GUIDANCE FOR TREATMENT OF RAINWATER HARVESTED FOR POTABLE USE IN BRITISH COLUMBIA

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1. Objective

This guidance document provides a general overview of assessing risks and treatment of rainwater for potable use in British Columbia (B.C.). It characterizes harvested rainwater as a type of surface water (i.e., water from a source which is open to the atmosphere) and includes streams, lakes, rivers, creeks and springs, as defined in the *Drinking Water Protection Regulation* (DWPR). This document is intended to supplement but not replace the existing surface water treatment objectives as found in the Ministry of Health's *Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia* (referred to herein as the B.C. Surface Water Treatment Objectives).

2. Background and Regulatory Framework

Two documents serve as the primary reference materials for treatment objectives for harvested rainwater: the B.C. Surface Water Treatment Objectives, and the *Rainwater Harvesting Systems standard CSA B805-ICC 805* (produced by the CSA Group and the International Code Council, Inc., and referred to herein as the CSA/ICC Rainwater Standard).

In this guidance document, *rainwater* means: water collected from natural precipitation, and any system used to collect, convey, store, treat and distribute rainwater for use is a *rainwater harvesting system.* This definition is consistent with the CSA/ICC Rainwater Standard.

British Columbia Building Code as well as local bylaws may have additional regulatory requirements for the use of harvested rainwater including its use within single-family dwellings and other buildings. These are not included in this guidance document but should be consulted for reference.

The owner of any drinking water supply system, servicing more than a single-family dwelling, and who wishes to harvest rainwater for domestic use, is required under the *Drinking Water Protection Act* (DWPA) and the DWPR to obtain the necessary permits from the local health authority (HA). The *Water Sustainability Act* (WSA) licences water use from a natural source of water supply, specifically a "lake, pond, river, creek, spring, ravine, gulch, wetland or glacier, whether or not usually containing water, including ice, but does not include an aquifer". As rainwater is not included in this definition, a licence under the WSA is not required for rainwater harvesting.

Under the DWPA, water suppliers have the responsibility to provide potable water to all users of their systems. As such, rainwater harvested for use as potable water in any drinking water supply system must be disinfected[1]. Schedule A of the DWPR specifies bacteriological water quality standards for potable water for the protection of human health. The DWPA and the DWPR give *Drinking Water Officers*[2] (DWOs) the flexibility to address further microbiological, chemical and physical risks through applying site-specific treatment requirements to construction and operating permits. The *Drinking Water Officers Guide* (DWOG) contains drinking water policies that must be considered by DWOs when making these statutory decisions. The DWOG further suggests best management practices which align and/or further build on those as detailed in the *Guidelines for Canadian Drinking Water Quality* (GCDWQ), as developed and updated regularly by Health Canada.

Note: Reliability of water volume and quality should be a key consideration during all phases of development, including during the subdivision of land parcels. Given seasonal variations in precipitation, a water supply that relies solely on rainwater may face significant challenges with volume and storage capacity during periods of drought. In many situations, harvested rainwater may be best suited as a supplementary source to existing water supplies for the purposes of reducing stresses related to water quality and/or quantity.

3. Purpose and Scope

3.1. Purpose

The intent of this guideline is to assist water suppliers and DWOs in ensuring harvested rainwater is made potable.

3.2 Scope

This focus of this guide is on the assessment of risks and appropriate treatment of harvested rainwater for potable use in drinking water supply systems.

This document does not address:

- Non-potable uses of rainwater. These are covered in the draft *Guidance for Using Non-Potable Ambient Water for Domestic Purposes in British Columbia*;
- Stormwater runoff[3] harvested rainwater;
- Assessing collection capacity, storage volumes, reliability nor sustainability of rainwater as a source of domestic water. Note that Annex C of the CSA/ICC Rainwater Standard recommends tank sizing and capacity methodologies;
- The appropriateness of rainwater sources as basis for subdivision approval; or

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[1] See section 5 of the Drinking Water Protection Regulation: http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/200_2003#section5.

