Water Quality

Ambient Water Quality Guidelines for Zinc

Overview Report

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

Original signed by Don Fast
Assistant Deputy Minister
Environment and Resource Management
March 15, 1999

Summary

This document is one in a series that establishes ambient water quality guidelines, formerly known as criteria, for British Columbia (Table 1). This document is mainly based on a report prepared by the BC Ministry of Environment, Lands and Parks for the Canadian Council of Ministers of the Environment (CCME). It sets guidelines for zinc (Zn) to protect drinking water, recreational and aesthetics, freshwater and marine aquatic life, and agricultural water (irrigation and livestock watering) uses.

Zinc guidelines were not set for wildlife and industrial water uses, since suitable data documenting the effects of zinc for these uses were not available in the literature.

Zinc is most toxic to microscopic organisms in the aquatic environments. It is also an essential element for aquatic and terrestrial biota and its removal from the environment below certain levels can also be harmful due to its deficiency. Zinc guidelines, tabulated above, are summarized in the chapter on Recommended Guidelines. A more detailed discussion of the guidelines or criteria is presented in the main body of the report.

Zinc may bind to particulate matter. Soluble species of zinc are readily available for biological reactions and, therefore, considered as most toxic. It has been shown that zinc in water is a better predictor of fish tissue contamination than zinc in either sediment or invertebrates (i.e., food source). It is, therefore, recommended that the zinc guideline may be interpreted in terms of the dissolved metal fraction when the total zinc concentration in the environment exceeds the guideline due to particulate matter and adverse effects due to zinc are not obvious.

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

Tables

Table 1: Recommended Guidelines for Zinc

Water Use	Guideline (µg/L Total Zinc)
Drinking Water	See Source Drinking Water Quality Guidelines: https://www2.gov.bc.ca/assets/download/1F11ABD2CBD24EB09A70B89AB50CE6B0
Marine Life	10
Livestock Watering	2000
Irrigation - soil pH less than 6	1000
Irrigation - soil pH equal to or greater than 6 and less than 7	2000
Irrigation - soil pH greater than or equal to 7	5000
Freshwater Aquatic Life - maximum concentration —— water hardness less than or equal to 90 water hardness equal to 100 water hardness equal to 200 water hardness equal to 300 water hardness equal to 400	Use the Equation 33 + 0.75 x (hardness -90) —— 33 40 115 190 265
Freshwater Aquatic Life - 30 day average concentration —— water hardness less than or equal to 90 water hardness equal to 100 water hardness equal to 200 water hardness equal to 300 water hardness equal to 400	Use the Equation 7.5 + 0.75 x (hardness -90) —— 7.5 15 90 165 240

1. When the ambient zinc concentration in the environment exceeds the guideline, then further degradation of the ambient or existing water quality should be avoided
2. These are instantaneous maximums
3. Averages are of five weekly measurements taken over a 30-day period.
4. Water hardness is measured as mg/L of $CaCO_3$

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 Water Management 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)

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.

Introduction

Zinc is an essential element in trace amounts for plants and animals. In mammals, it plays a vital role in the biosynthesis of nucleic acids, RNA polymerases, and DNA polymerases and, thus, is involved in the healing processes of tissues in the body. Other physiological processes such as hormone metabolism, immune response, and stabilization of ribosome and membranes also require zinc.

Zinc toxicosis is not a common problem, but zinc poisoning in humans (e.g., from acid foods or beverages stored in galvanized containers) and animals (e.g., from ingesting or exposure to galvanized metal objects, certain paints and fertilizers, zinc-containing coins, etc.) have been documented. Several factors such as water hardness, salinity, temperature, and the presence of other contaminants influence zinc toxicity in aquatic environments. This modification in zinc toxicity is the result of an effect on zinc availability and on sorption or binding of available zinc to biological tissues. The effect of water hardness on zinc toxicity is by far the most studied factor.

