the previous 1995 values, which were based on “total recoverable” cadmium. As noted above, the criteria equation must be modified for use with data for dissolved cadmium. The conversion factor contributes a multiplier that is generally less than 1.0, so the resulting criteria for use with dissolved cadmium data are less than the values for total recoverable cadmium for all hardness values.

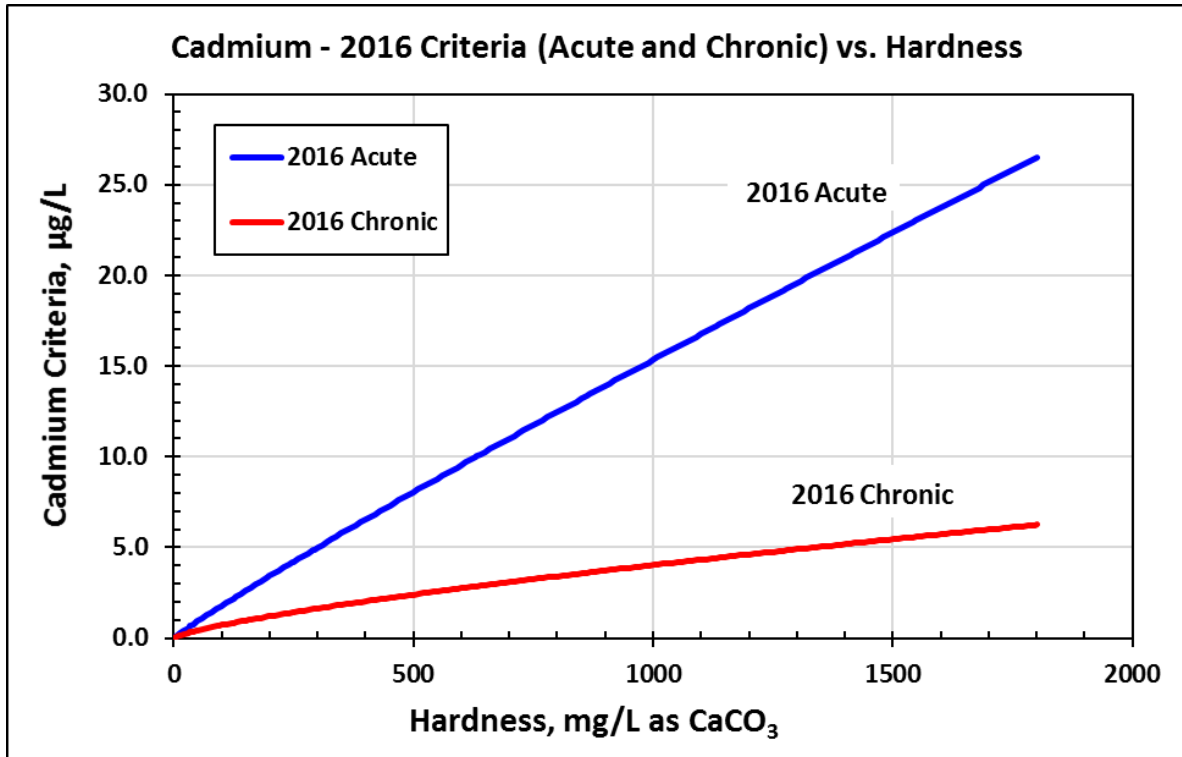
2016 Ambient Water Quality Criteria for Cadmium (EPA 2016)

In 2016, EPA published **“Aquatic Life Ambient Water Quality Criteria Cadmium – 2016”** for protection of aquatic life from acute and chronic exposure to cadmium in the water column. This final 2016 document considered all ecological studies published since the previous criterion was issued in 2001, and was refined by public comments and external peer review of the draft criteria document released in 2015. The criteria values and the calculations used to derive criteria values supersede all previous versions of the aquatic-life criteria for cadmium.

As with all previous updates of criteria values for cadmium, hardness is used in the 2016 criteria to estimate the effects of all ions on the toxicity of cadmium. EPA guidelines state that *“when sufficient data are available to demonstrate that toxicity is related to a water-quality characteristic, the relationship should be taken into account using an analysis of covariance.”* In its simplest form, the relationship between the independent variable (hardness) and the dependent variable (toxicity, as

quantified by cadmium criteria concentrations) can be described by the coefficient of determination (R^2). In the case of cadmium, toxicity is inversely correlated with hardness; that is, as hardness values increase, the toxicity of cadmium decreases. This means that cadmium criteria concentrations are higher in waters with higher values of hardness, for both acute and chronic exposures (Figure 1).

