Water Quality Guidelines for Nitrogen (Nitrate, Nitrite, and Ammonia)

Overview Report Update

Water Stewardship Division

Ministry of Environment

Province of British Columbia

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Summary

This document is an update to a previous report originally published in 2001. It assesses the freshwater aquatic life guideline for use in British Columbia (BC), and assesses more recent information and makes amendments to suit BC conditions. The guidelines are safe conditions or levels that have province-wide application and are intended to protect the most sensitive species and sensitive life stage, indefinitely. The nitrogen guideline document consists of three parts: this, an overview report, a technical appendix, and a technical appendix addendum.

A major use of the guidelines is to set ambient water quality objectives. The objectives are the guidelines modified or adapted to protect the most sensitive designated water use in a particular body of water. The water quality objectives are used in managing waste discharges and ambient water quality.

The change to the guidelines is as follows:

For nitrate (as N), the 30-d average concentration to protect freshwater aquatic life is 3.0 mg L^{-1} and the maximum concentration is 32.8 mg L^{-1}. For nitrate (as N), the 30-d average concentration to protect marine aquatic life 3.7* mg L^{-1}.

*Interim guideline

NOTE: The 30-d average (chronic) concentration is based on 5 weekly samples collected within a 30-day period.

Preface

The BC Ministry of Environment develops province-wide ambient water quality guidelines for variables that are important in the surface waters of BC for the protection of aquatic life. This work has the following goals:

- to provide guidelines that protect the most sensitive species and life stage indefinitely
- to provide guidelines for the evaluation of data on water, sediment and biota
- to provide guidelines for the establishment of site-specific ambient water quality objectives

Ambient water quality objectives for specific waterbodies will be based on the guidelines and also consider present and future uses, waste discharges, hydrology/limnology/oceanography, and existing background water quality. The process for establishing water quality objectives is more fully outlined in *Principles for Preparing Water Quality Objectives in British Columbia,* which is available online from the Ministry webpage.

The definition adopted for a guideline is:

> ***A maximum and/or a minimum value for a physical, chemical or biological characteristic of water, sediment or biota, which should not be exceeded to prevent specified detrimental effects from occurring to a water use, including aquatic life, under specified environmental conditions.***

The guidelines are province-wide in application, are use-specific, and are developed for some or all of the following specific water uses:

- aquatic life
- wildlife
- agriculture (livestock watering and irrigation)
- recreation and aesthetics

The guidelines are set after considering the scientific literature, guidelines from other jurisdictions, and general conditions in BC. The scientific literature gives information on the effects of toxicants on various life forms. This information is not always conclusive because it is usually based on laboratory work which, at best, only approximates actual field conditions; and is based on species which we have toxicity information on and therefore may not represent the most sensitive species. To compensate for this uncertainty, guidelines have built-in safety factors.

The site-specific water quality objectives are, in most cases, the same as guidelines. However, in some cases, such as when natural background levels exceed the guidelines, the objectives could be less stringent than the guidelines. In relatively rare instances, for example if the resource is unusually valuable or of special Provincial significance, the safety factor could be increased by using objectives, which are more stringent than the guidelines.

Guidelines are subject to review and revision as new information becomes available.

> ***The guidelines apply to the ambient raw water source before it is diverted or treated for domestic use.***
>
> ***Guidelines relating to public health at bathing beaches are the same as those used by the Ministry of Health and Health Canada, which regulate the recreation and aesthetic use.***

1.0 Recommended Guidelines

The freshwater aquatic life guideline is based on the August, 2001 Report Update titled Water Quality Criteria for Nitrogen (Nitrate, Nitrite, and Ammonia) **(**Nordin and Pommen 2001), the Technical Appendix titled *Ambient Water Quality Guidelines for Nitrate* (Nordin and Pommen 1986 and the addendum to the technical appendix (Meays 2009). The latest update (Meays 2009) and addendum are based on new information for nitrate as cited in the Canadian Water Quality Guidelines issued by the Canadian Council of Ministers of the Environment (CCME 2003), except as noted.

Nitrate, nitrite, and ammonia are the major inorganic nitrogen compounds occurring in surface waters. Table 1 provides a summary of water quality guidelines for these forms of nitrogen. There is little environmental information on other compounds, both inorganic and organic, which are minor constituents or do not appear to affect water uses. These are therefore not included in the report at this time.

The update to the nitrogen guideline is for nitrate only, and is as follows:

For nitrate (as N), the 30-d average concentration to protect freshwater aquatic life is 3.0 mg L^{-1} and the maximum concentration is 32.8 mg L^{-1}. For nitrate (as N), the 30-d average concentration to protect marine aquatic life 3.7* mg L^{-1}.

*Interim guideline (at least one more long-term temperate fish study is required for approved guideline).

