DRINKING WATER TREATMENT OBJECTIVES (MICROBIOLOGICAL) FOR SURFACE WATER SUPPLIES IN BRITISH COLUMBIA

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1. Objective

Provide a general overview of microbiological drinking water treatment objectives for surface water supplies in British Columbia.

2. Background and Regulatory Framework

There are three main types of micro-organisms (pathogens) that pose risks to human health in drinking water: viruses, bacteria and protozoa. The B.C. *Drinking Water Protection Act* (DWPA) (2001) and Drinking Water Protection Regulation (DWPR) (2003) specify water quality standards, monitoring schedules, applicability and recommended treatment aimed at reducing the risks from these pathogens.

Schedule A of the DWPR specifies bacteriological water quality standards for potable water[1] for the protection of human health. These standards represent partial drinking water treatment goals and are consistent with the *Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Escherichia coli* and total coliform (Health Canada, 2006).

Schedule B of the DWPR outlines the monitoring schedule and its applicability based on population served. Section 5 of the regulation requires that surface water sources must, as a minimum, receive disinfection. Reducing risks from virus and protozoa through disinfection of drinking water are dealt with through the application of best management principles as outlined in this document and detailed in the Guidelines for Canadian Drinking Water Quality (GCDWQ). As no one type of treatment system is effective in treating all hazards, a multi-barrier approach is usually required to adequately address all risks, which typically includes two or more forms of treatment.

The DWPA and the DWPR give drinking water officers (DWOs) the flexibility and discretion to address public health risks through treatment requirements in operating permits to deal with pathogenic risks. Discretion of the drinking water officer also includes, but is not limited to, understanding the source water characterization, effectiveness of system-specific treatment technologies, operational management issues and reasonable time frames to achieve incremental improvements in existing systems. With respect to water quality analyses, the issuing official should ensure that he/she has

[1] Potable water is defined under the *Drinking Water Protection Act* as water provided by a domestic water system that (a) meets the standards prescribed by regulation, and (b) is safe to drink and fit for domestic purposes without further treatment.

adequate data to determine that the proposed treatment is adequate to address public health risks in relation to relevant microbiological and chemical/physical parameters.

Existing water supply systems may have some appreciable risk for certain parameters without treatment in place. In such cases, it is acceptable from a public health perspective for water supply systems to present drinking water officers with a continuous improvement plan that addresses implementing treatment for these parameters within a reasonable time period.

3. Purpose and Scope

Under the DWPA, water suppliers are responsible for providing potable water to all users of their systems. Drinking water treatment requirements are site specific, risk based and dependent on a number of factors, including source water quality and efficacy of treatment technology.

This document provides the basic, minimum framework towards goals for drinking water treatment for pathogens in surface water supply systems in British Columbia. It may also be used as a general reference for assessing progress towards updating or improving existing water supply systems. This document does not address the treatment of groundwater or disinfection of distribution systems.

These objectives use the *Guidelines for Canadian Drinking Water Quality* (Health Canada, 2012) as a primary reference for potability. However, given site-specific conditions of water systems in various regions of B.C., it is necessary to apply these guidelines in consideration of a risk assessment of individual cases. In all cases, the drinking water officer must be contacted to confirm the necessary treatment objectives for microbiological parameters when planning or upgrading water supply systems.

4. Treatment Objectives

These objectives provide treatment requirements that address the following microbiological parameters: enteric viruses, pathogenic bacteria, *Giardia* cysts and *Cryptosporidium* oocysts. The general objectives are as follows and described in more detail below:

- 4-log reduction or inactivation of viruses.
- 3-log reduction or inactivation of *Giardia* and *Cryptosporidium.*
- Two treatment processes for surface water.
- Less than or equal to (≤) one nephelometric turbidity unit (NTU) of turbidity.
- No detectable *E. Coli*, fecal coliform and total coliform.