Figure 1. Calculated 2016 Criteria Values for Acute and Chronic Exposures versus Hardness.



Nevada's Current Water Quality Criteria for Cadmium

Cadmium is grouped into the category of "toxics," which have statewide values (or formulas) established to be protective of aquatic life (i.e., aquatic-life beneficial use). Nevada's current water quality standards for exposure of aquatic life to cadmium are based on EPA's previously promulgated criteria (EPA 2001). The current water quality standards for cadmium were accepted into NAC 445A.144 (now NAC 445A.1236) in 2006 and were approved by the EPA in a letter received by the NDEP on May 21, 2007.

Nevada's current cadmium criteria, based on EPA's 2001 criteria, are described in the following equations for acute and chronic exposures:

$$\text{Acute} = 1.136672 - ((\ln \text{ hardness}) * (0.041838)) * e^{(1.0166 * (\ln \text{ hardness}) - 3.924)}$$

$$\text{Chronic} = 1.101672 - ((\ln \text{ hardness}) * (0.041838)) * e^{(0.7409 * (\ln \text{ hardness}) - 4.719)}$$

Nevada's Proposed Water Quality Criteria for Cadmium

EPA's updated 2016 criteria, as proposed for adoption into Nevada's standards, are described in the following equations for acute and chronic exposures:

$$\text{Acute} = 1.136672 - ((\ln \text{ hardness}) * (0.041838)) * e^{(0.9789 * (\ln \text{ hardness}) - 3.866)}$$

$$\text{Chronic} = 1.101672 - ((\ln \text{ hardness}) * (0.041838)) * e^{(0.7977 * (\ln \text{ hardness}) - 3.909)}$$

Comparison of the calculated values for cadmium criteria using the 2001 and 2016 formulas is best described graphically. In general, the 2016 criteria values for acute exposures to aquatic life are slightly lower than the 2001 criteria values for acute exposures (Figure 2). However, the 2016 criteria values for chronic exposure to aquatic life are consistently greater than the 2001 values (Figure 3). (The "D" in the legend of the graphs below denote that the criteria values are for concentrations of dissolved cadmium.)

Figure 2. Comparison of Criteria Values for Acute Exposures, 2001 versus 2016.

