Water Quality

Ambient Water Quality Guidelines for Boron

Overview Report

Prepared pursuant to Section 2(e) of the
Environment Management Act, 1981

Original Signed by Margaret Eckenfelder
Assistant Deputy Minister
Water, Land and air Protection
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Authors: S.A. Moss, N.K. Nagpal. Cf.p.
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Summary

This document is one in a series that establishes ambient water quality guidelines (Table 1). This document is mainly based on a report prepared by the Ministry of Water, Land and Air Protection for the Canadian Council of Ministers of the Environment (CCME). It sets guidelines for boron (B) to protect drinking water, freshwater and marine aquatic life, and agricultural water uses.

Table 1: Recommended Guidelines for Boron

Ministry of Environment | Water Protection and Sustainability Branch, Environmental Sustainability and Strategic Policy Division | Mailing Address: PO Box 9362 Stn Prov Govt Victoria BC V8W 9M2 | Telephone: 250 387-9481 Facsimile: 250 356-1202 Website: www.gov.bc.ca/water

Water Use	Guideline (Total B)
Drinking Water	5.0 mg/L
Aquatic Life Freshwater Marine	 1.2 mg/L 1.2 mg/L
Wildlife	5.0 mg/L
Irrigation	0.5 - 6.0 (depends upon crop. See Table 2)
Livestock Watering	5.0 mg/L

Table 2: Recommended Irrigation Water Guidelines

Tolerance	Boron in Irrigation Water (mg/L)	Agricultural Crop
Very sensitive	< 0.5	Blackberry
Sensitive	0.5 - 1.0	Peach, cherry, plum, grape, cowpea, onion, garlic, sweet potato, wheat, barley, sunflower, mung bean, sesame, lupin, strawberry, Jerusalem artichoke, kidney bean, lima bean
Moderately sensitive	1.0 - 2.0	Red pepper, pea, carrot, radish, potato, cucumber
Moderately tolerant	2.0 - 4.0	Lettuce, cabbage, celery, turnip, Kentucky bluegrass, oat, corn, artichoke, tobacco, mustard, clover, squash, muskmelon
Tolerant	4.0 - 6.0	Sorghum, tomato, alfalfa, purple vetch, parsley, red beet, sugar beet

Very tolerant	6.0 - 15.0	Asparagus

Guidelines were not set for recreational and industrial water uses, since relevant B toxicity data for these uses were not available in the literature.

Preface

The **MINISTRY OF WATER, LAND AND AIR PROTECTION** develops ambient water quality guidelines for British Columbia. This work has two goals:

- to provide guidance for the evaluation of data on water, sediment and biota, and
- to provide basis for setting site-specific ambient water quality objectives.

The guidelines represent safe conditions or safe levels of a substance in water. Guideline is defined as "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 detrimental effects from occurring to a water use under given environmental conditions."

The guidelines are applied province-wide, but they are use-specific, and are being developed for these water uses:

- raw drinking water, public water supply and food processing[1]
- aquatic life and wildlife
- agriculture (livestock watering and irrigation)
- recreation and aesthetics[2]
- industrial water supplies

The guidelines are established after considering the scientific literature, existing guidelines from other jurisdictions, and environmental conditions in British Columbia. The scientific literature provides information about the persistence of toxicants in the environment and their effect on various life forms. This information is not always conclusive because it is usually based on laboratory work that, at best, only approximates field conditions. To compensate for this uncertainty, and applying the "precautionary principle", the guidelines have built-in safety factors that are conservative, but reflect the natural background levels.

The guidelines are used to set ambient site-specific water quality objectives for waterbodies. In setting the objectives, considerations are given to present and future water uses, waste discharges, hydrology, limnology, oceanography, and existing background water quality.

In most cases, the objectives are the same as the guidelines. However, when natural background levels exceed the guidelines, the objectives could be less stringent than the guidelines. In rare instances — for example, if the resource is unusually valuable or of special provincial significance — the safety factor could be increased, enabling objectives to be more stringent than the guidelines. Another approach would be to develop site-specific objectives by conducting toxicity experiments in the field. However, because this approach is costly and time consuming, it is seldom used.

Neither the guidelines nor the objectives derived from them have any legal standing. However, objectives can be used to calculate waste discharge limits for contaminants. These limits are outlined in waste management permits, orders and approvals, all of which have legal standing. Objectives are not usually incorporated as conditions of a permit.

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

Introduction

Boron is a naturally occurring dark brown/black substance found throughout the environment. It only occurs in combined form, usually as borax, colemanite ($Ca_2B_6O_{11}$-$5H_2O$), boronatrocalcite ($CaB_4O_7NaBO_2$-$8H_2O$) and boracite ($Mg_7Cl_2B_{16}O_{30}$). It belongs to Group 13 on the periodic table and has properties which are borderline between metals and non-metals. It is a semiconductor rather than a metallic conductor and it is more related chemically to silicon than to aluminum, gallium, indium, or thallium.

Deposits of boron mineral are found in three major belts — the Mojave Desert in California, the plateau of the Alpine-Himalayan system and the high plateau of the Andes — and are associated with volcanic activity or where marshes or lakes have evaporated under arid conditions. Major exporters of boron are the United States, Turkey, Argentina, China, Chile and Russia. Importers of boron include Western Europe, Japan, Brazil, Australia, Canada and Eastern Europe.

Boron is used in a variety of products including glass and glass products, cleaning products, agrochemicals, insecticides, flame-proofing compounds, corrosion inhibitors and antiseptics. Boron compounds are also used in treating skin cancer resulting in complete disappearance of melanoma without substantial side effects.