NOTE: The 30-d average (chronic) concentration is based on 5 weekly samples collected within a 30-day period.

Guidelines for ammonia and nitrite have not changed from the previous update (Nordin and Pommen 2001).

Aquatic Life (Freshwater, Marine and Estuarine)

In the literature, there has been more research on the response to nitrate, nitrite, and ammonia by freshwater biota, particularly fish, than by marine biota. There are few studies available on the toxicological response of temperate marine organisms to nitrate exposure. As a consequence, the data on which to base guidelines are much better for freshwater than marine water. Since few studies for nitrogen toxicity in marine estuarine environments are available, the marine guideline is the same as the interim guideline proposed by CCME (2003). The CCME (2003) interim guideline for marine life for nitrate was developed from a critical study that exposed temperate marine annelids to potassium nitrate under static conditions. The interim marine guideline for nitrate was derived by multiplying the 28-d LC50 for *Nereis grubei* by a safety factor of 0.05. A more conservative safety factor was chosen because the polychaete in the critical study was not tested at its most sensitive life stage; the critical endpoint was based on a median lethal effect rather than a low sub-lethal effect; and adverse effects have been observed in non-indigenous tropical species exposed to much lower concentrations of nitrate (CCME 2003).

At least one more long-term temperate fish study is needed to develop an approved marine guideline for nitrate.

For freshwater studies, the maximum guideline for nitrate was derived based on acute (LC50s) of the most sensitive species reported in the literature (Camargo et al. 2005, Camargo and Ward 1992). The most sensitive acute toxicity estimates for invertebrates exposed to $NaNO_3$ were 62.5, 97.3, and 113.5 mg L^{-1} NO_3^- (as N, 96-h exposures) for the amphipod *Echinogammarus echinosetosus*, and the caddisflies *Hydropsyche occidentalis* and *Cheumatopsyche pettiti*, respectively (Camargo et al. 2005, Camargo and Ward 1992). *Echinogammarus* and *Gammarus* sp. are in the same couplet only separated by the length of a single projection on a uropod (personal communication Sue Salter and Christopher Rogers). Generally, some organisms used in guideline development may be indicators for others. In this case *Echinogammarus* sp. and *Gammarus* sp. are both in the same family Gammaridae. It is acceptable to use data from species in the same phylum for freshwater invertebrates however; it is more desirable to use native species. Since *Echinogammarus echinosetosus* is an introduced species (and potential invader) the acute guideline was not based on it. Future bioassays on native *Gammarus lacustris* would be beneficial to see if the toxicity is comparable. The next most sensitive species was *Hydropsyche occidentalis* with a 120-h LC50 of 65.5 mg L^{-1} and a 96-h LC50 of 97.4 mg L^{-1}(Camargo et al. 2005). Since the least conservative uncertainty factor (.5) is being applied and using scientific judgement, the new acute guideline is 32.8 mg L^{-1} nitrate (as N). The 120-h LC50 was chosen since it would be more representative of a continuous discharge of nitrate in the environment from point and non-point sources. The aquatic phase of the life cycle of *Hydropsyche occidentalis* can be up to 1 year. **Note:** The maximum guideline applies in the initial dilution zone whereas the 30-day average guideline applies everywhere else. Maximum guidelines are developed to protect against lethal effects in the initial dilution zone whereas 30-day average guidelines are developed to protect against sub-lethal effects on the most sensitive species and life stage indefinitely.

For chronic studies on nitrate, the 2 most sensitive species identified in the literature from acceptable studies were embryo growth reduction in the red-legged frog (*Rana aurora*) (Schuytema and Nebeker 1999a) and larval growth reduction in the northern leopard frog (*Rana pipiens*) (Allran and Karasov 2000). CCME (2003) determined that the ecological relevance of the results were questionable because, although the reduction in length was significant, they only represented reductions in size of 3 to 6%. CCME (2003) therefore used the next most sensitive species, the Pacific treefrog (*Pseudacris regilla*) to determine the freshwater guideline. The recommended freshwater guideline for nitrate for BC is 3.0 mg L^{-1} nitrate (as N). The guideline was derived by multiplying the 10-d LOEC of 133 mg $NO_3^-L^{-1}$ (Schuytema and Nebeker 1999b) by a safety factor of 0.1 and converting to nitrate (as N). *Pseudacris regilla* (synonym *Hyla regilla*) is a relevant species in BC. Its present range is virtually all of central and southern BC (BC Frogwatch Program). Information taken from BC Species and Ecosystems Explorer (http://www.env.gov.bc.ca/atrisk/toolintro.html) suggest that 36% of amphibian species in BC are at risk. 30-day average guidelines are derived with the intention to protect all forms of aquatic life and all aquatic stages indefinitely. The most sensitive life stage of *Pseudacris regilla*

