APPENDIX C

Minimum Treatment Requirements and Process for Assigning Pathogen Log Reduction Credits to Filtration and Disinfection Processes

C1 Purpose

The purpose of this appendix is to outline the requirements for the assignment of log reduction credits for the removal or inactivation of pathogenic microorganisms (enteric protozoa, viruses, and bacteria) in Municipal Public Drinking Water Supply systems. This information must be used by the Approval Holder, design engineer, and any other person or persons responsible for the planning and design of new Municipal Public Drinking Water Supply systems in Nova Scotia or when considering modifications to existing systems. Bacterial reduction is typically sufficient if treatment systems are designed to meet enteric protozoa and virus log reduction requirements outlined in this document.

C2 Minimum Treatment Requirements

The Approval Holder shall ensure the level of treatment provided to remove or inactivate pathogenic organisms is commensurate with the source water type, as outlined in Table C1.

Where multiple raw water sources are combined and treated in the same Municipal Public Drinking Water Supply, the minimum log reduction requirements shall be based on the source water with the highest log reduction requirements for enteric protozoa and viruses.

Table C1: Minimum Pathogen Log Reduction and Treatment Requirements

Source Water Type	Minimum Required Pathogen Log Inactivation and Removal			Minimum Treatment
	***Cryptosporidium* oocysts**	***Giardia* cysts**	**Viruses**	
Surface Water and GUDI sources not assigned a Department-accepted natural filtration log credit	3-log	3-log	4-log	**Engineered filtration and disinfection** • Filtration shall be assigned treatment credits as outlined in Table C2. • Disinfection shall provide a minimum 0.5 log inactivation of *Giardia* cysts. • Where UV is used as a primary disinfectant and additional log inactivation is required for enteric viruses, chemical disinfection shall be used to meet the remaining log inactivation criteria for enteric viruses. • Where UV, ozone, or chlorine dioxide is used as a primary disinfectant, free chlorine or chloramines shall be used to provide secondary disinfection of the distribution system.
Medium-risk GUDI sources assigned a Department-accepted natural filtration log credit	3-log	3-log	4-log	**Filtration and disinfection** • Filtration may be via natural in-situ attenuation as outlined in Appendix B • Natural filtration is assigned a 1 log reduction for *Cryptosporidium* oocysts and *Giardia* cysts. • If the natural filtration log credit is awarded, UV disinfection is required to meet the remaining log reduction requirements for *Cryptosporidium* oocysts and *Giardia* cysts. • Chemical disinfection is required to meet remaining log inactivation criteria for viruses and provide secondary disinfection of the distribution system.
Low-risk GUDI sources assigned a Department-accepted natural filtration	3-log	3-log	4-log	**Filtration and disinfection** • Filtration may be via natural in-situ

Source Water Type	Minimum Required Pathogen Log Inactivation and Removal			Minimum Treatment
	***Cryptosporidium* oocysts**	***Giardia* cysts**	**Viruses**	
log credit				attenuation as outlined in Appendix B • Natural filtration is assigned a 3-log reduction for *Cryptosporidium* oocysts and *Giardia* cysts. • Chemical disinfection is required to meet remaining log inactivation criteria for viruses and provide secondary disinfection of the distribution system.
Non-GUDI sources	0-log	0-log	4-log	**Disinfection** • Chemical disinfection is required to meet log inactivation criteria for viruses and provide secondary disinfection of the distribution system.

C3 Determining Log Removal Credits for Filtration and Disinfection Treatment Processes

The following steps shall be taken by the Approval Holder or design engineer to determine the log removal credits for enteric protozoa and viruses assigned to the filtration process, if applicable, and the remaining credits that the disinfection process shall be designed to achieve:

a. Confirm the log reduction requirements for the source water type as outlined in Table C1.

b. Find the filtration log removal credits associated with the type of filtration system(s) employed as outlined in Table C2 and subtract this from the requirements specified in Table C1.

c. Determine if any additional filtration credits are available from enhanced filtration performance (if applicable) and subtract this from the remainder above.

d. The result is the log inactivation portion that shall be met by the disinfection process.

Systems using surface water and GUDI sources not assigned a Department-accepted natural filtration log credit: Engineered filtration is required for surface water and GUDI sources not assigned a Department-accepted natural filtration log credit. Additionally, a minimum of 0.5-log inactivation for *Giardia* must be provided by the disinfection process.