[2] Drinking Water Officer (DWO) is defined in the DWPA as a drinking water officer under Section 3 of the DWPA.

[3] Stormwater runoff, as per Section 3.1 of the CSA/ICC Rainwater Standard, is rainwater that is not roof runoff. This includes precipitation runoff from rain or snowmelt that flows over land and/or impervious surfaces (e.g. streets, parking lots, vegetative roofs, and roofs with public access).

- Standards for chemical contaminants. As with other sources, rainwater chemical parameters should be reviewed against the GCDWQ.

4. Rainwater Harvesting System Design

This section provides an approach to hazard identification, risks assessment and mitigation through system design, as well as determining appropriate treatment objectives to achieve potability.

Applications should be made to the local health authority for the issuance of construction and operating permits under the DWPA prior to commencing any construction. This process will look at how the water supplier plans to mitigate the risks identified for the proposed system. Water suppliers may consider employing contracted consultants familiar with drinking water processes and treatment objectives to assist with this process.

The process of designing a rainwater harvesting system should follow a risk assessment and mitigation strategy similar to any other potable water source in British Columbia. The *Comprehensive Drinking Water Source-To-Tap Assessment Guideline*, *Drinking Water Source-To-Tap Screening Tool* and the *Water System Assessment User's Guide* provide risk assessment and mitigation strategies suitable to a harvested rainwater water supply[4].

4.1 Rainwater Harvesting Risks

Harvested rainwater can become contaminated through numerous pathways of exposure including via airborne particles, animal fecal matter, tree litter, and by the materials used to collect and store rainwater.

Harvested rainwater is at risk of contamination prior to reaching a collection point. This can occur through contact with air pollutants that are either regularly occurring or associated with specific events (e.g., forest fire). As these risks will vary between locations and over time, all existing and potential risk should be considered as part of a risk mitigation approach.

At the collection stage, rainwater passes over surfaces (often a roof) which are likely to harbour residual matter, namely airborne contaminants such as dust, fecal matter from birds or mammals, chemical contaminants or other organic matter (Fewtree & Kay 2008). The source and concentration of contamination may vary depending on conditions, and in some cases with seasons (Zhang et al. 2014).

Materials used to make collection surfaces and conveyancing systems may also have a negative impact on harvested rainwater quality (Ward et al. 2010; Bae et al. 2019). In some environments, metal roofs, concrete tile and cool roofs (reflective roofs) produce a higher quality of harvested rainwater with lower dissolved organic carbon than shingle and green roofs. In particular, green roofs may produce high concentrations of dissolved organic carbon which can lead to the formation of disinfection by-products if not adequately treated (Mendez et al. 2010; Zhang et al. 2014). The growing medium used in some green roofs is further correlated with a higher concentration of metals (such as arsenic) (Mendez et al. 2010).

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[4] All three documents are available, along with others, on the **Resources for Water Systems Operators** page at https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/drinking-water-quality/resources-for-water-system-operators

The quality of a harvested rainwater supply is impacted by both storage time (stagnation), the environment, and the materials in which water is being stored (Crabtree et al. 1996; Ahmed et al. 2010a; 2010b). These factors further interact depending on the quality of harvested rainwater as described in the previous paragraph. In general, storage tanks made of a dark coloured polyethylene are associated with creating a warmer environment for harvested rainwater and may impact microbial contamination of rainwater (Struck 2011). The risk of opportunistic pathogens (e.g., Legionella) exists where water temperatures will be stored at a temperature above 25 degrees centigrade, therefore tanks should be stored out of direct sunlight, and storage should be in-ground if there is a risk of temperatures exceeding 25 degrees Celsius.

Best practice for the location of a storage tank recommends they not be located directly under sanitary, waste or storm drain pipes, or in any other location that may increase the risk of contamination, such as above an onsite sewage disposal system (see the CSA/ICC Rainwater Standard). Tanks and all associated components, including but not limited to sealants, fittings and linings contacting collected water, should comply with NSF/ANSI 61 and have a weighted average lead content of 0.25% or less when evaluated in accordance with NSF/ANSI 372. Solders and fluxes used in potable use rainwater harvesting systems should not exceed lead content greater than 0.2% by mass (see the CSA/ICC Rainwater Standard).

