Water Quality

Ambient Water Quality Guidelines for Mercury

Overview Report — First Update

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

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Summary

This report is one in a series that establishes ambient water quality guidelines for British Columbia. The guidelines are safe conditions or levels of contaminants, applicable province-wide, which are set to protect various water uses.

This report updates the 1989 BC Environment guidelines for total mercury (THg) by providing revised water quality guidelines to protect aquatic life from chronic effects of mercury. This was deemed to be necessary since the Canadian Council of Ministers of the Environment (CCME) have recently developed guidelines for mercury in the water column to protect aquatic life and in the flesh of aquatic life to protect wildlife. The report also outlines water quality guidelines to protect avian wildlife feeding on aquatic organisms. The updated guidelines are consistent with the CCME tissue residue guideline to protect wildlife from methyl mercury (MeHg) in their diet. The guidelines for drinking water, livestock, irrigation and recreation, are unchanged from in the 1989 report. The guidelines are summarized in Table 1, Table 2, and Table 3.

A major use of the guidelines is to set ambient water quality objectives. The objectives are the guidelines modified or adopted to protect the most sensitive designated water use in a particular body of water. The objectives are used in the preparation of waste management Permits, Orders, or Approvals, which are the only documents to have legal standing. The objectives, however, are not usually part of these documents.

Table 1: Summary of Water Quality Guidelines for Mercury

Water Use	30-d av. Conc.* (µg/L THg)	Maximum Conc. (µg/L THg)
Drinking Water, Primary-Contact Recreation, and Food Processing Industry	None proposed	1.0

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Wildlife and Aquatic Life (Freshwater Estuarine and Marine)+ When MeHg = 0.5% of THg When MeHg = 1.0% of THg When MeHg = 8.0% of THg	 0.02 0.01 0.00125	None proposed
Irrigation Water Supplies	None proposed	2.0
Livestock Water	None proposed	3.0

* The 30-day average is based on five weekly samples taken in a period of 30 days.
+ If natural levels exceed the guidelines for aquatic life, then any increase allowed above the natural levels should be based on site-specific data.

Table 2: Aquatic Life Guidelines for Fish / Shellfish when Human Diet is Based Primarily on Fish

Total Hg Concentration in the Edible Portion of Fish and Shellfish µg Total Hg/g Wet Weight	Safe Quantity for Weekly Consumption on Regular Basis grams Wet Weight
0.5	210
0.4	260
0.3	350
0.2	525
0.1	1050

Table 3: Tissue Residue Guidelines to Protect Wildlife from Mercury Toxicity

The concentration of methyl Hg in fish or shellfish consumed by wildlife should not exceed 0.033 µg/g wet weight.

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 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)
- 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.

Introduction

Mercury is a non-essential element for plants and animals. However, metallic mercury is widely used in industry for the manufacture of chemicals, electrical equipment, power generation, dental amalgams and metallurgical gold. The mercurial compounds have found applications in paints, drywall compounds, scientific supplies, pharmaceuticals, fungicides and bactricides.

Mercury is found naturally in the earth crust, rocks, minerals, and coal and base metal deposits. Areas of high mercury content associated with zones of instability and volcanic and thermal activity have been found over the globe.

Many natural and anthropogenic sources contribute to environmental mercury loading. In the environment, mercury can exist in both organic and inorganic forms. Methyl mercury (MeHg), the most toxic form of mercury, tends to bioaccumulate and biomagnify in the aquatic food chain. Piscivorous mammals, fish and birds accumulate most of their body burden through diet.

Mercury is known to damage renal, nervous, reproductive, and developmental systems. The chemical form of mercury and route of entry are important determinants of its toxicity. Ingestion of inorganic mercury is primarily responsible for erosion of intestinal tracts and kidney damage in both animals and humans. Methyl mercury and short-chain organic mercurials destroy neuronal cells in areas of central nervous systems concerned with sensory and co-ordination functions.

In British Columbia, economic grade deposits of mercury are commonly associated with sedimentary rocks such as limestone and sandstone of the Palaezoic to Recent age. The province's richest mercury deposits are in the Pinchi Lake fault zone which extends from Fort St. James northwest to the Omineca River. Other major areas of mercury mineralization in British Columbia include Kamloops Lake, Bridge River, and Yalakom River.

The concentration of mercury in natural waters is generally low. However, elevated concentrations of mercury have been reported in British Columbia in areas contaminated by the industrial activity (e.g., Squamish) and where extensive mercury mineralization has occurred.

