



Water Quality

Ambient Water Quality Criteria for Chlorine

Overview Report

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Summary

This report is one in a series which establishes ambient 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 chlorine to protect aquatic life in fresh water and marine water. It also sets a criterion to protect plants grown in soil-less media against chlorine in irrigation water. The criteria are summarized in the tables.

The criteria to protect aquatic life are set for either continuous exposure to chlorine or for intermittent exposure. For continuous exposure, we have a single criterion expressed as an average measured over a period of time. For intermittent exposure, the criteria are expressed as both average and maximum values, and are less stringent than for continuous exposure. These criteria are more flexible and detailed than the single criterion of the CCREM (now known as CCME) Canadian Water Quality Guidelines (1987).

We set the criterion for irrigation water as a maximum value to protect plants grown hydroponically or in inert media. We did not set criteria for other uses, such as drinking water, wildlife, or recreation because these uses can tolerate chlorine at levels far above those likely to occur in ambient waters.

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. Summary of Water Quality Criteria for Chlorine

Water Use	Average exposure continuous $\mu\text{g/L}$ (as TRC or CPO)	Average exposure controlled intermittent $\mu\text{g/L}$ (as TRC or CPO)	Maximum exposure controlled intermittent $\mu\text{g/L}$ (as TRC or CPO)
Freshwater aquatic life	2 $\mu\text{g/L}$	1074 (duration) ^{-0.74}	100 $\mu\text{g/L}$ regardless of the duration of exposure
Marine and Estuarine Aquatic Life	3 $\mu\text{g/L}$	20.36 (duration) ^{-0.4}	40 $\mu\text{g/L}$ regardless of the duration of exposure
Irrigation Water	None proposed	None proposed	1000 $\mu\text{g/L}$

1. The continuous exposure average should be based on at least 5 samples, equally spaced in time and the averaging period should be not less than 4 days nor more than 30 days for freshwater and not less than 2 hours nor more than 30 days for marine or estuarine water. This is the threshold of chronic toxicity.

2. The duration in controlled intermittent exposures is the exposure period in minutes. This is the threshold of acute toxicity.

3. For the maximum controlled, intermittent exposure of aquatic life, the total duration of exposure in any consecutive 24-hour period should not exceed 2 hours. This is the threshold of acute toxicity.

4. TRC is the total residual chlorine in fresh water.

5. CPO is the chlorine-produced oxidants in marine or estuarine water.

6. The irrigation criterion applies to plants grown in soil-less media and should be applied as a maximum under continuous or intermediate exposure situations.

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 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 developed 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 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. 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.

Recommended Guidelines

These criteria are based on a detailed analysis given in a technical document. The criteria are consistent with the Canadian Water Quality Guidelines (CCREM 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).

1. FRESHWATER AQUATIC LIFE

Total residual chlorine (TRC) is the sum of the free available chlorine plus the combined available chlorine. This includes all the forms of chlorine which are able to act as an oxidant.

1.1 Continuous Exposure

The average concentration of total residual chlorine should not exceed 2 µg/L. This is the threshold of chronic toxicity. The averaging period should not be less than 4 days nor more than 30 days. A minimum of 5 samples, equally spaced in time, should be used to calculate the average.

1.2 Controlled Intermittent Exposures

(a) The average total residual chlorine concentration should be time-related and should not exceed the numerical value (in µg/L) given by the formula $1074 (\text{duration})^{0.74}$, where duration is the uninterrupted exposure period (in minutes). This is the threshold of acute toxicity.

(b) The total duration of exposure in any consecutive 24-hour period should not exceed 2 hours.

(c) The maximum concentration of total residual chlorine should not exceed 100 µg/L regardless of the exposure period.

Examples based on these criteria (rounded to nearest µg/L) are as follows:

Duration of Exposure in Minutes	TRC Concentration in µg/L
less than 25	100, see 1.2(c)
30	87
45	64

60	52
90	38
120	31
greater than 120	use continuous exposure criterion, see 1.1

The CCREM guidelines specify only a maximum value which, by definition, is more restrictive than the average value recommended here. Also, the CCREM guidelines are not designed to apply to controlled intermittent exposures.

2. MARINE AND ESTUARINE AQUATIC LIFE

In marine or estuarine waters, the term chlorine-produced oxidants (CPO) is used because of the high concentrations of bromide naturally present in seawater. Bromide, in the presence of residual chlorine, forms free available bromine or combined available bromine which are able to act as oxidants.

2.1 Continuous Exposure

The average concentration of chlorine-produced oxidants should not exceed 3 µg/L. This is the threshold of chronic toxicity. The averaging period should not be less than 2 hours nor more than 30 days. A minimum of 5 samples, equally spaced in time, should be used to calculate the average.