Clinical manifestations of zinc deficiency in animals include growth retardation, testicular atrophy, skin changes, and poor appetite. Zinc is ubiquitous in the environment and its deficiency in humans and animals may be considered an unlikely problem. Nevertheless, zinc deficiency and related problems in humans, animals, birds, and plants have been reported in the literature.

Zinc ranks fourth among metals of the world in annual consumption, behind iron, aluminum and copper. British Columbia, Ontario, Yukon, and Northwest Territories are the major producers of zinc in Canada. Zinc uses are many:

- as a rust-resistant coating for iron and steel products;
- in the manufacture of brass and bronze in the die-casting industry;
- as ingredients of many household items, including utensils, cosmetics, powders, ointments, antiseptics and astringents, paints, varnishes, linoleum, rubber, and others;
- in the manufacture of parchment papers, glass, automobiles tires, television screens, dry cell batteries, electrical apparatus, agricultural fertilizers, insecticides, hardeners in cement and concrete, in printing and dyeing of textiles, in production of adhesives, as a flux in metallurgical operations, and as wood preservatives;
- in the manufacture of smoke bombs used for crowd dispersal, fire fighting exercises, and by military for screening purposes; and
- as medicine in the treatment of zinc deficiency, various skin diseases, wound healing, and to reduce pain in sickle cell anaemia patients.

The concentration of zinc in natural waters is generally low, but on occasion high levels have been measured in natural environments. High levels of zinc are always found in contaminated waters or waters flowing through a bedrock system containing zinc deposits.

Historical zinc concentrations should be viewed with caution. Results from cleaner laboratory analytical methods with lower detection limits show that background zinc concentrations are lower than previously thought. Older high values may be the artifacts of high detection limits and artificial contamination during measurement.

Recommended Guidelines

1. DRINKING WATER

See the Source Drinking Water Quality Guidelines: Guideline Summary Document

https://www2.gov.bc.ca/assets/download/1F11ABD2CBD24EB09A70B89AB50CE6B0

2. AQUATIC LIFE

Freshwater: Chronic

To protect freshwater aquatic life from chronic effects, the average concentration of total zinc (µg/L) should not exceed 7.5 µg/L when water hardness is less than or equal to 90 mg/L $CaCO_3$. When water hardness exceeds 90 mg/L $CaCO_3$, the average concentration is

determined by the following relationship:

Average Concentration (μg/L) = 7.5 + 0.75 (Water Hardness in mg/L $CaCO_3$ - 90)

The recommended guideline at hardness values less than or equal to 90 mg/L $CaCO_3$ is based on the lowest observed effect level (LOEL) of 15 μg Zn/L for copepod and a safety factor of 0.5. The safety factor was based on the ratio of the no effect levels and LOELs found in the literature. The linearity between zinc toxicity and water hardness was assumed for practical reasons. The slope in the above equation was obtained from the two LOELs at 90 (15 μg Zn/L) and 200 mg/L $CaCO_3$ (180 μg Zn/L) after applying a safety factor of 0.5.

Freshwater: Acute

To protect freshwater aquatic life from acute and lethal effects, the maximum concentration of total zinc (μg/L) at any time should not exceed 33 μg/L when water hardness is less than or equal to 90 mg/L $CaCO_3$. When water hardness exceeds 90 mg/L $CaCO_3$, the maximum concentration is determined by the following relationship:

Maximum Concentration (μg/L) = 33 + 0.75 (Water Hardness in mg/L $CaCO_3$ - 90)

The guidelines for maximum concentration are based on 96-h LC_{50} of 66 mg/L at 9.5 mg/L $CaCO_3$ for rainbow trout. The slope and the start of the relationship between zinc toxicity and water hardness was assumed to be the same as that for the chronic toxicity.

Acute LOELs lower than 66 μg/L were reported in literature. However, they were not used in development of the guidelines, because the data were dated, original articles were not available for confirmation of data quality, or data were incomplete (e.g., water hardness was not stated). Such rejection of suspect or incomplete data is consistent with the CCME and the Ministry of Environment, Lands and Parks protocols for the development of guidelines.