These drinking water treatment objectives provide a minimum performance target for water suppliers to treat water to produce microbiologically safe drinking water. Depending on specific situations, the actual amount of treatment required will depend on the risks identified and may require greater levels of treatment. Water treatment is only one part of the multi-barrier approach to providing safe drinking water. Choosing an appropriate water source, protecting that source and reducing distribution system risks can be essential complementary steps to providing treatment when dealing with microbiological risks.

While there are numerous precautionary treatment steps available to reduce the risk of microbiological contamination of drinking water supplies, no system is fail-safe. Risk management is based on applying

scientific evidence that documents the quality and variability of the water source and the efficacy of management measures selected to achieve acceptable public health outcomes.

4.1. 4-log Inactivation of Viruses

Viruses are micro-organisms that are incapable of replicating outside a host cell. In general, viruses are host specific, which means that viruses that infect animals or plants do not usually infect humans, although a small number of enteric viruses have been detected in both humans and animals (Health Canada, 2010). Viruses are ubiquitous and often species-specific. Viruses of concern in drinking water are those that cause human illness or are capable of cross-species transfer. The role of nonhuman viruses as facilitators of pathogens or in transmitting genetic material that could be pathogenic is not clearly understood; hence, overall reductions of viruses in source water are preferred.

Health Risk Management Outcomes for Enteric Viruses

The level of risk deemed tolerable or acceptable by Health Canada for enteric viruses has been adopted from the World Health Organization's (WHO) *Guidelines for Drinking-Water Quality* (WHO, 2004; cited in Health Canada, 2010) based on the Disability Adjusted Life Year (DALY) as a unit of measure for risk.

The basic principle of the DALY is to calculate a value that considers both the probability of experiencing an illness or injury and the impact of the associated health effects (Murray and Lopez, 1996a; Havelaar and Melse, 2003; cited from Health Canada, 2010). The WHO (2004) guidelines adopt 10^{-6} DALY/person per year as a health risk management target. Table 1 describes the relationship between viruses in source water and the level of treatment necessary to achieve this health risk management goal.

Table 1: Overall treatment requirements for virus log reduction as a function of approximate source water concentration to meet a level of risk of 1×10^{-6} DALY/person per year (Health Canada, 2010)

Source water virus concentration (no./100 L)	Overall required treatment reduction for viruses (log_{10})
1	4
10	5
100	6
1000	7

Treatment Objectives for Enteric Virus

A minimum 4-log reduction of enteric viruses is recommended for all surface water sources. Depending on the surface water source, especially those subject to human fecal contamination, a greater than 4-log reduction may be necessary (See Table 1).

Reductions can be achieved through physical removal processes, such as filtration, and/or through inactivation processes, such as disinfection (Health Canada, 2010). Disinfection of water systems is recommended as a means to provide safeguards to the water system. Enteric viruses are readily inactivated by the use of chemical disinfection such as chlorine.

Ultraviolet (UV) light disinfection systems may be used to reduce viruses in water, but the effectiveness of UV varies significantly among different types of viruses. Double-stranded DNA viruses, such as adenoviruses, are more resistant to UV radiation than single-stranded RNA viruses, such as HAV (Meng and Gerba, 1996; cited in Health Canada, 2010).

Because of their high level of resistance to UV treatment and because some adenoviruses can cause illness, particularly in children and immunocompromised adults, adenoviruses have been used by the U.S. EPA as the indicator pathogen for establishing UV light inactivation requirements for enteric viruses in the *Long Term 2 Enhanced Surface Water Treatment Rule* (LT2ESWTR) (U.S. EPA, 2006). Accordingly, the LT2ESWTR requires aUV dose of 186 mJ/cm^2 to achieve 4-log inactivation of viruses (U.S. EPA, 2006).

For water supply systems in Canada, UV disinfection is commonly applied, most often in combination with chlorine disinfection or other physical removal barriers such as filtration (Health Canada, 2010). A UV dose of 40 mJ/cm^2 is considered to be protective of human health as most enteric viruses are inactivated at this dosage; however, this dosage would provide only a 0.5-log inactivation of adenovirus. Additional log removal credits may be obtained through the addition of free chlorine.