2.2 Controlled Intermittent Exposures

(a) The average chlorine-produced oxidant concentration should be time-related and should not exceed the numerical value (in µg/L) given by the formula $20.36 (\text{duration})^{-0.4}$, where duration is the uninterrupted exposure period (in minutes). This is the threshold of acute toxicity.

(b) The total duration of exposure in any consecutive 24-hour period should not exceed 2 hours.

(c) The maximum concentration of chlorine-produced oxidants should not exceed 40 µg/L regardless of the exposure period.

Examples based on these criteria (rounded to nearest µg/L) are as follows:

Duration of Exposure in Minutes	CPO Concentration in µg/L
less than 0.2	40, see 2.2(c)
5	11
10	8
15	7
30	5
60	4
90	3
greater than 120	use continuous exposure criterion, see 2.1

3. IRRIGATION WATER

The average concentration of chlorine-produced oxidants should not exceed 3 µg/L. This is the threshold of chronic toxicity. The averaging period should not be less than 2 hours nor more than 30 days. A minimum of 5 samples, equally spaced in time, should be used to calculate the average.

There are no CCREM guidelines for chlorine in irrigation water.

Application of Guidelines for Aquatic Life

To determine whether monitoring is necessary, a worst-case scenario should be formulated using site-specific information which includes the effluent concentration of TRC and the minimum dilution available at the edge of the initial dilution zone. If the average criterion value for continuous exposure is not exceeded by the calculated estimate under worst-case conditions, then monitoring is unnecessary regardless of whether the exposure is intermittent or continuous. If calculations show that the average criterion value for continuous exposure could be exceeded, for freshwater or seawater as appropriate, then monitoring should be initiated.

When monitoring for TRC or CPO is necessary, the amperometric method of analysis is recommended. Furthermore, it is recommended that an individual, experienced in the operation of an amperometer, be designated to perform the analyses. While frequent monitoring may be necessary to determine if criteria are being met, usually only a short-term monitoring program is necessary. Such a monitoring program should be performed at times when minimum dilution is available, in keeping with the worst-case scenario.

An initial assessment should be made to determine whether exposure at the edge of the initial dilution zone is continuous or intermittent. In some situations this determination may be obvious. For example, if a discharge is continuously chlorinated then, in all likelihood, the exposure will be continuous and the appropriate criteria will apply. However, if a discharge is intermittently chlorinated it does not necessarily follow that exposure is intermittent. For example, if the discharge is to a moving body of water such as a river then, in all likelihood, exposure will be intermittent. On the other hand, if TRC is discharged intermittently to a relatively motionless body of water such as a lake, exposure may be intermittent or continuous depending upon whether residuals persist between the chlorination periods. If residuals do persist through the periods of non-chlorination, then the situation should be treated as continuous exposure and the continuous exposure criteria should apply. If residuals do not persist at the edge of the initial dilution zone, then the intermittent exposure criteria should apply.

While the monitoring schedule should be somewhat flexible to determine if criteria are being met, enough samples should be taken to provide a relatively accurate profile of the exposure characteristics. For continuous exposure situations, at least 5 samples, equally spaced in time, are recommended to determine an average concentration over the averaging periods. The minimum duration of the averaging periods is 4 days for freshwater, and only 2 hours for marine or estuarine waters, but may be as long as 30 days.

For an intermittent exposure situation, some knowledge of the chlorination schedule, including the start times, duration of the chlorination period, and daily frequency, would be helpful prior to monitoring. This prior knowledge would provide an indication of when to start monitoring so that samples could be collected over the entire exposure period. Monitoring should be continued as frequently as possible over the chlorination period and until the concentration at the edge of the initial dilution zone drops below the continuous exposure criterion (i.e., 2 or 3 µg/L for fresh or marine water as appropriate). The concentrations measured over the uninterrupted duration of exposure should be averaged and the average value should not exceed the appropriate freshwater 1.2(a) or marine and estuarine 2.2(a) criterion. No individual sample should exceed 100 µg/L TRC in freshwater or 40 µg/L CPO in marine or estuarine water, as per Sections 1.2(c) or 2.2(c). Since the intermittent exposure criteria formulae (1.2(a) or 2.2(a)) are based on the acute toxicity threshold, application of these criteria at the edge of the initial dilution zone could lead to acutely toxic conditions for a short time within the initial dilution zone, depending upon the dilution available and upon the exposure time of organisms in the initial dilution zone. These items should be considered on a site-specific basis.

It should be noted that while intermittent exposures are not restricted by a lower chronic criterion, they are restricted in terms of a maximum exposure period of 2 hours in any consecutive 24-hour period. If the duration of exposure at the edge of the initial dilution zone exceeds 2 hours in any consecutive 24-hour period, then the more stringent continuous criterion should be applied.