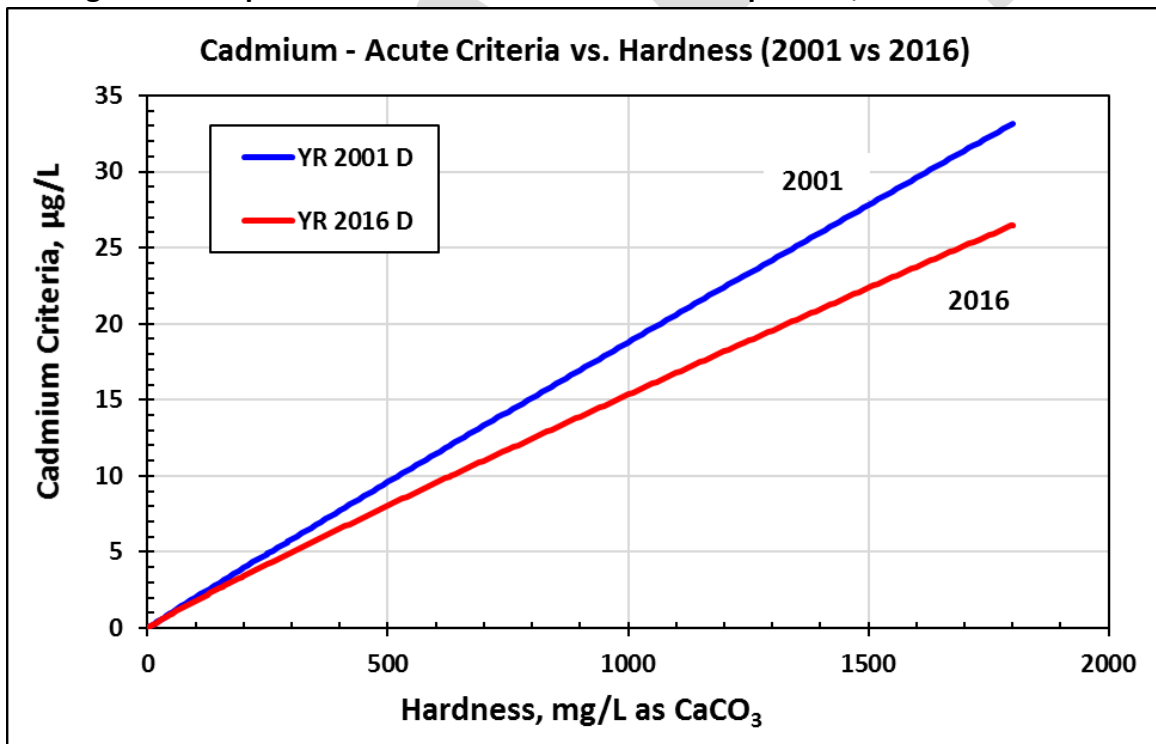
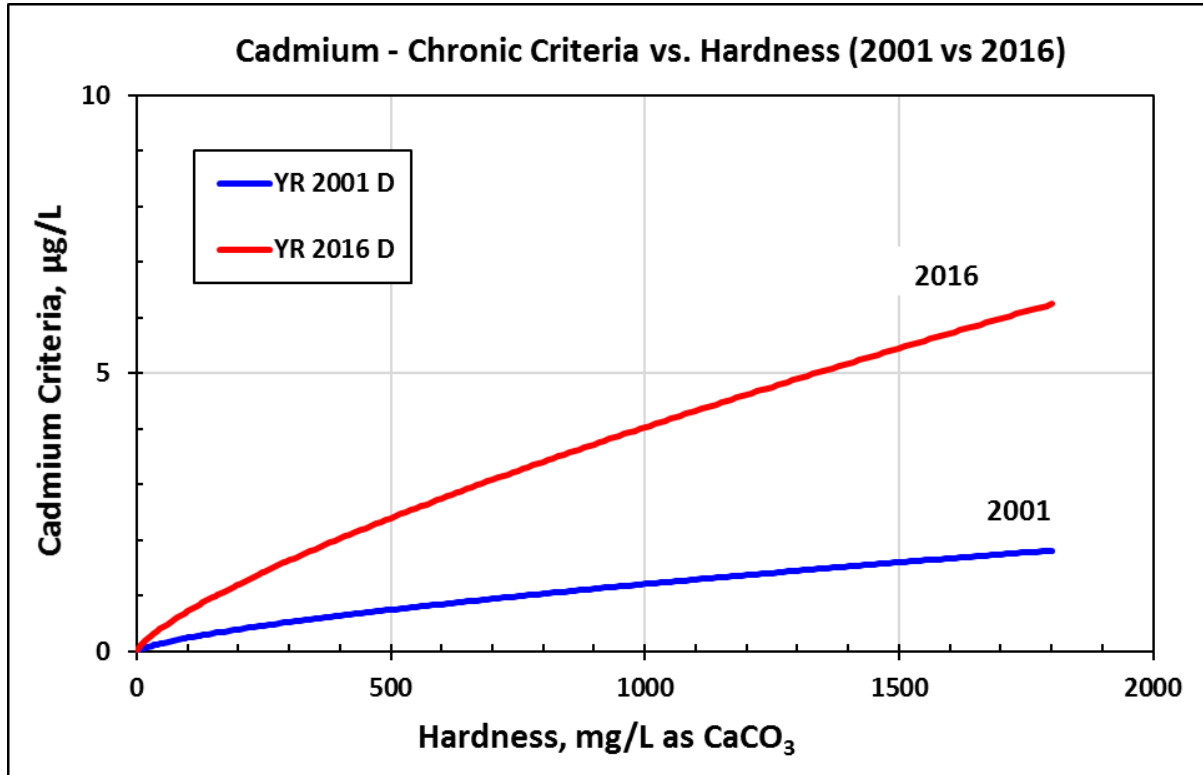


Figure 3. Comparison of Criteria Values for Chronic Exposures, 2001 versus 2016.