For drinking water sources considered to be less vulnerable to human fecal contamination, the drinking water officer may accept an enteric virus such as rotavirus as the target pathogen to determine the UV dose required for 4-log inactivation of viruses. Where a system relies solely on UV disinfection for pathogen control and the source water is known or suspected to be contaminated with human sewage[2], either a higher UV dose such as that stated in the LT2ESWTR or a multi-barrier treatment strategy should be adopted.

The physical removal of viruses can be partially achieved by clarification and filtration processes. Clarification is generally followed by the filtration process. Some filtration systems, however, are used without clarification (direct filtration). Many treatment processes are interdependent and rely on optimal conditions upstream in the treatment process for efficient operation of subsequent treatment steps.

Drinking water treatment plants that meet the turbidity limits established in the *Guidelines for Canadian Drinking Water Quality: Supporting Documentation — Turbidity* (Health Canada, 2003) can apply the estimated physical removal credits for enteric viruses. For example, for conventional filtration, the virus credit is 2-log and for direct filtration the virus credit is 1-log.

Alternatively, log removal rates can be established on the basis of demonstrated performance or pilot studies. The physical log removal credits can be combined with the disinfection credits to meet overall treatment goals. In all cases, the drinking water officers must be consulted when planning treatment for a water supply system.

It is recommended that water supply systems should provide, as a minimum, 4-log reduction of viruses for all surface water systems.

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[2] The Ministry of Health is awaiting further clarification from Health Canada as to what constitutes as *human fecal contamination*. In lieu of clarification, it is best to use as much available information as possible to make an informed decision on a case-by-case basis.

4.2. 3-log Inactivation of *Giardia* and *Cryptosporidium*

Protozoa such as *Giardia* and *Cryptosporidium* are relatively large pathogenic micro-organisms that multiply only in the gastrointestinal tract of humans and other animals. They cannot multiply in the environment, but their cysts/oocysts can survive in water longer than intestinal bacteria, and they are more infectious and resistant to disinfection than most other micro-organisms (Health Canada, 2004).

Health Risk Management Outcomes for Giardia and Cryptosporidium

While *Giardia* and *Cryptosporidium* can be responsible for severe and, in some cases, fatal gastrointestinal illness, the *Guidelines for Canadian Drinking Water* have not established maximum acceptable concentrations for these protozoa in drinking water. Routine methods available for the detection of cysts and oocysts have low recovery rates and do not provide any information on their viability or human infectivity. Until better monitoring data and information on the viability and infectivity of cysts and oocysts present in drinking water are available, measures should be implemented to reduce the risk of illness as much as possible.

Treatment Objectives for *Giardia* and *Cryptosporidium*

The goal of surface water treatment is to reduce the presence of disease-causing organisms and associated health risks to an acceptable safe level.

Treatment of drinking water is another integral part of the multi-barrier approach. In addition to disinfection, where warranted by source water conditions, physical treatment of surface supplies should be included. Because *Giardia* and *Cryptosporidium* are ubiquitous in surface waters in Canada and more resistant to disinfection than most other infectious organisms, it is desirable that treatment achieves at least a 99.9% (3-log) reduction of *Giardia* and *Cryptosporidium* (Health Canada, 2004).

Giardia may be partially inactivated by large doses of free chlorine, ozone or chlorine dioxide. Filtration can be effective in removing *Giardia* cysts and *Cryptosporidium* oocysts, but the performance is significantly dependant on the methods of filtration and operational performance. *Giardia* and *Cryptosporidium* may also be inactivated using UV disinfection. Many commercially available UV systems have undergone testing to verify that the dosage provided under design operating conditions achieves the 3-log inactivation required.

It is recommended that water supply systems should provide, as a minimum, 3-log reduction of *Giardia* and *Cryptosporidium* for systems that have a water source considered to have low risk of these parasites and have not had an outbreak of the disease. A higher level of reduction may be required if the situation justifies it.