to nitrate is the tadpole (30.1 mg L^{-1} nitrate (as N) resulted in a 15% reduction in body weight). The current CCME water quality guideline (3.0 mg L^{-1} NO_3 as N) is based on the *Pseudacris regilla* study. A study by McGurk et al. (2006) looking at acute and chronic toxicity of nitrate on early life stages of lake trout (*Salvelinus namaycush*) and lake whitefish (*Coregonus clupeaformis*) supports the validity of the nitrate guideline for freshwater life by showing that the early life stages of these species were as susceptible to sub-lethal effects as the early life stages of the Pacific treefrog. *Salvelinus namaycush* is widely distributed and of significant importance in BC. In the McGurk et al. (2006) study, larval weight of lake trout was significantly inhibited at low nitrate concentrations (6.25 mg L^{-1} LOEC and 1.6 mg L^{-1} NOEC). If the least conservative uncertainty factor is applied to the LOEC for the lake trout, the chronic water quality guideline would be 3.1 mg L^{-1} nitrate (as N). The maximum acceptable toxic concentration (MATC) is 3.16 mg L^{-1} nitrate (as N). Mean background nitrate + nitrite concentrations in lotic systems throughout BC fall below 0.5 mg L^{-1}. Therefore, a guideline of 3.0 mg L^{-1} nitrate (as N) allows an increase of 6 times above background concentrations.

It should be noted that in waterbodies that have mixtures of ammonium, potassium, and nitrate, the mixture is likely more toxic than the concentrations measured individually.

There are some concerns that nitrate may be an endocrine disruptor (Secondi et al. 2009, Edwards and Guillette 2007, Guillette and Edwards 2005). Further research into this issue is warranted.

UPDATED:

For nitrate (as N), the 30-d average concentration to protect freshwater aquatic life is 3.0 mg L^{-1} and the maximum concentration is 32.8 mg L^{-1}. For nitrate (as N), the 30-d average concentration to protect marine aquatic life 3.7* mg L^{-1}.

*Interim guideline

†Revision note: Minor edits to the 2009 document were made in July 2010. The 30-d average guideline to protect freshwater aquatic life (3.0 mg L^{-1} nitrate (as N)) did not change. The maximum guideline for nitrate (as N) increased slightly from 31.3 to 32.8 mg L^{-1}.

Nitrite has been shown to be quite toxic to some groups of fish, particularly salmonids, and consequently more investigations have been done.

For nitrite, the 30-d average concentration for freshwater aquatic life is 0.020 mg L^{-1} (as N) for low chloride water (i.e. <2 mg L^{-1}, also see Table 2), and the maximum concentration is 0.060 mg L^{-1} (as N) for low chloride water.

Allowable concentrations of nitrite increase with ambient concentrations of chloride, as shown in Table 2. The recommended guidelines vary with chloride concentration to reflect the marked influence of chloride on nitrite toxicity and chronic guidelines have also been recommended to provide adequate protection to the salmonids prevalent in BC, particularly at low chloride concentrations.

Ammonia has been the subject of intensive investigation and there are many studies on which to base a guideline. Because ammonia has been investigated for a long period, increasingly sophisticated and accurate guidelines are being derived. Ammonia guidelines have evolved from a single value to tabular guidelines relating toxicity to important physical or other interactive factors, which affect toxicity. Two factors, which are important to the toxicity of ammonia to aquatic organisms are the pH and temperature of the water environment. The pH and temperature affect the amount of un-ionized ammonia, which is the form most toxic to aquatic life.

Tables 3 and 4 give the recommended freshwater guidelines for maximum and 30-d average concentrations for ammonia (as N).

NOTE: These guidelines are similar to those developed by the U.S. Environmental Protection Agency (EPA). The U.S. EPA is planning to re-evaluate the 1999 *Ammonia Aquatic Life Criteria Update* since new studies suggest that the early life stages of freshwater mussels (Unionidae) are amongst the most sensitive aquatic organisms. In North America, greater than 70% of freshwater mussel populations are listed as endangered, threatened, or of special concern (Augspurger et al. 2003). BC has at least 85 species of freshwater molluscs including 54 snails, 5 mussels, and 26 clams. The BC ammonia guideline will be revisited and updated in the future based on the new scientific literature including the new studies with Unionidae.

For marine studies, less information is available on which to base guidelines. For nitrite, insufficient data are available to propose any guidelines.

NOTE: The marine ammonia guidelines found in this document are from the 2001 update of values found in the overview report *Ambient Water Quality Guidelines for Ammonia to Protect Marine Aquatic Life*.

Tables 5 and 6 give the recommended marine guidelines for the maximum and 30-d average concentrations for ammonia (as N).