C4 Treatment Credits for Filtration (Log Removal)

Drinking water treatment technologies meeting the turbidity limits and operational requirements outlined in Table C2 will be assigned the corresponding log removal credits for *Cryptosporidium, Giardia* and viruses by the Department.

Municipal Public Drinking Water Supplies with Engineered Filtration: If the Approval Holder or design engineer believes the engineered filtration technology can achieve a higher log removal credit than is identified in Table C2, a higher log removal credit may be granted by the Department based on a demonstration of filter performance. For example, Municipal Public Drinking Water Supply systems with conventional or direct filtration that achieve 0.15 NTU 95% of the time each calendar month in combined filter effluent are eligible to receive an additional 0.5-log removal credit for protozoa. Municipal Public Drinking Water Supply systems with conventional or direct filtration that achieve 0.15 NTU 95% of the time each calendar month in individual filter effluent are eligible to receive an additional 1.0-log removal credit for protozoa.

Table C2- Log Removal Credits Assigned to Treatment Technologies Meeting Prescribed Turbidity Limits and Other Requirements

Treatment Technology	Protozoa Credit		Virus Credit[1]	Individual Filter Turbidity Limits (unless stated otherwise) and Operational Requirements
	Cryptosporidium[1]	*Giardia* [1]		
Conventional filtration[2] – includes chemical mixing, coagulation, flocculation, clarification, and rapid gravity filtration	3.0-log		2.0-log	a. Shall be less than or equal to 0.2 NTU in at least 95% of the measurements made or at least 95% of the time each calendar month. b. Shall not exceed 1.0 NTU at any time. c. Filter-to-waste[3] - filters shall be capable of directing filtered water to waste or recycle immediately following a backwash for a period of time until the filtrate turbidity value is below 0.2 NTU d. For direct filtration systems that use free chlorine alone as their primary disinfectant, to achieve log reduction requirements for *Cryptosporidium*, the turbidity shall be less than or equal to 0.15 NTU in at least 95% of the measurements made or at least 95% of the time each calendar month.
Direct filtration [2] - includes chemical mixing, coagulation,flocculation, and rapid gravityfiltration	2.5-log		1.0-log	
Slow sand filtration	3.0-log		2.0-log	a. Shall be less than or equal to 1.0 NTU in at least 95% of the measurements made or at least 95% of the time each calendar month. b. Shall not exceed 3.0 NTU at any time. c. Filter-to-waste[3] shall be provided to ensure filtered water, immediately after filter cleaning, is directed to a waste or recycle stream.
Diatomaceous earth filtration	3.0-log		1.0-log	a. Shall be less than or equal to 1.0 NTU in at least 95% of the measurements made or at least 95% of the time each calendar month. b. Shall not exceed 3.0 NTU at any time. c. Filter-to-waste[3] shall be provided to ensure filtered water, immediately after filter backwashing, is

Treatment Technology	Protozoa Credit		Virus Credit[1]	Individual Filter Turbidity Limits (unless stated otherwise) and Operational Requirements
	Cryptosporidium[1]	*Giardia* [1]		
				directed to a waste or recycle stream.
Micro-filtration[4,5,6]	Removal efficiency demonstrated through challenge testing and verified by direct integrity testing.		No Credit	a. Shall be less than or equal to 0.1 NTU in at least 99% of the measurements made or at least 99% of the time each calendar month. b. If turbidity exceeds 0.1 NTU for more than 15 minutes, direct integrity testing shall be immediately conducted on the membrane treatment unit. c. Shall not exceed 0.3 NTU at any time. d. Filter-to-waste[3] shall be provided for operational flexibility. e. The membrane system used for pathogen reduction shall have continuous indirect integrity testing. f. Continuous indirect integrity testing shall be conducted at a minimum frequency of once every 5 minutes. Indirect integrity testing shall follow that outlined in the EPA *Membrane Filtration Guidance Manual*, as amended from time to time. g. The actual removal efficiency of a membrane shall be verified by third party challenge testing. Acceptable challenge testing shall follow that provided in the EPA *Membrane Filtration Guidance Manual*, as amended from time to time. h. Direct integrity testing shall be able to verify a log removal value equal to or greater than the removal
Ultra-filtration[4,5,6]	Removal efficiency demonstrated through challenge testing and verified by direct integrity testing.		Removal efficiency demonstrated through challenge testing and verified by direct integrity testing.	