This petition seeks to adopt the EPA's updated criteria for aquatic-life exposures to dissolved cadmium (EPA, 2016) into the NAC.

Summary

EPA's water quality regulations at 40 CFR 131.11(a)(1) require states to adopt protective criteria that are based on scientifically defensible rationale. Such criteria must contain sufficient parameters or constituents to protect the designated use. Nevada's existing cadmium criteria for the protection of aquatic life as a beneficial use are based on EPA criteria published in 2001. In 2016, EPA published updated cadmium criteria, which reflect results of significant research and peer review that have taken place since the 2001 cadmium criteria were promulgated.

The NDEP is proposing to amend Nevada Administration Code (NAC) 445A.070 – 445A.2234, Standards for Water Quality, to align with the most-current numeric criteria recommended by the EPA for cadmium to protect the aquatic-life beneficial use of waterbodies in Nevada. Adoption of EPA's 2016 recommendations by the State of Nevada will ensure that the most appropriate level of protection is provided for aquatic life in Nevada's surface waters. The proposed revisions to the NAC include the following:

Table 2 Example of NAC 445A.1236 showing the proposed changes

Chemical	Municipal or Domestic Supply (µg/l)	Aquatic Life ^(1,2) (µg/l)	Irrigation (µg/l)	Watering of Livestock (µg/l)
INORGANIC CHEMICALS⁽³⁾				
Antimony	146 ^a	-	-	-
Arsenic	50 ^b	-	100 ^c	200 ^d
1-hour average	-	340 ^{e,(4)}	-	-
96-hour average	-	150 ^{e,(4)}	-	-
Barium	2,000 ^b	-	-	-
Beryllium	0 ^a	-	100 ^c	-
Boron	-	-	750 ^a	5,000 ^d
Cadmium	5 ^b	-	10 ^d	50 ^d
1-hour average	-	$(1.136672 - \{\ln(\text{hardness})(0.041838)\})$ $*e^{(1.0166 - 0.9789\{\ln(\text{hardness})\} - 3.924 - 3.866)}$ e,(4)	-	-
96-hour average	-	$(1.101672 - \{\ln(\text{hardness})(0.041838)\})$ $*e^{(0.7409 - 0.7977\{\ln(\text{hardness})\} - 4.719 - 3.909)}$ e,(4)	-	-
Chromium (total)	100 ^b	-	100 ^d	1,000 ^d
Chromium (VI)	-	-	-	-
1-hour average	-	16 ^{e,(4)}	-	-
96-hour average	-	11 ^{e,(4)}	-	-
Chromium (III)	-	-	-	-
1-hour average	-	$(0.316) * e^{(0.8190\{\ln(\text{hardness})\} + 3.7256)}$ e,(4)	-	-
96-hour average	-	$(0.860) * e^{(0.8190\{\ln(\text{hardness})\} + 0.6848)}$ e,(4)	-	-
Copper	-	-	200 ^d	500 ^d
1-hour average	-	$(0.960) * e^{(0.9422\{\ln(\text{hardness})\} - 1.700)}$ e,(4)	-	-
96-hour average	-	$(0.960) * e^{(0.8545\{\ln(\text{hardness})\} - 1.702)}$ e,(4)	-	-
Cyanide	200 ^a	-	-	-
1-hour average	-	22 ^{e,(5)}	-	-
96-hour average	-	5.2 ^{e,(5)}	-	-
Fluoride	-	-	1,000 ^d	2,000 ^d
Iron	-	-	5,000 ^d	-
96-hour average	-	1,000 ^e	-	-

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U.S. Environmental Protection Agency (EPA). 1980. Ambient Water Quality Criteria for Cadmium. October. EPA 440/5-80-025. 190 pp.

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EPA. 1993. Additional Material for Water Quality Standards Handbook. October 1, 1993 Memorandum: Office of Water Policy and Technical Guidance on Interpretation and Implementation of Aquatic Life Metals Criteria.

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EPA. 2016. Aquatic Life Ambient Water Quality Criteria Cadmium – 2016. March. EPA-820-R-16-002.

EPA. 2018. Webpage for cadmium documents: <https://www.epa.gov/wqc/aquatic-life-criteria-cadmium>