4.2 Risk Identification and Assessment

Identifying hazards and implementing control measures to mitigate potential health hazards is an essential aspect of any potable water supply system. A risk assessment process, such as the one outlined in Figure 1 below, serves as a tool for water systems to develop a more comprehensive understanding of the risks to drinking water safety and availability, designing risk mitigation measures, operating more effectively, and ensuring the best possible water quality. Understanding threats and vulnerabilities to drinking water supplies and the interdependency of their components equips water suppliers with the ability to make informed decisions about reducing or mitigating risks.

Figure 1: Flow Diagram for Rainwater Harvesting Risk Assessment Process

Site Visit

Identify potential off-site source contaminants that could impact catchment area, such as:

- Air pollutants, agricultural chemicals and land use practices
- Waste disposal sites, industrial complexes or farming practices
- Local zoning, historical and current property use
- Rural vs urban landscapes

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Hazard Identification

Identify potential on-site contaminants that could impact water quality, such as:

- Fecal pathogens from animals or natural reservoirs of disease
- Chemical contamination from on-site air pollutants
- Leaching from collection and storage materials
- Debris or pests
- Pathogen proliferation caused by stagnation within the system

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Source Water Quality Study

Assess the proposed treatment technologies effectiveness in providing potable water

- Collect and analyze raw-water samples to determine baseline water quality
- Identify constituents that can adversely affect treatment technologies
- Collect samples during initial portion of a storm event following arid conditions
- DWOs can require suppliers to complete source assessment

A thorough evaluation should be done on land use in the vicinity of the collection surface for both human and natural activity. Hazards identified should be documented to inform risk analysis, application of risk mitigation measures, and for measuring successes over time. The process may include surveys of potential sources of contamination and the frequency of occurrence of contamination events. A period of sampling for microbiological and/or chemical quality to characterize typical nature of the water quality may be valuable to ensuring that the design and treatment objectives (see section 5 in this guideline) applied are appropriate. It may be appropriate to sample in different seasons to obtain a robust representation of water quality throughout the year.

Several tools exist to assist with the above-described process. The *Comprehensive Drinking Water Source-To-Tap Assessment Guideline,* the *Drinking Water Source-To-Tap Screening Tool* and the *Water System Assessment User's*

Guide are intended to help water suppliers develop a better understanding of the risks to drinking water safety and availability[5].

4.3 Design Considerations

Central to the risk assessment process is the implementation of control measures to ensure appropriate and effective risk mitigation. Table 1 below identifies some of the essential design considerations that can be administered in a rainwater harvesting system.

Table 1: Rainwater Harvesting Water System Design Considerations

Design Consideration	Reasoning
Air Gap or Backflow Preventer	Prevent potential cross contamination of other water supply system(s)
NSF/ANSI 61, NSF/ANSI 372 and NSF P151 Materials (or third-party certification)	Ensures the materials adhere to minimum established health effects requirements for any chemical contaminants or impurities that are imparted to the water (USEPA, 2002[6])
Inlet Pre-Filter[7] Systems	Prevents entry of debris and pests into water supply
First-Flush Diverter[8]	Reduce contaminants in the harvested water supply
Collection Potential	Amount of available precipitation in the area
Output Demand	Required storage volume for intended use
Food-Grade Plastic Storage	Retains acidic nature of harvested rainwater which can inhibit microbial growth
Covered or Shaded Storage	Retains cool temperatures of stored water which can slow microbial growth
Mixing Systems	Recirculate, aerate or disinfection of water supply to prevent stagnation and stratification of water supply
Alarm Systems	Systems to monitor, alert or shut-off supply when intake or output water quality standards not being achieved
Secured Access	Prevents unauthorized access to water supply