Treatment Technology	Protozoa Credit		Virus Credit[1]	Individual Filter Turbidity Limits (unless stated otherwise) and Operational Requirements
	Cryptosporidium[1]	*Giardia* [1]		
				credit awarded to the membrane filtration process. i. Direct integrity testing shall be conducted on each membrane filtration unit at least once per day and as soon as the Approval Holder becomes aware when the turbidity exceeds 0.1 NTU for more than 15 minutes.
Reverse osmosis and nanofiltration[4,5,6]	Removal efficiency demonstrated through challenge testing and verified by direct integrity testing.		Removal efficiency demonstrated through challenge testing and verified by direct integrity testing.	a. Shall be less than or equal to 0.1 NTU in at least 99% of the measurements made or at least 99% of the time each calendar month. b. Shall not exceed 0.3 NTU at any time. c. Filter-to-waste[3]- a filter-to-waste feature shall be provided foroperational flexibility. d. To assign pathogen log reduction credits for reverse osmosis and nano-filtration units, direct integrity testing shall be available to verify removal efficiency. e. If the membrane process is assigned pathogen log reduction credits by the Department, the Approval Holder shall adhere to the following additional requirements: i. The membrane system used for pathogen reduction shall have continuous indirect integrity testing. ii. Continuous indirect integrity testing shall be conducted at a minimum frequency of once every 5 minutes. Indirect integrity testing shall follow that outlined in the EPA's *Membrane Filtration Guidance Manual*, as amended from time to time. f. The actual removal efficiency of a membrane shall

Treatment Technology	Protozoa Credit		Virus Credit[1]	Individual Filter Turbidity Limits (unless stated otherwise) and Operational Requirements
	Cryptosporidium[1]	*Giardia* [1]		
				be verified by third party challenge testing. Acceptable challenge testing shall follow that provided in the EPA's *Membrane Filtration Guidance Manual*, as amended from time to time. g. Direct integrity testing shall be able to verify a log removal value equal to or greater than the removal credit awarded to the membrane filtration process. h. Direct integrity testing shall be conducted on each membrane filtration unit at least once per day and as soon as the Approval Holder becomes aware when the turbidity exceeds 0.1 NTU for more than 15 minutes.

Treatment Technology	Protozoa Credit		Virus Credit[1]	Individual Filter Turbidity Limits (unless stated otherwise) and Operational Requirements
	Cryptosporidium[1]	*Giardia* [1]		
Cartridge filtration, one unit (1 micron absolute pore size)	2-log		No credit	a. For systems serving less than 500 persons, differential pressure across the filter medium is measured and recorded a minimum of once daily and does not exceed the manufacturer's requirements. b. For systems serving more than 500 persons, differential pressure across the filter medium is continuously measured and recorded at a minimum frequency of one measurement every five minutes and does not exceed the manufacturer's requirements. c. Shall be less than or equal to 0.3 NTU in at least 95% of the measurements made or at least 95% of the time each calendar month. d. Shall not exceed 1.0 NTU at any time. e. The cartridge filtration process is tested and confirmed by an independent testing agency for at least 3 log removal of *Cryptosporidium* oocysts or surrogate particles. Challenge testing shall demonstrate at least 3 log removal of *Cryptosporidium* oocysts and *Giardia* cysts.
Cartridge filtration, two units in series (1 micron absolute pore size)	2.5-log		No credit	
Natural In-situ Attenuation for Medium Risk GUDI Sources[7]	1.0-log [7]		No credit	a. Shall be less than or equal to 1.0 NTU in at least 95% of the measurements made or at least 95% of the time each calendar month at each individual GUDI wellhead. b. Continuous turbidity monitoring - required at each individual GUDI wellhead. c. Microscopic Particulate Analysis[8] - MPA testing is required every two years for each individual GUDI well following a significant rainfall in

Treatment Technology	Protozoa Credit		Virus Credit[1]	Individual Filter Turbidity Limits (unless stated otherwise) and Operational Requirements
	Cryptosporidium[1]	*Giardia* [1]		
				accordance with Step 3 of the GUDI protocol[8].
Natural In-situ Attenuation for Low-Risk GUDI Sources[7]	3.0-log[7]		No credit	a. Shall be less than or equal to 1.0 NTU in at least 95% of the measurements made or at least 95% of the time each calendar month at each individual GUDI wellhead or the combined flow. b. Continuous turbidity monitoring - required at each individual GUDI wellhead. c. Microscopic Particulate Analysis[8] - MPA testing is required every two years for each individual GUDI well following a significant rainfall in accordance with Step 3 of the GUDI protocol[8].

