Water Quality

Ambient Water Quality Criteria for Ammonia to Protect Marine Aquatic Life

Overview Report

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Summary

This report is one in a series which establishes water quality criteria for British Columbia. The criteria are safe conditions or levels of contaminants, applicable province-wide, which are set to protect various water uses. This report sets criteria for ammonia to protect aquatic life in marine or saltwater ecosystems. The criteria update those for ammonia in marine waters issued in 1986 and are summarized in Tables 1 and 2.

The criteria to protect marine life are set for either continuous exposure to ammonia or for maximum acceptable concentrations. For continuous exposure, values are tabulated to take into account the effect on toxicity of pH, temperature, and salinity. Maximum acceptable concentrations are similarly presented in tabular form with the same three variables. These criteria are more flexible and detailed than the criteria for ammonia in marine waters of a previous Ministry criteria document (Nordin and Pommen, 1986). The CCREM (now known as CCME) Canadian Water Quality Guidelines (1987) do not consider marine water quality.

A major use of the criteria is to set ambient water quality objectives. The objectives are the criteria modified or adopted to protect the most sensitive water use in a particular body of water. The objectives are used in the preparation of waste management permits, which are the only entity to have legal standing. The objectives, however, are not usually part of the permit.

Tables

Table 1. Maximum Concentration of Total Ammonia Nitrogen for Protection of Saltwater Aquatic Life (mg/L of Nitrogen).

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

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

2. The criterion 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 2. Average 5 to 30-Day Concentration of Total Ammonia Nitrogen for Protection of Saltwater Aquatic Life (mg/L of Nitrogen).

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

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

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

Preface

THE MINISTRY OF ENVIRONMENT, LANDS AND PARKS (now called Ministry of Water, Land and Air Protection) develops province-wide ambient water quality guidelines for variables that are important in the surface waters of British Columbia. This work has the following goals:

1. to provide guidelines for the evaluation of data on water, sediment, and biota
2. 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*, copies of which are available from the Water Quality Section of the Environmental Quality Branch.

Neither guidelines nor objectives which are derived from them, have any legal standing. The objectives, however, can be used to calculate allowable limits or levels for contaminants in waste discharges. These limits are set out in waste management permits and thus have legal standing. The objectives are not usually incorporated as conditions of the permit.

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 designed for some or all of the following specific water uses:

- raw drinking, public water supply and food processing
- aquatic life and wildlife
- agriculture (livestock watering and irrigation)
- recreation and aesthetics
- industrial (water supplies)

The guidelines are set after considering the scientific literature, guidelines from other jurisdictions, and general conditions in British Columbia. The scientific literature gives information on the effects oftoxicants 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. To compensate for this uncertainty, guidelines have built-in safety factors which are conservative but reflect natural background conditions in the province.

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. Another approach in such special cases is to develop site-specific guidelines by carrying out toxicity experiments in the field. This approach is costly and time-consuming and therefore seldom used.

Guidelines are subject to review and revision as new information becomes available, or as other circumstances dictate.

The guidelines apply to the ambient raw water source before it is diverted or treated for domestic use.

The Ministry of Health regulates the quality of water for domestic use after it is treated and delivered by a water purveyor.

Guidelines relating to public health at bathing beaches are the same as those used by the Ministry of Health which regulates the recreation and aesthetic use.

Background

Because the fields of environmental toxicology and the setting of quantitative values (criteria) to protect specific water uses are relatively new, it should be expected that the generation of new knowledge might require changes in criteria over even relatively short time periods.

The purpose of this short report is to update one portion of a previous criteria document on inorganic nitrogen compounds (nitrate, nitrite and ammonia), issued in 1986. In 1986, the Ministry published a criteria document for inorganic nitrogen compounds (nitrate, nitrite and ammonia) (Nordin and Pommen, 1986). In that document criteria were proposed for a variety of water uses for each of these nitrogen compounds. One particular area where few data were available was for ammonia toxicity to aquatic life in saltwater. Criteria were proposed based primarily on the review by Haywood (1983) of ammonia toxicity to marine fish. The criteria proposed were an average of less than 1.0 mg/L and a maximum of 2.5 mg/L, based on total ammonia nitrogen. In 1985, the U.S. Environmental Protection Agency (EPA) had reviewed the existing data for toxicity with regard to aquatic life and concluded that there was insufficient information to set criteria for the marine (saltwater) environment.

By 1989 the EPA had again attempted to assess the data that were available in the literature. This time the agency determined that sufficient information existed in the scientific literature for both acute and chronic toxicity to a variety of marine species (fish, crustaceans and mollusks) and that criteria could be established. The report which was issued (United States Environmental Protection Agency, 1989) set new criteria for ammonia in salt water.

The approach taken in that report is similar to the approach taken in their 1985 criteria report for ammonia in freshwater. One difference was that in the earlier report the criteria values were primarily keyed to the un-ionized form of ammonia. For the 1986 Ministry of Environment report, the un-ionized values were converted to total ammonia so they would be more readily compared to analytical results. In the 1989 EPA marine ammonia criteria document, this use of total ammonia for the criteria values was also made. In reviewing the 1989 EPA criteria document, the technical basis was examined and appeared to be sound. Rather than re-examining all the references cited by EPA a number were reviewed to verify the procedure and interpretation. The EPA report was then updated by a literature search to locate applicable published data from 1987-89 (the most recent EPA citations are for 1986); on the basis of this work, it was determined that minor modification and adoption of the EPA criteria would be the best course of action. The purpose of this document is to update and improve the 1986 Ministry of Environment criteria document.