4.3. Two Methods of Treatment (Dual Treatment)

Health Risk Management Outcomes for Dual Treatment of Drinking Water

Some microbiological agents of concern are more resistant to certain forms of treatment than others. Ultimately, the best approach to ensure complete disinfection of water intended for human use is a multi-barrier one, which begins with collecting water from the cleanest source possible.

As most disinfection systems require clear water to ensure maximum efficiency, it may be necessary to combine multiple specific treatment technologies. To provide the most effective protection, the *Guidelines for Canadian Drinking Water* recommend that filtration and one form of disinfection be used to meet the treatment objectives.

Alternatively, two forms of disinfection (for example, chlorination and UV disinfection) may be considered if certain criteria are met.

A water supply system may be permitted to operate without filtration if the following conditions for exclusion of filtration are met, or a timetable to implement filtration has been agreed to by the drinking water officer:

1. Overall inactivation is met using a minimum of two disinfections, providing 4-log reduction of viruses and 3-log reduction of *Cryptosporidium* and *Giardia*.
2. The number of *E. coli* in raw water does not exceed 20/100 mL (or if *E. coli* data are not available less than 100/100 mL of total coliform) in at least 90% of the weekly samples from the previous six months. The treatment target for all water systems is to contain no detectable *E. coli* or fecal coliform per 100 ml. Total coliform objectives are also zero based on one sample in a 30-day period. For more than one sample in a 30-day period, at least 90% of the samples should have no detectable total coliform bacteria per 100 ml and no sample should have more than 10 total coliform bacteria per 100 ml.
3. Average daily turbidity levels measured at equal intervals (at least every four hours) immediately before the disinfectant is applied are around 1 NTU, but do not exceed 5 NTU for more than two days in a 12-month period.
4. A watershed control program is maintained that minimizes the potential for fecal contamination in the source water. (Health Canada, 2003)

Applying the exclusion of filtration criteria does not mean filtration will never be needed in the future. A consistent supply of good source water quality is critical to the approach, but source quality can change. Therefore, the exclusion of filtration must be supported by continuous assessment of water supply conditions.

Changing source water quality can occur with changes in watershed conditions. Increased threats identified through ongoing assessment and monitoring may necessitate filtration. Maintaining the exclusion condition relies on known current and historic source water conditions, and provides some level of assurance to water suppliers that a filtration system may not be necessary unless the risk of adverse source water quality increases.

It is recommended that dual water treatment should be applied to all surface water.

4.4 ≤1 NTU in Turbidity

Events such as sedimentation from road surfaces, higher surface runoff peak flows, landslides and debris flows increase a condition commonly referred to as “turbidity.” Turbidity in water is caused by suspended organic and colloidal matter, such as clay, silt, finely divided organic and inorganic matter, bacteria, protozoa and other microscopic organisms. It is measured in nephelometric turbidity units (NTU) and is generally acceptable when less than 1 NTU, as per the exclusion criteria in section 4.3, and becomes visible when above 5 NTU.

Health Risk Management Outcomes for Turbidity

Turbidity is an indicator of the potential presence of human pathogens such as bacteria and protozoa. Furthermore, a greater concentration of organic and/or microbiological matter in source water has the potential to disrupt or overload drinking water disinfection processes, such as UV light and chlorination, to the point that they may no longer effectively control pathogens in the water. In

addition, organic matter in the water can react with disinfectants such as chlorine to create byproducts that may cause adverse health effects (Health Canada, 2003).

Treatment Objectives for Turbidity

In general, turbidity is caused by particles in water and can be effectively reduced by filtration. Depending on the filtration technologies applied to the water, filtered water from well operated filtration systems could have turbidity ranges from 0.1 to 1.0 NTU. The Canadian guideline on turbidity applies to filtered surface water and is categorized by the type of filtration technology: conventional and direct filtration; slow sand or diatomaceous earth filtration; and membrane filtration. To comply with the Canadian guideline on turbidity, continuous monitoring of turbidity is required.