Marine Water: Chronic

To protect marine aquatic life in marine environments, the average concentration of total zinc should not exceed 10 µg/L.

The recommended guideline is based on lowest observed effect (chronic) levels of 19-19.6 µg/L zinc for the marine algae *S. schroederi* and *S. constatum*. A safety factor of 0.5 was used.

Marine Water: Acute

To protect aquatic life from acute or lethal effects in the marine environment, the maximum concentration of total zinc at any time should not exceed 55µg/L.

The recommended guideline is based on lowest observed acute values of 112-168 µg/L (96-h LC_{50}) for Arctic grayling and 119-310 µg/L (48-h LC_{50}) for Pacific oyster. A safety factor of 0.5 was used.

3. IRRIGATION

The maximum concentration of total zinc in irrigation water supplies should not exceed 1000 µg/L for soils with pH less than 6.0; 2000 µg/L for soils with pH ranging between 6.0 and 7.0, and 5000 µg/L for soils with pH greater than 7.0.

These guidelines replace the 1987 CCME guidelines which were based on old (pre 1980) data.

4. LIVESTOCK WATERING

To protect livestock water use, the concentration of total zinc in livestock watering should not exceed 2000µg/L.

This guideline replaces the 1987 CCME guideline which was based on old (pre 1980) data.

Application of the Guidelines

Zinc is ubiquitous in the environment. Its impact on the environment depends upon several factors related to Zn sources and environmental variability. Therefore, care must be exercised when the water quality guidelines are applied to assess environmental impacts of zinc.

1. ASSESSMENT OF EXISTING WATER QUALITY

Zinc shows variable behaviour in binding to particulate matter depending upon physical-chemical characteristics of the aquatic system. The literature shows that particulate zinc in rivers and lakes varied from 10-78% of the total zinc concentration. Furthermore, soluble species of zinc are readily available for biological reactions and, therefore, most toxic. It has also been shown in the literature that zinc concentration in water is a better predictor of fish tissue contamination than the concentration in either sediment or invertebrates (i.e., food). In view of these facts, it is recommended that the zinc guideline should be interpreted in terms of the dissolved metal fraction when the total zinc concentration in the environment exceeds the guideline due to particulate matter and adverse effects due to zinc are not obvious.

The water quality guidelines recommended in this document are primarily based on controlled, laboratory bioassays in which the toxic effects on organisms were measured in terms of the zinc levels in water. However, the zinc body burden of aquatic organisms in their natural environments is the result of exposure to both water and food sources. Zinc associated with the sediment fraction may also become available to the organisms under favourable environmental conditions. Thus, the zinc concentrations in water alone should not be taken as a true reflection of the potential zinc problem in a given waterbody. Other assessment techniques may be required to address issues related to zinc, including measurement of zinc concentrations in fish and/or sediment and long-term bioassays with resident species using local water. If available, guidelines for maximum and average zinc concentrations in fish tissue and sediment should also be used to assess existing water quality. Long-term bioassays are complex and costly; they are likely to be undertaken for waterbodies with high resource values and which are threatened by a controllable point-source of zinc pollution.

2. SETTING OF WATER QUALITY OBJECTIVES

In most cases, water quality objectives will be the same as the guidelines. When concentrations of zinc 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 objectives which are less stringent than the guidelines. Site-specific impact studies would be required in such cases.

Zinc availability, and hence its toxicity, in the aquatic environment can be influenced by many factors, including water hardness. Although the literature alludes to this fact, there is a general lack of available research in this area. However, methods (e.g., water effects ratio, resident species toxicity in the field, etc.) are available to adapt the recommended guidelines to a given site by considering these factors (other than hardness which has been considered in this document). Where necessary, these methods can be employed to set site-specific water quality objectives. Because these approaches are costly and time consuming, they are seldom used.

In some instances, the ambient or existing concentrations of zinc in the environment may exceed the recommended guidelines. This may be true especially in the soft water (hardness less than or equal to 90 mg/L $CaCO_3$) environments. To protect aquatic life in such environments, it is recommended that degradation of the existing water quality should be avoided.