The highest concentrations of boron are found in sediments and sedimentary rock, particularly clay rich marine sediments. The high boron concentration in seawater, which averages around 4.5 mg B/L,

ensures that marine clays are rich in boron relative to other rock types. Boron is released into the environment very slowly and at low concentrations by natural weathering processes. This amounts to approximately 360 000 tonnes of boron per year world-wide. Boron can also be found naturally in soils at concentrations of 5 to 150 parts per million (ppm). Anthropogenic sources of boron in the environment include sewage sludge and effluents, coal combustion, glass, cleaning compounds and agrochemicals.

Worldwide production of boron is at the same order of magnitude as natural weathering; however, it is thought that the large input of available boron to the environment comes from natural weathering rather than anthropogenic sources. Boron is less persistent in light textured acidic soils and in areas with high rainfall because of its tendency to leach. As a result boron toxicity tends to be more of a problem in arid climates.

Generally, environmental concentrations found in surface water are below levels identified as toxic to aquatic organisms. In British Columbia, median values for boron in surface water is about 0.1 mg/L and in Canadian coastal marine water it ranges from 3.7 to 4.3 mg/L. In British Columbia's ground water, the median total boron was found to be 0.069 mg/L. Boron retention in soil depends on the concentration in the soil solution, soil pH, texture, organic matter, cation exchange capacity, type of clay and mineral coating on the clay. Research suggests that less than 5% of soil boron is available for plants.

Boron is an essential trace element for the growth of terrestrial crop plants and some algae, fungi and bacteria, but can be toxic in excess. Toxicity to aquatic organisms, including vertebrates, invertebrates and plants can vary depending on the organism’s life stage and environment. Early stages are more sensitive to boron than later ones, and the use of reconstituted water shows higher toxicity in lower boron concentrations than natural waters. In mammals, excessive consumption (i.e. >1000 mg B/kg diet; >15 mg B/kg body weight daily) can adversely affect growth, reproduction or survival.

There is no evidence of carcinogenicity or mutagenicity; however, egg injection studies have indicated potential embryo teratogenicity.

Recommended Guidelines

1. Drinking Water

It is recommended that the total concentration of boron in drinking water should not exceed 5.0 mg/L.

Rationale:

The maximum acceptable concentration was set because the available treatment technologies are inadequate to reduce boron concentrations in Canadian drinking water supplies to less than 5.0 mg/L. Because boron concentration levels in British Columbia's surface and ground water are less than this value, boron toxicity is not expected to pose a significant risk to drinking water. This guideline is consistent with the Health Canada drinking water guideline.

2. Aquatic Life

Freshwater:

It is recommended that the maximum concentration of total boron for the protection of freshwater aquatic life should not exceed 1.2 mg B/L.

Rationale:

The recommended interum guideline is based on the lowest observed effect level (LOEL) of 12.3 mg/L in the growth of *Selenastrum capricornutum* exposed to boron and a safety factor of 0.1. The safety factor is consistent with the CCME and British Columbia protocols for guideline development.

Marine Water:

It is recommended that the maximum concentration of total boron for the protection of marine aquatic life should not exceed 1.2 mg B/L.

Rationale:

The recommended guideline is based on a 283h-LC_{50} of 12.2 mg B/L for coho salmon (*Oncorhynchus kisutch*). A safety factor of 0.1 was used to derive the guideline in the marine environment.

3. Wildlife

To protect wildlife from adverse effects, the maximum concentration of total boron should not exceed 5.0 mg B/L.

Rationale:

There are limited data on the effects of boron on wildlife. Therefore, the use of the guideline set for livestock watering is recommended on an interim basis.

4. Irrigation

It is recommended that the maximum concentration of total boron for the protection of irrigated crops should not exceed those shown in Table 2. These guidelines depend on the sensitivity of the crops and are consistent with the CCME guidelines.

Rationale:

The province's agriculture industry is widely diversified in the variety of crop species grown, from the boron-sensitive crops of blackberry, peach and strawberry to the more tolerant crops such as asparagus, carrot and tomato. However, due to the very low residual levels of boron in the surface water (0.01 mg/L) and ground water (0.069 mg/L), boron toxicity is not expected to be an issue.

5. Livestock Watering

It is recommended that the maximum concentration of total boron in livestock watering should not exceed 5.0 mg B/L.

Rationale:

There were insufficient data to calculate an interim guideline for livestock species using the CCME's protocol. This level is also used in the USA and in Australia and New Zealand for the protection of livestock watering.One study found a safe tolerance of boron in livestock drinking water was between 40 and 150 mg/L. Based on this data point, the recommended guideline will provide a safety factor of at least 8:1. It should be kept in mind that, in general, normal drinking water has less than 1.0 mg B/L and it is unlikely that livestock will be exposed to high levels of boron in their drinking water.

Application of Guidelines for Aquatic Life

The water quality guidelines recommended in this document are primarily based on controlled, laboratory bioassays in which organisms are exposed to boron only. In the environment, however, boron toxicity may be modified by local conditions. To adjust the guideline recommended here to take local conditions into consideration, the B.C. Ministry Of Environment, Lands & Parks publication, “Methods for Deriving Site-Specific Water Quality Objectives in British Columbia and Yukon” should be followed.

In most cases, water quality objectives will be same as guidelines. When concentration of boron in undeveloped waterbodies are less than the recommended guidelines, then more stringent values, if justified, could apply. In some cases, socioeconomic or other factors (e.g., higher background levels) may justify site-specific objectives that are less stringent than the guidelines. Site-specific impact studies would be required in such cases. Where ambient boron concentrations exceed the guideline, it is recommended that degradation of existing water quality should be avoided to protect aquatic life.