[5] All three documents are available, along with others, on the **Resources for Water Systems Operators** page at https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/drinking-water-quality/resources-for-water-system-operators

[6] USEPA (2002) *Permeation and Leaching. Distribution System Issue Paper.* https://www.epa.gov/sites/production/files/2015-09/documents/permeationandleaching.pdf

[7] Inlet pre-filter, as per Section 3.1 of the CSA/ICC Rainwater Standard, is a device installed on the rainwater conveyance pipe prior to the primary storage vessel on a rainwater system. Note: An inlet pre-filter is intended to mitigate the introduction of, e. g. vermin, leaves, sticks, needles, tree fruit, bark, moss, or any unwanted debris or roof contaminant that could enter the system.

[8] First-flush diverter, as per Section 3.1 of the CSA/ICC Rainwater Standard, is a device or method for removal of sediment and debris from collection surface by diverting initial rainfall from entry into the storage tank. NSF/ANSI 61 provides further guidance on how to perform an effective flush.

5. Treatment Objectives

Drinking water treatment objectives provide a minimum performance target for water suppliers to treat water to produce potable water from harvested rainwater. The actual amount of treatment required will depend on the risks identified (see Section 4.1 and 4.2) and may require levels of treatment over and above those outlined below.

5.1 Treatment Objectives (Microbiological)

As this document has categorized rainwater as a surface water supply, most of the treatment objectives and the supporting reference material for this section can be found in the B.C. Surface Water Treatment Objectives. Further reasoning and explanation is provided when necessary within each sub-section where the treatment objectives differ or expand in the B.C. Surface Water Treatment Objectives.

This section outlines the following treatment objectives for the following pathogenic microbes: enteric viruses, bacteria, enteric protozoa in harvested rainwater for potable use:

- 4-log reduction or inactivation of viruses;
- 4-log reduction or inactivation of *Giardia* and *Cryptosporidium*;
- Two methods of treatment (dual treatment) for harvested rainwater;
- Less than or equal to (≤) one nephelometric turbidity unit (NTU) of turbidity; and
- No detectable *E. coli*, fecal coliforms and total coliform;

5.2.1. 4-log Inactivation of Viruses

A minimum 4-log reduction of enteric viruses is recommended for all potable rainwater harvested systems. This is the same as the B.C. Surface Water Treatment Objectives which also requires a 4-log reduction of enteric viruses.

While the CSA/ICC Rainwater Standard assumes that elevated collection surfaces are unlikely to become contaminated with human viruses and recommends this level of reduction only where a water supply system includes a below-ground tank (where there is potential for sewage contamination), this guideline takes a more precautionary approach to ensure air transported human viruses, or viruses that are capable of cross-species transfer are inactivated.

It is recommended that water supply systems should provide, as a minimum, 4-log reduction of viruses for all rainwater harvesting potable water systems. This is consistent with requirements for surface water in the B.C. Surface Water Treatment Objectives.

5.2.2. 4-log Inactivation of *Giardia* and *Cryptosporidium*

Protozoa, such as *Giardia* and *Cryptosporidium,* can be responsible for severe and, in some cases, fatal gastrointestinal illness. Local climate, the rate of pathogen occurrence, and the potential for higher pathogen concentrations increase the risks to human health associated with harvested rainwater for potable use (Ahmed et al. 2013; Schoen et al. 2017). As reliable and ongoing monitoring remains a challenge with a water supply such as harvested rainwater, the measures in place to ensure protection should aim to reduce the level of risk as much as possible.

A minimum 4-log reduction of enteric protozoa is recommended for all potable rainwater harvested systems. This is a higher level of reduction than recommended in the B.C. Surface Water Treatment Objectives but is aligned with the CSA/ICC Rainwater Standard (see Table 8.1). The 4-log reduction is based on the United States Environmental

Protection Agency (USEPA) health-based target of an annual risk of less than 1/10,000 persons per year (10^{-4} ppy) (USEPA 1989).