There are no CCME Guidelines for ammonia for marine aquatic life.

Irrigation and Livestock Watering

Water with excessive amounts of ammonia may affect agricultural uses such as irrigation or water supplied to livestock. Insufficient information is available to establish a guideline for nitrogen in irrigation water since an allowable concentration would be dependent on soil type, irrigation rate, and other factors. The proposed guidelines for livestock watering exclude ammonia since few data exists (see Table 1).

For nitrate or nitrate plus nitrite, the maximum concentration for livestock watering is 100 mg L^{-1} (as N) and the maximum concentration for nitrite alone is 10 mg L^{-1} (as N). The same concentrations are recommended for waters that might be used by wildlife as a drinking water supply.

There are no CCME nitrogen guidelines for wildlife.

Application of Guidelines

Most of the guidelines proposed are self-explanatory; however, Tables 4 and 6 (chronic ammonia guidelines for freshwater and marine aquatic life) do require additional explanation. To determine compliance with the guidelines, 5 weekly samples would be taken within a 30-day period. In addition to ammonia, each sample must be measured for pH and temperature. The temperature is that of the water in the field, and the pH is the laboratory pH at the time of analysis, although field pH is also acceptable if accurate measurements can be obtained.

The average measured ammonia concentration is calculated as an arithmetic mean. Using the individual temperature and pH values, the corresponding guideline values are obtained from the table. A mean of these guideline values is compared to the mean of the measured ammonia values. If the mean value for measured total ammonia exceeds the mean guideline value, the guideline would then be considered to be exceeded. If the mean value does not exceed the mean guideline value, it is still necessary to compare individual guidelines to corresponding analytical results to ascertain whether or not more than 20% of the measured values exceed the mean guideline value by more than 150%. If more than 20% of the measured values do exceed the

mean guideline by 150%, the guideline is exceeded even if the measured mean is less than the mean guideline value. This provision restricts the occurrence of fluctuating concentrations, which can be more detrimental to aquatic life than a steady concentration.

Tables

Table 1. Summary of Water Quality Guidelines for Nitrogen

Water Use	Nitrate mg L^{-1} as Nitrogen	Nitrite mg L^{-1} as Nitrogen	Ammonia* (total) mg L^{-1} as Nitrogen
Drinking Water	See Source Drinking Water Quality Guidelines: https://www2.gov.bc.ca/assets/download/1F11ABD2CBD24EB09A70B89AB50CE6B0		
Fresh Water Aquatic Life - acute	32.8 (maximum)	0.06 (maximum)	see Tables 3 and 4
Fresh Water Aquatic Life - chronic	3.0 (30-d average)	0.02 (30-d average) when the chloride is less than or equal to 2 - also see Table 2	see Tables 3 and 4
Marine Aquatic Life - acute	None proposed	None proposed	See Table 5
Marine Aquatic Life - chronic	3.7 (30-d average)	None proposed	See Table 6
Livestock Watering	100 (maximum)	10 (maximum)	None proposed
Wildlife	100 (maximum)	10 (maximum)	None proposed
Recreation and Aesthetics	10 (maximum)	1 (maximum)	None proposed

*U.S. EPA is planning to re-evaluate ammonia criteria based on new studies with freshwater mussels.

1. The average value is calculated from at least 5 weekly samples taken in a period of 30 days.

2. Where nitrate and nitrite are present, the total nitrate-nitrite nitrogen should not exceed these values.

Table 2. Guidelines for Nitrite for Protection of Freshwater Aquatic Life

Chloride in mg L^{-1}	Maximum Nitrite mg L^{-1} as Nitrogen	30-d Average Nitrite mg L^{-1} as Nitrogen
less than 2	0.06	0.02
2 to 4	0.12	0.04
4 to 6	0.18	0.06
6 to 8	0.24	0.08
8 to 10	0.30	0.10
greater than 10	0.60	0.20

The 30-day average chloride concentration should be used to determine the appropriate chronic 30-day average nitrite guideline.

Table 3. Maximum (Acute) Concentration of Total Ammonia Nitrogen for Protection of Aquatic Life (mg L^{-1} of Nitrogen)