1 Disinfection shall provide a minimum 0.5-log inactivation for *Giardia* unless a higher log inactivation credit is required. Where disinfection is used to address any shortfall in the log reduction requirements for *Cryptosporidium*, an alternate disinfectant such as UV, chlorine dioxide or ozone shall be required.

2 Municipal Public Drinking Water Supplies with conventional or direct filtration that achieve 0.15 NTU 95% of the time each calendar month in combined or individual filter effluent are eligible to receive additional log removal credits for protozoa to meet minimum treatment requirements as follows: combined 0.5-log; individual 1.0-log.

3 Alternatives that demonstrate an equivalent benefit to filter-to-waste may be considered by the Department on a case-by-case basis for existing facilities. All new systems shall include a filter-to-waste provision.

4 If membrane filtration is the sole treatment technology employed, disinfection shall follow the filtration process to meet virus inactivation requirements.

5 Membrane removal efficiency shall be demonstrated through challenge testing and verified by direct integrity testing. See Appendix G for additional information on membrane filtration.

6 If the unit passes direct integrity testing, it may continue to be used for water treatment; if not, the unit shall be taken out of service.

7 A natural in-situ attenuation log credit may be assigned if the *Guidelines for the Determination of Natural Filtration Log Removal for Protozoa* are followed (Appendix B) and the Department Regional Hydrogeologist accepts the determination in writing.

8 MPA testing shall be completed in accordance with Step 3 of the Protocol for Determining Groundwater Under the Direct Influence of Surface Water as outlined in Appendix A (e.g. if there is a 15 day time-of-travel, then the well shall be sampled 15 days after a surface water event).

C5 Disinfection Credits (Log Inactivation)

Disinfection is required to inactivate any microbial pathogens that pass through previous treatment processes.

a. Disinfection shall provide any remaining log reduction credits necessary to meet the minimum treatment requirements specified in Table C1.

b. Where disinfection is used to address any shortfall in the log reduction requirements for *Cryptosporidium*, an alternate disinfectant such as UV, chlorine dioxide, or ozone is required.

c. Where UV disinfection is used to inactivate protozoa, chemical disinfection is required to meet remaining log inactivation requirements for viruses.

d. Where UV, chlorine dioxide, or ozone are used as primary disinfectants, free chlorine or chloramines must be used to provide secondary disinfection of the distribution system.

C5.1 CT Concept for Chemical Disinfection

Nova Scotia's treatment standards require application of the CT concept for chemical disinfection. CT is calculated by multiplying the disinfectant concentration (C) by the time that 10 percent of the water is in contact with the disinfectant (T10). T10 is calculated by multiplying the theoretical hydraulic detention time (e.g., tank volume divided by flow rate) by the baffling factor of the contact chamber. T10 may also be established by tracer studies.

The CT equation is as follows:

Formula: CT = Concentration (mg/L) x Time (minutes) x Baffling Factor

C5.1.1 Acceptable Primary Disinfectants

The Approval Holder shall use Department-accepted chemical disinfectants including free chlorine, chlorine dioxide, or ozone. Due to the poor disinfecting capability of chloramines, chloramines are not accepted by the Department as a primary disinfectant.

C5.1.2 Baffling Factors

The baffling factor used in CT calculations shall be acceptable to the Department. Baffling factors are provided in Table C3. Examples of baffling factors to use for sample contact chamber designs are included in Appendix E.

C5.1.3 Clearwell or Storage Tank Volume and Flowrate

For Approval Holders that include the volume of water in the clearwell or on-site storage tank for CT determination, the calculation shall be made based on the minimum operating level in the tank. The highest flow condition shall also be confirmed (inflow or outflow).

Note: Distribution system storage is not eligible for CT credits. The required CT shall be achieved before the municipal public drinking water supply's first customer.