Turbidity is effectively reduced through filtration, using one of a number of common technologies. The goal of treating water for turbidity is to reduce its level to as low as possible and minimize fluctuation. For this reason, when filtration technology is employed, the system should strive to achieve a treated water turbidity target from individual filters or units of less than 0.1 NTU at all times. Where this is not achievable, the treated water from filters or units should be less than or equal to 0.3 NTU for conventional and direct filtration; less than or equal to 1.0 NTU for slow sand or diatomaceous earth filtration; and less than or equal to 0.1 NTU for filtration systems that use membrane filtration. Inability to achieve these objectives in filtered systems indicates a breakdown of the treatment train and potential health impacts to users.

For nonfiltered surface water to be acceptable as a drinking water source supply, average daily turbidity levels should be established through sampling at equal intervals (at least every four hours) immediately before the disinfectant is applied. Turbidity levels of around 1.0 NTU but not exceeding 5.0 NTU for more than two days in a 12-month period should be demonstrated in the absence of filtration. In addition, source water turbidity should not show evidence of harbouring microbiological contaminants in excess of the exemption criteria in section 4.3 of this document.

It is recommended that turbidity of treated surface water should be maintained at less than 1 NTU. Where filtration is part of the treatment process, the turbidity levels should comply with the Canadian guideline on turbidity, entitled *Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Turbidity (Health Canada, 2003)* (expected turbidity reduction depends on the filtration methods). Continuous monitoring of turbidity should be required for water systems with filtration to verify compliance with system performance objectives. Systems that meet the criteria for exclusion from the requirement for filtration should be monitored to verify that the system continues to meet the exclusion criteria.

4.5. No Detectable *E. Coli*, Fecal Coliform and Total Coliform

E. coli and other fecal coliforms are members of the total coliform group of bacteria, but *E. coli* is the only member found exclusively in the feces of humans and other animals. Other members of the total coliform group (including fecal coliforms) are found naturally in water, soil, and vegetation, as well as in feces. The presence of *E. coli* and other fecal coliforms in water indicates not only recent fecal contamination, but also the possible presence of intestinal disease-causing bacteria, viruses, and protozoa.

Health Risk Management Outcome for *E. Coli* and Total Coliform

The absence of *E. coli*, fecal coliform and total coliform is used as an indicator that treated water is free from intestinal disease-causing bacteria. Their presence in drinking water distributed from a treatment plant indicates a serious failure and that corrective action is necessary. The presence of total coliform bacteria in the water distribution system indicates that the system may be vulnerable to contamination or experiencing bacterial regrowth.

Treatment Objectives for *E. coli*, Fecal Coliform and Total Coliform

E. coli, fecal coliform and total coliform are easily controlled with disinfection processes such as chlorine or UV light and can also be reduced by filtration. The DWPR calls for water suppliers to provide water with nondetectable *E. coli*, fecal coliform and total coliform based on sampling frequency established by the DWPR or through agreement with the drinking water officer.

In summary, according to Schedule A of the DWPR (updated 2008), the treatment target for all water systems is to contain no detectable *E. coli* or fecal coliform per 100 ml. Total coliform objectives are also zero based on one sample in a 30-day period. For more than one sample in a 30-day period, at least 90% of the samples should have no detectable total coliform bacteria per 100 ml and no sample should have more than 10 total coliform bacteria per 100 ml.

5. Conclusion

These objectives are intended to provide general requirements for surface water supply treatment systems in B.C. and rely on the *Guidelines for Canadian Drinking Water Quality* (Health Canada, 2012) as a primary reference for potability and treatment. However, given site-specific physical, chemical and biological conditions of water supplies throughout various regions in B.C., it may be necessary to apply these guidelines based on risk assessment of individual cases.

In all cases, the treatment objectives for microbiological parameters in specific water supply systems must be developed in consultation with a drinking water officer when planning or upgrading drinking water supply systems in the province.

6. References

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