Temperature (T) in degrees Celcius

pH	T = 0.0	T = 1.0	T = 2.0	T = 3.0	T = 4.0	T = 5.0	T = 6.0
6.5	28.7	28.3	27.9	27.5	27.2	26.8	26.5
6.6	27.9	27.5	27.2	26.8	26.4	26.1	25.8
6.7	26.9	26.5	26.2	25.9	25.5	25.2	24.9
6.8	25.8	25.5	25.1	24.8	24.5	24.2	23.9
6.9	24.6	24.2	23.9	23.6	23.3	23.0	22.7
7.0	23.2	22.8	22.5	22.2	21.9	21.6	21.4
7.1	21.6	21.3	20.9	20.7	20.4	20.2	19.9
7.2	19.9	19.6	19.3	19.0	18.8	18.6	18.3
7.3	18.1	17.8	17.5	17.3	17.1	16.9	16.7
7.4	16.2	16.0	15.7	15.5	15.3	15.2	15.0
7.5	14.4	14.1	14.0	13.8	13.6	13.4	13.3
7.6	12.6	12.4	12.0	11.9	11.9	11.7	11.6
7.7	10.8	10.7	10.5	10.4	10.3	10.1	10.0
7.8	9.26	9.12	8.98	8.88	8.77	8.67	8.57
7.9	7.82	7.71	7.60	7.51	7.42	7.33	7.25
8.0	6.55	6.46	6.37	6.29	6.22	6.14	6.08
8.1	5.21	5.14	5.07	5.01	4.95	4.90	4.84
8.2	4.15	4.09	4.04	3.99	3.95	3.90	3.86
8.3	3.31	3.27	3.22	3.19	3.15	3.12	3.09
8.4	2.64	2.61	2.57	2.54	2.52	2.49	2.47
8.5	2.11	2.08	2.06	2.03	2.01	1.99	1.98
8.6	1.69	1.67	1.65	1.63	1.61	1.60	1.59
8.7	1.35	1.33	1.32	1.31	1.30	1.29	1.28

8.8	1.08	1.07	1.06	1.05	1.04	1.04	1.03
8.9	0.871	0.863	0.856	0.849	0.844	0.839	0.836
9.0	0.703	0.697	0.692	0.688	0.685	0.682	0.681

Temperature (T) in degrees Celcius

pH	T = 7.0	T = 8.0	T = 9.0	T = 10.0	T = 11.0	T = 12.0	T = 13.0
6.5	26.2	26.0	25.7	25.5	25.2	25.0	24.8
6.6	25.5	25.2	25.0	24.7	24.5	24.3	24.1
6.7	24.6	24.4	24.1	23.9	23.7	23.5	23.3
6.8	23.6	23.4	23.1	22.9	22.7	22.5	22.3
6.9	22.5	22.2	22.0	21.8	21.6	21.4	21.3
7.0	21.1	20.9	20.7	20.5	20.3	20.2	20.0
7.1	19.7	19.5	19.3	19.1	18.9	18.8	18.7
7.2	18.1	17.9	17.8	17.6	17.4	17.3	17.2
7.3	16.5	16.3	16.2	16.0	15.9	15.7	15.6
7.4	14.8	14.7	14.5	14.4	14.2	14.1	14.0
7.5	13.1	13.0	12.9	12.7	12.6	12.5	12.4
7.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9
7.7	9.92	9.83	9.73	9.65	9.57	9.50	9.43
7.8	8.48	8.40	8.32	8.25	8.18	8.12	8.07
7.9	7.17	7.10	7.04	6.98	6.92	6.88	6.83
8.0	6.02	5.96	5.91	5.86	5.81	5.78	5.74
8.1	4.80	4.75	4.71	4.67	4.64	4.61	4.59
8.2	3.83	3.80	3.76	3.74	3.71	3.69	3.67
8.3	3.06	3.03	3.01	2.99	2.97	2.96	2.94
8.4	2.45	2.43	2.41	2.40	2.38	2.37	2.36
8.5	1.96	1.95	1.94	1.93	1.92	1.91	1.91

8.6	1.58	1.57	1.56	1.55	1.55	1.54	1.54
8.7	1.27	1.26	1.26	1.25	1.25	1.25	1.25
8.8	1.03	1.02	1.02	1.02	1.02	1.02	1.02
8.9	0.833	0.832	0.831	0.831	0.832	0.834	0.838
9.0	0.681	0.681	0.681	0.682	0.684	0.688	0.692