C5.1.4 CT Ratio (CT Achieved/CT Required)

a. The Approval Holder shall compare the calculated CT achieved using the equation above to the CT required. The CT required is found in log inactivation tables for *Cryptosporidium*, *Giardia* and/or viruses first published by the US EPA. CT tables for free chlorine, chlorine dioxide, and ozone are included in Appendix D. The science-based impacts of pH and temperature on the effectiveness of some disinfectants have been taken into account where applicable.

b. The Approval Holder shall ensure the ratio of the calculated value (CT achieved) to the table value (CT required) is equal to or greater than one to receive log inactivation credits for the disinfection process.

c. The Approval Holder shall ensure design ranges for the disinfection process are set for worst case scenarios For free chlorine, worst case design ranges typically include the following:

    - Lowest temperature of the water to be disinfected;
    - Highest pH value of the water to be disinfected with chlorine;
    - Lowest chlorine residual found at the outlet of the designated chlorine contact volume; and
    - Minimum contact time (typically occurs under highest flow conditions).

Sample CT calculations are provided in Appendix F for various sources and treatment technologies.

Where free chlorine is used, it is recommended that the Approval Holder minimizes the formation of disinfection by-products. However, this should be done in consideration of operational requirements (e.g., water quality and quantity, distribution system disinfectant residual, etc.) and without compromising the effectiveness of disinfection.

C5.1.5 Disinfection Byproducts

The Approval Holder shall balance effective disinfection for microbial protection against the creation of disinfection by-products.

The Approval Holder shall make every effort to maintain concentrations of disinfection by-products as low as reasonably achievable without compromising the effectiveness of primary disinfection.

Table C3: Baffling Factors

Baffling Condition	Baffling Factor T10/T0	Baffling Description
Unbaffled (mixed flow)	0.1	• Agitated basin • Very low length-to-width ratio • High inlet and outlet flow velocities • High potential for stagnant zones and short-circuiting
Poor	0.3	• Single or multiple unbaffled inlets and outlets • No intra-basin baffles • Potential for stagnant zones or short-circuiting
Average	0.5	• Baffled inlet or outlet • Some intra-basin baffles
Superior	0.7	• Perforated inlet baffle • Serpentine or perforated intra-basin baffles • Outlet weir or perforated launders • Most of tank volume is utilized
Perfect (plug flow)	1	• Length to width ratio greater than or equal to 10:1 • Perforated inlet, outlet and intra-basin baffles

C5.2 IT Concept for UV Disinfection

These treatment standards require application of the IT concept. IT is calculated by multiplying the UV intensity (I) by the exposure time (T) to demonstrate that required disinfection credits are achieved.

Formula: UV dose = UV intensity (Watts/cm^2) x Time of exposure (seconds)

The amount of UV light delivered to pathogens in a reactor is called "UV dose" and is measured in millijoules per square centimetre (mJ/cm^2). The UV dose depends on:

- UV intensity, or magnitude of UV light, measured by UV intensity sensors in Watts/cm^2 or Watts/m^2;
- UV transmittance (UVT); and
- Water flow rate and hydraulics in the reactor.

Previous treatment standards required a minimum UV dose (IT) of 40 mJ/cm^2 for all Municipal Public Drinking Water Supplies. A UV dose of 40 mJ/cm^2 achieves 0.5-log reduction for viruses based on adenovirus inactivation.

a. Where UV light is used for primary disinfection, chemical disinfection shall be required to meet any remaining log inactivation criteria for viruses.

b. Where UV light is used for primary disinfection a lower UV dose than 40mJ/cm^2 may be acceptable to the Department for enteric protozoa (i.e., *Giardia, Cryptosporidium*) based on required log inactivation credits, UV lamp design and validation, energy conservation goals, etc.

c. For virus inactivation, the target microorganism will remain adenovirus (0.5 log inactivation at 40 mJ/cm^2) for municipal drinking water supplies unless the Approval Holder demonstrates that there is no risk of adenovirus being present. In this case, rotavirus may be considered the target virus. Log inactivation credits will be considered and accepted by the Department on a system-specific basis.

d. Where UV light is used as a primary disinfectant, free chlorine or chloramines shall be required to provide secondary disinfection of the distribution system.

e. To receive inactivation credit, a UV reactor must operate within the validated limits (e.g., intensity is greater than the minimum specified, flow is below the maximum specified, UVT is above the minimum specified).

f. UV systems are required to have a shut off feature and alarm when the equipment malfunctions, loses power or ceases to provide the appropriate level of disinfection.

Additional information is provided in Appendix G.