Water Quality

Water Quality Criteria for Microbiological Indicators

Overview Report

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Summary

This report is part of a series establishing water quality criteria for British Columbia. It sets criteria for microbiological indicators, which are bacteria indicating the risk of disease from pathogenic bacteria. The criteria are set to protect drinking water, livestock watering, and irrigation. Sections of this report on industrial water use, recreational water use and shellfish harvesting have been removed. B.C. no longer develops or supports guidelines for industrial water use. See the Recreational Water Quality Guidelines: Guideline Summary for the latest B.C. recreational guideline recommendations, including shellfish harvesting.

Fecal coliforms have historically been the indicator of choice, but their presence does not always correlate well with the incidence of disease. Coliforms are therefore now being supplanted by more specific indicators. These include *Escherichia* coli and enterococci which are good indicators of gastrointestinal disease, and *Pseudomonas aeruginosa* which correlates well with ear and skin infections. Criteria are set in this report for these three other indicators as well as for fecal coliforms. The Canadian Water Quality Guidelines published by the CCREM in 1987 deal only with coliform bacteria for drinking water, recreation and irrigation. They are consistent with our criteria except for irrigation which we address in more detail.

Tables

Table 1. Summary of Water Quality Criteria for Microbiological Indicators

Water Use	Escherichia coli	Enterococci	Pseudomonas aeruginosa	Fecal coliforms
Raw Drinking Water Sources	less than or equal to 10/100 mL 90th percentile	less than or equal to 3/100 mL 90th percentile	None applicable	None applicable
Wildlife	None applicable	None applicable	None applicable	None applicable
Livestock - free range animals	None applicable	None applicable	None applicable	None applicable
Livestock - general livestock use	200/100 mL maximum	50/100 mL maximum	None applicable	200/100 mL maximum
Livestock - closely confined (no treatment)	0/100 mL maximum	0/100 mL maximum	None applicable	0/100 mL maximum
Livestock - closely confined (disinfection only)	less than or equal to 10/100 mL 90th percentile	less than or equal to 3/100 mL 90th percentile	None applicable	less than or equal to 10/100 mL 90th percentile
Livestock - closely confined (partial treatment)	less than or equal to 100/100 mL 90th percentile	less than or equal to 25/100 mL 90th percentile	None applicable	less than or equal to 100/100 mL 90th percentile
Livestock - closely confined (complete treatment)	None applicable	None applicable	None applicable	None applicable
Irrigation - crops eaten raw	less than or equal to 77/100 mL geometric mean	less than or equal to 20/100 mL geometric mean	None applicable	less than or equal to 200/100 mL geometric mean
Irrigation - public access - livestock access	less than or equal to 385/100 mL geometric mean	less than or equal to 100/100 mL geometric mean	less than or equal to 10/100 mL 75th percentile	None applicable

Irrigation - general irrigation	less than or equal to 1000/100 mL geometric mean	less than or equal to 250/100 mL geometric mean	None applicable	less than or equal to 1000/100 mL geometric mean

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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 goal:

- To provide guidelines for the evaluation of data on water, sediment, and biota.

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:

- drinking water
- aquatic life
- wildlife
- agriculture (livestock watering and irrigation)
- recreation and aesthetics

Guidelines do not have any legal standing. 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.

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

Contaminated water has always been an important agent in the spread of disease. Ingestion may cause gastrointestinal diseases, and skin diseases may be caused by immersion. Water treatment and disinfection have markedly reduced the incidence of many diseases, but the need for constant vigilance and enforcement of standards is highlighted by the occasional water-borne disease epidemic. Microbiological criteria are presently undergoing re-evaluation throughout the world, and the historical dependence upon total and fecal coliforms is being supplanted by more specific, epidemiologically-derived indicators of water quality. Eventually, each use of the water and source of contamination should have a representative specific indicator associated with a regression equation so that disease risks can be quantified. Once this occurs, the costs of achieving a given water quality could be directly compared with the savings in health care costs resulting from this level of water quality.

Organisms which are pathogenic to humans are rarely capable of survival as free-living organisms for very long. Virtually all the water-borne diseases affecting humans are a result of poor waste treatment and disposal practices; the disposal of disease organisms carrying resistance to antibiotic drugs is of particular concern. The harvesting of shellfish for human consumption is particularly sensitive to water quality since these organisms filter out and concentrate pathogens found in the water at relatively low levels. Contaminated shellfish have been responsible for many disease epidemics, but due to the rigorous sanitary surveys carried out before shellfish harvesting areas are opened, no sewage-contaminated shellfish have caused a disease outbreak in British Columbia.