Temperature (T) in degrees Celcius

pH	**T = 14.0**	**T = 15.0**	**T = 16.0**	**T = 17.0**	**T = 18.0**	**T = 19.0**	**T = 20.0**
6.5	24.6	24.5	24.3	24.2	24.0	23.9	23.8
6.6	23.9	23.8	23.6	23.5	23.3	23.3	23.2
6.7	23.1	23.0	22.8	22.7	22.6	22.5	22.4
6.8	22.2	22.0	21.9	21.8	21.7	21.6	21.5
6.9	21.1	21.0	20.8	20.7	20.6	20.5	20.4
7.0	19.9	19.7	19.6	19.5	19.4	19.3	19.2
7.1	18.5	18.4	18.3	18.2	18.1	18.0	17.9
7.2	17.1	16.9	16.8	16.8	16.7	16.6	16.5
7.3	15.5	15.4	15.3	15.2	15.2	15.1	15.1
7.4	13.9	13.9	13.8	13.7	13.6	13.6	13.5
7.5	12.4	12.3	12.2	12.2	12.1	12.1	12.0
7.6	10.8	10.8	10.7	10.7	10.6	10.6	10.5
7.7	9.37	9.31	9.26	9.22	9.18	9.15	9.12
7.8	8.02	7.97	7.93	7.90	7.87	7.84	7.82
7.9	6.79	6.75	6.72	6.69	6.67	6.65	6.64
8.0	5.71	5.68	5.66	5.62	5.61	5.60	5.74
8.1	4.56	4.54	4.53	4.51	4.50	4.49	4.49
8.2	3.65	3.64	3.63	3.62	3.61	3.61	3.61

8.3	2.93	2.92	2.92	2.91	2.91	2.91	2.91
8.4	2.36	2.35	2.35	2.35	2.35	2.35	2.36
8.5	1.90	1.90	1.90	1.90	1.90	1.91	1.92
8.6	1.54	1.54	1.54	1.55	1.56	1.56	1.57
8.7	1.25	1.25	1.26	1.26	1.27	1.28	1.29
8.8	1.02	1.03	1.03	1.04	1.05	1.06	1.07
8.9	0.842	0.847	0.853	0.861	0.870	0.880	0.891
9.0	0.698	0.704	0.711	0.720	0.729	0.740	0.752

Table 4. 30-Day Average (Chronic) Concentration of Total Ammonia Nitrogen for Protection of Aquatic Life (mg L^{-1} of Nitrogen)

Temperature (T) in degrees Celcius

pH	T = 0.0	T = 1.0	T = 2.0	T = 3.0	T = 4.0	T = 5.0	T = 6.0
6.5	2.08	2.05	2.02	1.99	1.97	1.94	1.92
6.6	2.08	2.05	2.02	1.99	1.97	1.94	1.92
6.7	2.08	2.05	2.02	1.99	1.97	1.94	1.92
6.8	2.08	2.05	2.02	1.99	1.97	1.94	1.92
6.9	2.08	2.05	2.02	1.99	1.97	1.94	1.92
7.0	2.08	2.05	2.02	1.99	1.97	1.94	1.92
7.1	2.08	2.05	2.02	1.99	1.97	1.94	1.92
7.2	2.08	2.05	2.02	1.99	1.97	1.94	1.92
7.3	2.08	2.05	2.02	1.99	1.97	1.94	1.92
7.4	2.08	2.05	2.02	2.00	1.97	1.95	1.92
7.5	2.08	2.05	2.02	2.00	1.97	1.95	1.92
7.6	2.09	2.05	2.03	2.00	1.97	1.95	1.93
7.7	2.09	2.05	2.03	2.00	1.98	1.95	1.93
7.8	1.78	1.75	1.73	1.71	1.69	1.67	1.65
7.9	1.50	1.48	1.46	1.44	1.43	1.41	1.39
8.0	1.26	1.24	1.23	1.21	1.20	1.18	1.17
8.1	1.00	0.989	0.976	0.963	0.952	0.942	0.932
8.2	0.799	0.788	0.777	0.768	0.759	0.751	0.743
8.3	0.636	0.628	0.620	0.613	0.606	0.599	0.594
8.4	0.508	0.501	0.495	0.489	0.484	0.479	0.475
8.5	0.405	0.400	0.396	0.381	0.387	0.384	0.380
8.6	0.324	0.320	0.317	0.313	0.310	0.308	0.305
8.7	0.260	0.257	0.254	0.251	0.249	0.247	0.246

8.8	0.208	0.206	0.204	0.202	0.201	0.200	0.198
8.9	0.168	0.166	0.165	0.163	0.162	0.161	0.161
9.0	0.135	0.134	0.133	0.132	0.132	0.131	0.131