Although the EPA approach is a reasonable one, it is not without weakness. The EPA criteria (for a wide range of water quality characteristics) are designed to protect only 95% of the species tested and a caveat is usually included which notes that some local sensitive species may not be adequately protected. If these criteria values are used in setting site specific water quality objectives, this information has to be taken into account. In the compilation of toxicity data there is a distinct bias in terms of the amount of data for Atlantic marine species (US and Europe) in contrast to Pacific (and specifically British Columbia) species. Ideally, toxicity data for a wide range of BC species should be the basis for provincial criteria; however, in the absence of such data, the EPA data base and the approach taken serves as an

interim but satisfactory solution. The criteria proposed here were considered because they represent an improvement over the previous approach. The EPA criteria tables provide the advantages of considering both acute and chronic effect and are far more specific than the previous Ministry criteria since they take into account temperatures, salinity and pH. The criteria are particularly needed in British Columbia at the present time because of the large number of aquaculture operations which exist or are proposed and the concern over the environmental effects of these operations. Ammonia is a particular item of interest in this regard.

The levels proposed in the 1986 Ministry criteria document were 1.0 mg/L average and 2.5 mg/L maximum total ammonia nitrogen. In comparison to the EPA criteria table values, both 2.5 mg/L and 1.0 would best be described as mid-range values in the context of the newer criteria tables. In the new table for maximum values (Table 1), 2.5 mg/L is obtained at a temperature of 15'C and a pH of 8.6. For conditions of lower pH and lower temperatures (in general) the 2.5 mg/L value would be overprotective. Also for pH greater than 8.6 or temperatures of greater than 10 or 15 degrees celcius, the 2.5 mg/L would be under-protective. Similarly, the previous average criterion of 1.0 mg/L corresponds to approximately pH 8.2 and 15 degrees celcius in the new table (Table 2) and would have been either overprotective or under-protective at other pH, temperature or salinity combinations. It is clear that the new EPA tables (adapted here) are a significant improvement on the 1986 Ministry criteria.

There are several considerations in using the tables. They are not applicable to inland saltwater lakes as the criteria values are based on toxicity to marine organisms. As such the tables only apply to salinities greater than 10 g/kg (parts per thousand). For salinities less than 10 g/kg, the freshwater criteria should be used. For the range of values in the tables, intermediate values of pH, temperature or salinity should be interpolated linearly.

For calculation of acceptable average concentrations at a particular site over a period of time (Table 2) a series of samples is usually taken (e.g., 5 samples in 30 days). To compare the field result to the value in the table, the five field temperature values should be averaged, as should the field pH and salinity data. Using the average pH, temperature and salinity values, the criterion value can then be obtained from Table 2 and compared to the average ammonia result.

One area which requires more work is the toxicity thresholds for organisms in the brackish water salinity range, say between 500 mg/L to (0.5 g/kg) and 10 g/kg. Although at higher pH the toxicities are comparable to freshwater data, at lower pH there is considerable difference between the freshwater and marine criteria. Apparently, the paucity of data at lower salinities (less than 10 g/kg) is the reason for this. In the absence of sufficient data to generate a separate criteria table for brackish water, the more protective freshwater criteria for ammonia should apply.

Recommended Guidelines

The criteria for ammonia in saltwater are consistent with the approach taken in the Canadian Water Quality Guidelines issued by the Canadian Council of Resource and Environment Ministers (1987) except as noted (the CCREM is now known as the CCME, or Canadian Council of Ministers of the

Environment). However, the CCREM Guidelines consider only freshwater applications. These criteria apply exclusively and specifically to the single water use of protection of marine aquatic life.

1. Maximum Concentrations

> ***The criteria provided in Table 1 are maximum values, which should not be exceeded at any time. The values listed are related to data for acute toxicity.***

2. Average Concentrations

> ***The criteria provided in Table 2 are designed to provide protection for aquatic life over the long term. The values in this table are related to data for chronic toxicity.***

To evaluate whether conditions meet these numerical limits, it is necessary to take samples over a period of not less than 5 days nor more than 30 days. A minimum of 5 samples, equally spaced in time, should be used to calculate the average. The criterion value is obtained by entering the mean pH, temperature and salinity values into the Table. The criterion can then be compared to the average of the measured concentrations.

Coincident with the analytical measurement of ammonia, accurate measurement of field pH, field temperature and salinity are necessary to provide the basis of comparison to criteria values. Intermediate values of pH, temperature or salinity should be interpolated (linearly) from the table. The criteria given here apply only to locations where salinity is equal to or greater than 10 g/kg. The freshwater criteria (1986) apply at salinities less than 10 g/kg.

The data in both Tables 1 and 2 have been adopted from the US Environmental Protection Agency report: *Ambient Water Quality Criteria for Ammonia (Saltwater). 1989*.

References

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