Since the direct monitoring of all possible pathogens would be too slow and uneconomical for routine water quality control, microbiological water quality is commonly estimated or monitored using a single or a few indicator organisms. The validity and usefulness of the indicator concept depends upon the existence of a constant quantitative relationship between the indicator organism and the pathogens it is monitoring. Establishing such relationships is a complex process, and several indicators are necessary if acceptable health risks are to be assigned to all pathogens in an economical manner. This indicator-to-

pathogen ratio may change when an epidemic occurs or if changes take place in the quality of health care and treatment.

Pseudomonas aeruginosa is a common opportunistic pathogen of man which causes ear infections and other non-gastrointestinal infections when present in recreational waters. These include hot tubs, whirl pools and swimming pools. It is not adequately monitored by such gastrointestinal indicators as the coliforms and needs to be monitored directly. Enterococci are better indicators than fecal coliforms and most closely approach the ideal characteristics of an indicator for gastrointestinal diseases. They are the best indicators for recreational uses, especially in marine waters where E. coli do not survive as well. They are not as useful in water with high organic wastes from vegetable processing, but are good in assessing reservoir quality, sewage-contaminated water supplies and chlorinated water high in organics. *Escherichia coli* is a better indicator than fecal coliforms since *Klebsiella* is not enumerated in the *E. coli* test. *Klebsiella* may multiply in water containing pulp mill effluent and other organics, which is not contaminated by human sewage, and thus gives false positives for fecal contamination. These indicators have higher correlations with specific types of disease under specified conditions than does the fecal coliform test, and are recommended as replacements for fecal coliforms.

Both employees and the general public may be subjected to pathogens in aerosols formed in several industrial processes. For example, *Klebsiella* pneumonia builds up in pulp mill process water and *Legionella pneumophila* multiplies in cooling towers, humidifiers and air conditioning systems. These problems can not be controlled by ambient water quality control since contamination and multiplication often occur subsequent to delivery of the water to the plant. These are waste-water management problems or process control problems.

The criteria are based on bacteria present in human and animal feces as distinct from other bacteria which may be found in sewage. These indicators are meant to be fecal indicators as opposed to sewage indicators. While these terms may, in some circumstances be synonymous, they are not necessarily so and some conditions will be found where different indicators are best for quantifying sewage contamination. The fecal bacteria from animals indicate less risk of disease to people than do those from humans. Since ambient water can contain a mix of human and animal fecal contamination, the criteria may be over-protective if all the indicator organisms came from animals or under-protective if all the indicator organisms came from humans.

There are no routine monitoring techniques for viruses, hence no criteria for viruses have been set. The risk of viral disease is not always known when using criteria based on bacteria. However, given the usual uses of ambient water in the province, the criteria presented here are expected to provide a high degree of protection.

A summary of the Water Quality Criteria for Microbiological Indicators is given in Table 1.

Recommended Guidelines

The criteria are based on detailed analyses given in the technical document.

Raw Drinking Water

Most surface waters should be treated before distribution to the consumer. The BC Ministry of Health recommends that all supplies derived from surface water and shallow ground water sources receive disinfection as a minimum treatment. The degree of treatment needed is a function of the quality of the raw water. Protection of surface water to a degree that would eliminate health risks without treatment of the raw water is impractical in most cases. The criteria describe the raw water quality necessary for a given level of water treatment. If prevention fails to maintain raw water quality, then additional treatments or location of alternate water supplies with their added costs, become necessary. The intent of the treatment processes is to deliver water to the consumer's tap which is free of potentially harmful microorganisms, is aesthetically acceptable to the user and otherwise meets drinking water quality standards.

Most water treatments reduce viruses to a certain extent, but none except disinfection can do a complete job. Both chlorine and ozone are effective in clear water. Generally speaking [at pH's below 8.0, turbidities below 1 NTU, temperatures above 40 degrees celcius, and a free chlorine residual above 0.5 mg/L] 30 minutes exposure is required to achieve virus-free water. However, there are exceptions and viral monitoring must take place to determine the effectiveness of the treatment.

Most existing criteria were set using fecal coliform bacteria as the indicator and may need to be adjusted to reflect the use of *Escherichia coli*, as the indicator of choice in this report. If, as is the case for shellfish harvesting sites, testing shows that most of the fecal coliforms are *E. coli*, then the *E. coli* criteria may be numerically identical to those of the present fecal coliform criteria. Fecal coliform criteria are also given and are intended as interim criteria. while the change to *E. coli* is taking place. Until testing is carried out and the correct ratio of *E. coli* to fecal coliforms is determined on a site-specific basis, *E. coli* criteria will be recommended as the numerical equivalent of the fecal coliform criteria. Regression equations developed by the EPA show a 4:1 ratio between the criteria for *E. coli* and the criteria for enterococcus, at the recommended risk level of 8/1000. This same ratio is used in the criteria below.