Temperature (T) in degrees Celcius

pH	T = 7.0	T = 8.0	T = 9.0	T = 10.0	T = 11.0	T = 12.0	T = 13.0
6.5	1.90	1.88	1.86	1.84	1.82	1.81	1.80
6.6	1.90	1.88	1.86	1.84	1.82	1.81	1.80
6.7	1.90	1.88	1.86	1.84	1.83	1.81	1.80
6.8	1.90	1.88	1.86	1.84	1.83	1.81	1.80
6.9	1.90	1.88	1.86	1.84	1.83	1.81	1.80
7.0	1.90	1.88	1.86	1.84	1.83	1.81	1.80
7.1	1.90	1.88	1.86	1.84	1.83	1.81	1.80
7.2	1.90	1.88	1.86	1.85	1.83	1.81	1.80
7.3	1.90	1.88	1.86	1.85	1.83	1.82	1.80
7.4	1.90	1.88	1.87	1.85	1.83	1.82	1.80
7.5	1.91	1.88	1.87	1.85	1.83	1.82	1.81
7.6	1.91	1.89	1.87	1.85	1.84	1.82	1.81
7.7	1.91	1.89	1.87	1.86	1.84	1.83	1.81
7.8	1.63	1.62	1.60	1.59	1.57	1.56	1.55
7.9	1.38	1.36	1.35	1.34	1.33	1.32	1.31
8.0	1.16	1.15	1.14	1.13	1.12	1.11	1.10
8.1	0.922	0.914	0.906	0.899	0.893	0.887	0.882
8.2	0.736	0.730	0.724	0.718	0.714	0.709	0.706
8.3	0.588	0.583	0.579	0.575	0.571	0.568	0.566
8.4	0.471	0.467	0.464	0.461	0.458	0.456	0.455

8.5	0.377	0.375	0.372	0.370	0.369	0.367	0.366
8.6	0.303	0.301	0.300	0.298	0.297	0.297	0.296
8.7	0.244	0.243	0.242	0.241	0.241	0.240	0.240
8.8	0.197	0.197	0.196	0.196	0.196	0.196	0.196
8.9	0.160	0.160	0.160	0.160	0.160	0.161	0.161
9.0	0.131	0.131	0.131	0.131	0.132	0.132	0.133

Temperature (T) in degrees Celcius

pH	T = 14.0	T = 15.0	T = 16.0	T = 17.0	T = 18.0	T = 19.0	T = 20.0
6.5	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.6	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.7	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.8	1.78	1.77	1.64	1.52	1.42	1.32	1.22
6.9	1.78	1.77	1.64	1.53	1.42	1.32	1.22
7.0	1.79	1.77	1.64	1.53	1.42	1.32	1.22
7.1	1.79	1.77	1.65	1.53	1.42	1.32	1.23
7.2	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.3	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.4	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.5	1.80	1.78	1.66	1.54	1.43	1.33	1.23
7.6	1.80	1.79	1.66	1.54	1.43	1.33	1.24
7.7	1.80	1.79	1.66	1.54	1.44	1.34	1.24
7.8	1.54	1.53	1.42	1.32	1.23	1.14	1.07
7.9	1.31	1.30	1.21	1.12	1.04	0.970	0.904
8.0	1.10	1.09	1.02	0.944	0.878	0.818	0.762
8.1	0.878	0.874	0.812	0.756	0.704	0.655	0.611

8.2	0.703	0.700	0.651	0.606	0.565	0.527	0.491
8.3	0.564	0.562	0.523	0.487	0.455	0.424	0.396
8.4	0.453	0.452	0.421	0.393	0.367	0.343	0.321
8.5	0.366	0.365	0.341	0.318	0.298	0.278	0.261
8.6	0.296	0.296	0.277	0.259	0.242	0.227	0.213
8.7	0.241	0.241	0.226	0.212	0.198	0.186	0.175
8.8	0.197	0.198	0.185	0.174	0.164	0.154	0.145
8.9	0.162	0.163	0.153	0.144	0.136	0.128	0.121
9.0	0.134	0.135	0.128	0.121	0.114	0.108	0.102

1. The average of the measured values must be less than the average of the corresponding individual values.

2. Each measured value is compared to the corresponding individual values. No more than one in five of the measured values can be greater than 1.5 x the corresponding guideline values.

Table 5. Maximum (Acute) Concentration of Total Ammonia Nitrogen for Protection of Saltwater Aquatic Life (mg L^{-1} as N). (See 2001 Overview Report *Ambient Water Quality Guidelines for Ammonia to Protect Marine Aquatic Life* for explanation and details*)*.

Salinity equals 10 g/kg; Temperature (T) in degrees Celcius

pH	T = 0	T = 5	T = 10	T = 15	T = 20	T = 25
7.0	270	191	131	92	62	44
7.2	175	121	83	58	40	27
7.4	110	777	52	35	25	17
7.6	69	48	33	23	16	11
7.8	44	31	21	15	10	7.1
8.0	27	19	13	9.4	6.4	4.6
8.2	18	12	8.5	5.8	4.2	2.9
8.4	11	7.9	5.4	3.7	2.7	1.9
8.6	7.3	5.0	3.5	2.5	1.8	1.3
8.8	4.6	3.3	2.3	1.7	1.2	0.92
9.0	2.9	2.1	1.5	1.1	0.85	0.67