It is recommended that water supply systems should provide, as a minimum, 4-log reduction of *Giardia* and *Cryptosporidium* for all rainwater harvesting potable water systems. The higher level of reduction is recommended based on the potential rainwater harvested systems to harbour significantly higher concentrations of protozoa, as well as the potential for such water sources to experience an unpredictable rate of pathogen occurrence, when compared to other surface water sources.

5.2.3. Two Methods of Treatment (Dual Treatment)

To provide the most effective protection, the GCDWQ and the B.C. Surface Water Treatment Objectives recommend that filtration and one form of disinfection be used to meet the treatment objectives. The CSA/ICC Rainwater Standard also supports dual treatment and recommends filtration and disinfection of harvested rainwater supplies used for potable purposes.

It is recommended that dual treatment should be applied to all rainwater harvested potable water supply systems. This is consistent with requirements for surface water in the B.C. Surface Water Treatment Objectives.

5.2.4. ≤1 NTU in Turbidity

Turbidity of treated harvested rainwater should be maintained at less than 1 NTU. Turbidity levels should comply with the GCDWQ on turbidity, as referenced in the B.C. Surface Water Treatment Objectives, and the same exceptions apply (see section 4.4).

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

Schedule A of the DWPR requires that the treatment target for all potable 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. If deemed necessary, the DWO may require increased frequency of testing within the operating permit.

5.3. Treatment Objectives (Physical and Chemical)

This document does not outline the required treatment mechanisms or equipment to remove chemical/physical contaminants but recognizes that such contaminants can reduce the effectiveness of disinfection methods (e.g., by increasing the chlorine demand or by blocking/absorbing UV irradiation). Where the risk assessment or subsequent monitoring identifies potential concerns due to the presence of chemicals or turbidity, appropriate treatment technologies should be applied. The GCDWQ should be consulted for further guidance.

6. Operation, Monitoring, Maintenance and Training.

Operational monitoring is critical for ensuring the treatment objectives and control measures in place are effective, and that a system is supplying potable water. Identifying and monitoring critical control points in a water system allows opportunities for corrective actions to be taken. As part of any operation, monitoring and maintenance plan, robust record keeping is required.

Water quality should be monitored for all parameters identified in the risk assessment, regardless if these parameters are required in the DWPR. If there is uncertainty of how water quality from a new supply may vary over time, the DWO may establish different sampling frequencies and parameters than those specified in section 8 of the DWPR.

For rainwater harvesting systems, maintenance activities could include: cleaning and sanitizing the collection, conveyance and storage systems; inspecting and verifying inlet pre-filters and first flush diverters are in working order; and removing overgrown foliage and pest harborage locations.

In B.C., the level of training and certification required for operators is tied to the size of the system and classification level assigned to a drinking water system by the Environmental Operator's Certification Program (EOCP) or as required by the DWO through conditions on the operating permit. Many small water systems are exempt from training as per the DWPR, however a DWO may impose training requirements through conditions on permit when deemed necessary. Training specific to rainwater harvesting systems are listed (based on availability) on the EOCP Customer Relationship Management System, under the Career Management tab. The EOCP website and training guides are available to and recommended for anyone in the water industry.

Unforeseen circumstances that fall outside of an owner/operators' control will always pose a risk to the quality of water produced within any drinking water system. Water suppliers are required, as per Section 10 of the DWPA with requirements outlined under Section 13 of the DWPR, to have an Emergency Response Plan (ERP).
The Ministry of Health's Emergency Response and Contingency Planning for Small Water Systems is a useful tool for developing an ERP. Water suppliers are encouraged to engage with their local DWO on ERP planning.

7. Conclusion

The guidance provided in this document includes recommendations for the purposes of harvesting rainwater for potable use in B.C. and relies on the existing DWOG and the GCDWQ as the primary references for water treatment and potability.

For any water system seeking to use harvested rainwater for potable purposes, the treatment objectives for microbiological, chemical and physical parameters in specific water supply systems must be developed in consultation with a DWO when planning or upgrading drinking water supply systems in the Province.

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