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

Recommended Guidelines

Table 1 summarizes all guideline values including those that have been updated. This was deemed to be necessary since the Canadian Council of Ministers of the Environment (CCME) have recently developed guidelines for mercury in the water column to protect aquatic life and in the flesh of aquatic life to protect wildlife. There is obviously a need to reconcile all these guideline values in one document for the benefit of resource managers.

1. DRINKING WATER SUPPLY

For the protection of human health, the concentration of total mercury in raw drinking water should not exceed 1.0 µg/L at any time. No change has been made to the existing guideline. Therefore, this guideline is consistent with the 1999 CCME and the 1989 BC Environment guidelines.

2. AQUATIC LIFE (FRESHWATER, ESTUARINE AND MARINE)

These guidelines replace the 1989 BC Environment guidelines for fresh, marine and estuarine waters.

(a) The 30-day average guidelines for marine, estuarine and fresh waters are the same, due to the facts that:

- the bioaccumulation potential of mercury in marine and freshwater food chain is similar; and
- both are based on the 1999 CCME recommended tissue residue guideline to protect the most sensitive consumers of aquatic life (e.g., avian species).

The average concentration of total mercury in water as measured over a 30-day period (based on five weekly samples) should not exceed 0.02 ug/L when the methyl mercury (MeHg) constitutes less than or equal to 0.5% of the total mercury concentration. When the proportion of MeHg is greater than 0.5%, the guideline should be adjusted as indicated in the Table 4 below. The rationale for the graduated guideline is the fact that MeHg concentrations may vary in the environment. For example if the percent of MeHg is 11% the guideline would be calculated by the following equation:

0.1ng MeHg/L (WQGwl *see below in rationale section*) ÷ 0.11 (i.e. the % MeHg)
= 0.9 (guideline ng/L total Hg)

Table 4: The Total Hg Guideline as a Function of the Percentage of Methyl Mercury

% MeHg (of total Hg)	Guideline (ng/L total Hg)
0.5	20.0 ng/L
1.0	10.0 ng/L
2.5	4.0 ng/L
5.0	2.0 ng/L

These levels will protect freshwater aquatic life from chronic effects of mercury. They will also prevent undesirable accumulation of mercury from water to the food chain that may harm the most sensitive consumers (e.g., avian species) of aquatic life.

Rationale:

The following assumptions were made to update the 30-day average guideline to protect from mercury bioaccumulation in fish to a level that may harm wildlife consuming the mercury-contaminated fish:

All mercury in fish tissue is in the methylated form. This conclusion is consistent with observations made by researchers in the literature.

The MeHg bioaccumulation factor at a higher trophic level (level 3 or fish consumed by avian species) is 320,000 on wet-weight (BAF_{3ww}) basis or 1,600,000 on dry-weight (BAF_{3dw}) basis. This BAF is consistent with the US EPA recommended value and values observed in Squamish, British Columbia.

Based on recommended level of methyl mercury at 33 µg/kg wet-weight (diet) and the methyl mercury BAF_{3ww} of 320,000, the acceptable concentration in water for the protection of wildlife consuming fish can be estimated as follows:

$$WQGwl = (33\ \mu g\ MeHg\ kg^{-1} \times 1000\ mg/\mu g) / 320{,}000 = 0.1\ ng\ MeHg/L$$

(where WQGwl is the water quality guideline to protect wildlife)

Table 5 below expresses WQGwl in terms of the comparable THg levels for various percentages of MeHg as a function of THg.

Table 5. WQGwl In Terms of the Comparable THg Levels for Various Percentages of MeHg as a Function of THg

% MeHg (of total Hg)	WQGwl (ng/L total Hg)
0.5	20.0 ng/L
1.0	10.0 ng/L
2.5	4.0 ng/L
8.0	1.25 ng/L

This analysis suggests that the 1989 BC Environment's 30-day average guideline of 0.02 mg/L (or 20 ng/L) total mercury is valid as long as MeHg is less than or equal to 0.5% of the total mercury concentration. Appropriate water quality guidelines for MeHg concentrations other than those specified in the above table can be determined using a linear relationship between WQGwl and MeHg (%).

It should be noted that the CCME (2000) in developing guidelines for fresh and marine waters did not consider bioaccumulation effects per se, but based their guidelines on chronic toxicity. They caution that the guidelines that they have developed 'may not protect wildlife that consume aquatic life'. As well, they considered marine and fresh waters separately, even though there is no reason to suspect that the chemistry of each affects mercury or its bioaccumulation in fish and avian wildlife and do not provide a guideline for MeHg in marine water.

(b) The 1989 BC Environment guidelines for a maximum mercury concentration in either fresh or marine waters has been deleted due to the bioaccumulative nature of mercury which is the most important consideration in developing guidelines. Direct toxic effects that a maximum concentration is meant to protect against are seldom encountered and will be accounted for in bioaccumulation in most cases.