Salinity equals 20 g/kg; Temperature (T) in degrees Celcius

pH	T = 0	T = 5	T = 10	T = 15	T = 20	T = 25
7.0	291	200	137	96	64	44
7.2	183	125	87	60	42	29
7.4	116	79	54	37	27	18

7.6	73	50	35	23	17	11
7.8	46	31	23	15	11	7.5
8.0	29	20	14	9.8	6.7	4.8
8.2	19	13	8.9	6.2	4.4	3.1
8.4	12	8.1	5.6	4.0	2.9	2.0
8.6	7.5	5.2	3.7	2.7	1.9	1.4
8.8	4.8	3.3	2.5	1.7	1.3	0.94
9.0	3.1	2.3	1.6	1.2	0.87	0.69

Salinity equals 30 g/kg; Temperature (T) in degrees Celcius

pH	**T = 0**	**T = 5**	**T = 10**	**T = 15**	**T = 20**	**T = 25**
7.0	312	208	148	102	71	48
7.2	196	135	94	64	44	31
7.4	125	85	58	40	27	19
7.6	79	54	37	25	21	12
7.8	50	33	23	16	11	7.9
8.0	31	21	15	10	7.3	5.0
8.2	20	14	9.6	6.7	4.6	3.3
8.4	12.7	8.7	6.0	4.2	2.9	2.1
8.6	8.1	5.6	4.0	2.7	2.0	1.4
8.8	5.2	3.5	2.5	1.8	1.3	1.0

9.0	3.3	2.3	1.7	1.2	0.94	0.71

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1. g/kg salinity is equivalent to parts per thousand (ppt)

2. The guideline value is obtained by using the average pH, temperature and salinity field values, and is compared to the mean of the measured ammonia concentrations.

Table 6. 30-Day Average (Chronic) Concentration of Total Ammonia Nitrogen for Protection of Saltwater Aquatic Life (mg L^{-1} of Nitrogen). (See 2001 Overview Report *Ambient Water Quality Guidelines for Ammonia to Protect Marine Aquatic Life for explanation and details)*.

Salinity equals 10 g/kg; Temperature (T) in degrees Celcius

pH	T = 0	T = 5	T = 10	T = 15	T = 20	T = 25
7.0	41	29	20	14	9.4	6.6
7.2	26	18	12	8.7	5.9	4.1
7.4	17	12	7.8	5.3	3.7	2.6
7.6	10	7.2	5.0	3.4	2.4	1.7
7.8	6.6	4.7	3.1	2.2	1.5	1.1
8.0	4.1	2.9	2.0	1.4	0.97	0.69
8.2	2.7	1.8	1.3	0.87	0.62	0.44
8.4	1.7	1.2	0.81	0.56	0.41	0.29
8.6	1.1	0.75	0.53	0.37	0.27	0.20
8.8	0.69	0.50	0.34	0.25	0.18	0.14
9.0	0.44	0.31	0.23	0.17	0.13	0.10

Salinity equals 20 g/kg; Temperature (T) in degrees Celcius

pH	T = 0	T = 5	T = 10	T = 15	T = 20	T = 25
7.0	44	30	21	14	9.7	6.6
7.2	27	19	13	9.0	6.2	4.4

7.4	18	12	8.1	5.6	4.1	2.7
7.6	11	7.5	5.3	3.4	2.5	1.7
7.8	6.9	4.7	3.4	2.3	1.6	1.1
8.0	4.4	3.0	2.1	1.5	1.0	0.72
8.2	2.8	1.9	1.3	0.94	0.66	0.47
8.4	1.8	1.2	0.84	0.59	0.44	0.30
8.6	1.1	0.78	0.56	0.41	0.28	0.20
8.8	0.72	0.50	0.37	0.26	0.19	0.14
9.0	0.47	0.34	0.24	0.18	0.13	0.10

Salinity equals 30 g/kg; Temperature (T) in degrees Celcius

pH	**T = 0**	**T = 5**	**T = 10**	**T = 15**	**T = 20**	**T = 25**
7.0	47	31	22	15	11	7.2
7.2	29	20	14	9.7	6.6	4.7
7.4	19	13	8.7	5.9	4.1	2.9
7.6	12	8.1	5.6	3.7	3.1	1.8
7.8	7.5	5.0	3.4	2.4	1.7	1.2
8.0	4.7	3.1	2.2	1.6	1.1	0.75
8.2	3.0	2.1	1.4	1.0	0.69	0.50
8.4	1.9	1.3	0.90	0.62	0.44	0.31
8.6	1.2	0.84	0.59	0.41	0.30	0.22

8.8	0.78	0.53	0.37	0.27	0.20	0.15
9.0	0.50	0.34	0.26	0.19	0.14	0.11

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1. g/kg salinity is equivalent to parts per thousand (ppt)

2. The guideline value is obtained by using the average pH, temperature and salinity field values, and is compared to the mean of the measured ammonia concentrations.

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