> *- Escherichia coli should not exceed 10/100 mL in at least 90% of the raw water samples taken in a 30-day period.*
>
> *- Enterococci should not exceed 3/100 mL in at least 90% of the raw water samples taken in a 30-day period.*

Application of Raw Drinking Water Criteria

While they are not specifically recommended as indicators, *Salmonella*, *Campylobacter*, *Vibrio*, *Klebsiella pneumoniae*, *Aeromonas hydrophila, Giardia lamblia*, *Shigella*, *Yersinia enterocolitica*, *Clostridium perfringens*, *Mycobacterium tuberculosis*, enteric viruses and *Proteus* should be monitored occasionally since they can not always be quantitatively predicted by the recommended indicators. A health hazard may exist if they are found in any 100 mL sample of raw or treated water.

The recommended criteria for raw water are not meant to be necessarily sufficient, but only represent minimum guides. After treatment, the finished water must meet the British Columbia Drinking Water Quality Standards (1982) at the consumer's tap. If the indicated raw water treatment cannot produce water of the required quality from the raw water supply, then either better quality raw water must be sought or more advanced treatment used. The interim fecal coliform criteria are the same as the CCREM Guidelines.

Wildlife

No criteria are recommended for this use of fresh and marine waters due to a lack of epidemiological or other objective data. No CCREM Guideline is given for this use of the water.

Livestock

Three distinct types of livestock operations are recognized based upon animal density and thus the risk of a disease epidemic.

For unconfined or free-ranging animals no criteria are recommended.

For closely confined animals, battery, feedlot and other high density operations, the raw drinking water criteria are recommended.

> *- Escherichia coli should not be present in any 100 mL sample of raw drinking water*
>
> *- Enterococci should not be present in any 100 mL sample of raw drinking water*
>
> *- Pseudomonas aeruginosa should not be present in any 100 mL sample of raw drinking water*
>
> *- Fecal coliforms should not be present in any 100 mL sample of raw drinking water*

For general livestock use on farms, where neither of the two previously mentioned animal density extremes occurs, the recommended criteria are based on those of Manitoba in 1979.

> *- The fecal coliform density in fresh waters used by livestock should not exceed a maximum of 200/100 mL*
>
> *- The E. coli density in fresh waters used by livestock should not exceed a maximum of 200/100 mL*
>
> *- The enterococci density in fresh waters used by livestock should not exceed a maximum of 50/100 mL*

There is no specific CCREM Guideline for livestock water. CCREM recommends that high-quality water be given to livestock in high density operations, and that the water supply of free-range livestock be monitored for pathogens and chlorinated if necessary.

Irrigation

These criteria are designed to protect the ultimate consumers of the crop, grazing animals, farm workers, and in the case of non-farm irrigation, the general public. The criteria depend upon the method of applying the irrigation water, the type of crop grown, and the way the crop is used.

Water Used to Irrigate Crops Eaten Raw

Water used for the sub-surface, surface or spray irrigation of produce which may be eaten raw, can not be adequately washed, or is not processed sufficiently to kill pathogens, should ideally meet the drinking water criteria for raw water without treatment except that the Pseudomonas aeruginosa criterion does not apply. Examples of such crops include strawberries, cauliflower, lettuce, cabbage and broccoli, and uses include aerial spraying of vineyards, market gardens and orchards. However, until epidemiological evidence becomes available we propose using the primary-contact recreation criteria.

Water Used to Irrigate Areas Open to the Public or to Livestock

Water used for the irrigation of parks, playgrounds, and school yards, or where there is public or livestock access to the recently irrigated area, or to the aerosols during irrigation, should meet the following secondary-contact recreation criteria.

> *- The Escherichia coli level should not exceed 385/100 mL as a geometric mean. There should be at least 5 samples in a 30-day period.*
>
> *- The Enterococci level should not exceed 100/100 mL as a geometric mean. There should be at least 5 samples in a 30-day period.*
>
> *- The Pseudomonas aeruginosa level should not exceed 10/100 mL in at least 75% of the samples. There should be at least 5 samples in a 30-day period.*

Water Used to Irrigate Areas where there is no Public or Livestock Access and the Crops are not Eaten Raw

Water used for all other uses where there is no public or grazing access and the crops are not eaten raw by humans should meet the following Alberta, Saskatchewan and Manitoba criteria.

> *- The fecal coliform level should not exceed 1000/100 mL as a geometric mean. There should be at least 5 samples in a 30-day period.*
>
> *- The Escherichia coli level should not exceed 1000/100 mL as a geometric mean. There should be at least 5 samples in a 30-day period.*
>
> *- The enterococci level should not exceed 250/100 mL as a geometric mean. There should be at least 5 samples in a 30-day period.*

The CCREM tentative guideline is a maximum of 100/100 mL of fecal coliforms and 1000/100 mL of total coliforms in all irrigation water from a surface or ground water source. We believe that the CCREM guideline is too stringent for general irrigation use. Different uses of irrigation water require different criteria depending upon the health risk perceived for each use. Epidemiological studies are needed to determine the proper criteria for crops irrigated with contaminated water then eaten raw.