(c) To protect human health, the maximum concentration of total mercury in the edible portion of fish / shellfish should not exceed 0.5 mg/g wet weight. For people whose diet is based primarily on fish, this guideline may need to be varied, as indicated in Table 2. This is consistent with the 1989 BC Environment and the Health and Welfare Canada guideline.

3. WILDLIFE

The 30-day average concentration of total mercury in water to protect wildlife should not exceed levels shown in Section 2 above. These guidelines are based on the tissue residue guideline recommended by the CCME (2000), and will protect the most sensitive avian life feeding on aquatic organisms that may accumulate undesirable levels of mercury in their tissues. This guideline replaces the 1989 BC Environment guideline of 3.0 mg THg/L that had been based on livestock sensitivity to mercury since there were insufficient data on mercury toxicity to avian wildlife. The CCME (2000) did not recommend mercury guidelines for wildlife.

Additionally, the methyl mercury concentration should not exceed 0.033 µg/g wet weight in the diet of wildlife. This guideline is consistent with the CCME (2000) tissue guidelines to protect avian wildlife feeding on fish and shellfish containing mercury.

4. LIVESTOCK WATER SUPPLY

The concentration of total mercury in livestock water supply should not exceed 3.0 µg/L at any time. This is consistent with the 1989 BC Environment and the CCME (1999) guidelines.

5. IRRIGATION

The maximum concentration of total mercury in irrigation water should not exceed 2.0 µg/L. This is consistent with the 1989 BC Environment guideline. The CCME (1999) did not recommend mercury guidelines for water used for irrigation.

6. RECREATION AND AESTHETICS

In waters used only for primary-contact recreation such as swimming, the total mercury concentration should not exceed 1.0 µg/L at any time.

This is consistent with the 1989 BC Environment guideline. The CCME (1999) did not recommend mercury guidelines for recreational water use.

7. INDUSTRIAL WATER SUPPLY

The concentration of total mercury in water used in the food processing industries should not exceed 1.0 µg/L at any time, since such water could be consumed by humans in significant quantities. No guidelines are recommended for other industries at this time due to lack of information.

This is consistent with the 1989 BC Environment guideline. The CCME (1999) did not recommend mercury guidelines for industrial water supplies.

Application of the Guidelines

1. FORMS OF MERCURY

Toxicity of mercury has been expressed in terms of both total and methyl forms of mercury. However, total mercury is recommended for setting water quality objectives for a given waterbody. The advantages of expressing toxicity on the basis of total mercury concentrations are:

i. all the mercury that may potentially be toxic is included in the measurement; if the total mercury concentration in water is within the guideline limits, then it is safe to conclude that no mercury pollution exists;
ii. for comparison purposes, there is a considerable amount of historical information available for total mercury; and
iii. total mercury measurements are routine and relatively inexpensive.

Mercury in aquatic organisms (e.g., fish) is predominantly in the methyl form and should also be measured when investigating mercury contamination problems in aquatic systems. The CCME recommended tissue residue guideline (0.033 micrograms MeHg/g wet weight-diet) should apply to protect wildlife consumers of fish.

The main disadvantage of using total mercury to assess water quality is that a large fraction of mercury may become biologically unavailable by forming complexes with the organic and suspended solids fractions of water. Nevertheless, given favourable environmental conditions, mercury complexed in such a manner will be released into the environment in readily available forms, becoming part of the food chain.

2. ASSESSMENT OF EXISTING WATER QUALITY

The guidelines recommended in this document are primarily based on laboratory bioassays that usually are performed with soluble forms of mercury under controlled conditions. Aquatic organisms in a natural environment, however, obtain their mercury burden from both water and food. Mercury from sediments could become available to the organisms under certain environmental conditions. Thus measuring total mercury in water alone cannot be taken as a true measure of a mercury problem in a given waterbody.

Other assessment techniques include measurements of mercury in fish, and long-term bioassays with resident species using local water. The guidelines for mercury in fish can be used for to assess existing water quality. Long-term bioassays are complex and costly, and should be used for waterbodies with high fisheries values that are threatened by a controllable source.

3. SETTING WATER QUALITY OBJECTIVES

Natural mercury concentrations in a waterbody may not always meet the guidelines. In such a case, the objective should be based on the natural levels and any increase in total mercury to be allowed should be based on site-specific investigations. When natural concentrations of total mercury in undeveloped waterbodies are less than the guideline levels, then the guidelines or more stringent values if justified, should apply. In some cases, socioeconomic factors may justify objectives that are less stringent than the guidelines. Site-specific impact studies would be required in such cases.