Treatment Standard
for
Municipal Surface Source Water Treatment Facilities

NOVA SCOTIA
Environment and Labour

Approval Date: December 2002 Effective Date: April 1, 2003

Version Control: Latest revision November 8, 2004 (administrative amendments)

Preamble

This treatment standard sets the minimum level for treated water quality parameters. It would be considered unacceptable for systems capable of exceeding this standard to allow their water quality to degrade in quality to only meet the minimum requirements. Nova Scotia has entrenched the health-related Guidelines for Canadian Drinking Water Quality (GCDWQ) within provincial legislation covering water treatment and distribution systems. For parameters not covered in this treatment standard, the GCDWQ will serve as the minimum requirements for facility operations. In addition to the GCDWQ, this treatment standard is not intended to replace, but to be used in conjunction with, the Nova Scotia Guidelines for Monitoring Public Drinking Water Supplies.

Background

One of the major objectives of a water supplier is to provide users with drinking water that is free of microbial pathogens to prevent waterborne disease. Water suppliers can achieve this level of public health protection by providing treatment to assure that pathogens found in water supplies are removed or inactivated.

The provision of a safe drinking water product is a major public health issue. Proper treatment and disinfection advancement during the 20th century and into the 21st century has shown how important a safe drinking water supply is to society. One hundred years ago, typhoid and cholera epidemics were common in North America. Disinfection was a major factor in reducing these epidemics. However, disinfection is only one step in a multi-barrier approach for the delivery of safe water.

In 1990, the Environmental Protection Agency's Science Advisory Board concluded that minimizing the risk of exposure to pathogens in water was likely the greatest remaining health challenge for water suppliers. Acute health effects from exposure to these pathogens are documented and associated illness can range from mild to moderate cases lasting only a few days to more severe infections that can last several weeks and may result in death for those with weakened immune systems.

In the past 10 to 15 years, those in the water treatment and delivery industry have learned that some microbial pathogens are resistant to traditional disinfection. During the 1990's, *cryptosporidium* and *giardia* have caused major public health concerns or outbreaks of illness in many North American communities including: North Battleford, Saskatchewan; Kelowna, British Columbia; Ontario communities of Collingwood and Walkerton; and in the United States in Milwaukee, Nevada, Oregon and Georgia. These are only a sampling of communities that have had problems. The Kelowna outbreak in 1996 resulted in approximately 10,000 reported illnesses. In the case of Milwaukee there were 400,000 people that experienced some form of intestinal illness

with over 4,000 being hospitalized.

The State of the Nova Scotia Environment Report, which was released in July 1998, identified contamination of surface water supplies from viruses and protozoa, such as *cryptosporidium* and *giardia* as a 'new threat'. At that time, and up until the present, no municipal waterborne related outbreaks in Nova Scotia have been linked to these protozoans.

The recognized water treatment philosophy is to incorporate the multi-barrier strategy to best protect the public health from waterborne disease. Microbial pathogens, including protozoan parasites, bacteria, and viruses, can be physically removed by flocculation, sedimentation, and filtration or inactivated by disinfection processes. Effective use of these processes will provide the best method of utilizing the multi-barrier approach.

Section 2 of the Nova Scotia Environment Act clearly states its purpose is to support and promote the protection, enhancement and prudent use of the environment while recognizing certain goals, such as maintaining environmental protection as essential to the integrity of ecosystems, human health and the socio-economic well-being of society. Section 2 (e) identifies government as having a catalyst role in many areas including the development of policies, standards, objectives and guidelines.

Based on the Department's responsibilities, minimum water treatment requirements have been identified to verify that systems in Nova Scotia meet current environmental standards. Nova Scotia Environment and Labour believes that through the implementation of the minimum treatment standards in Nova Scotia, the health of all Nova Scotians and visitors will be better protected by reducing the likelihood of an adverse water quality event by implementing industry accepted standards for safety and protection from exposure to pathogens.

The major area for these identified minimum standard requirements are for surface water treatment facilities or for ground water supplies that have, or may be susceptible, to surface water influence.

The goals of the treatment standard include:

- setting treatment efficiency levels to remove/inactivate *cryptosporidium*, *giardia* and viruses;
- identify the specific filter effluent turbidity performance standards;
- detailing minimum disinfection benchmarks;

- defining ‘groundwater under direct influence of surface water’.

Surface Water Treatment Standard

Effective Date

April 01, 2003

Affected Systems

All municipal Public Water Supplies (PWS) using surface water sources or groundwater sources under the direct influence of surface water (GUDI). For the purposes of this treatment standard, groundwater source facilities falling under GUDI are considered to be a surface water source facility.

GUDI is defined as: “any water beneath the surface of the ground with:

(i) significant occurrence of insects or other macro-organisms, algae, organic debris, or large-diameter pathogens such as *Giardia lamblia* or *Cryptosporidium*; or

(ii) significant and relatively rapid shifts in water characteristics such as turbidity, temperature, conductivity, or pH which closely correlate to climatological or surface water conditions.”

Groundwater under the direct influence may be determined for individual sources in accordance with criteria established and/or accepted by the NSEL.

The NSEL determination of direct influence may be based on site-specific measurements of water quality and/or documentation of well construction characteristics and geology with field evaluation.

Basic Provisions

All water systems are to provide a ‘System Assessment Report’ to Nova Scotia Environment and Labour. The findings of this report will determine the system requirements to meet the standards.

This standard establishes criteria under which filtration and disinfection are required. Based on the System Assessment Report, all systems that do not meet the minimum treatment requirements will be required to work towards full compliance within the identified timelines. Given that some systems will require time to upgrade treatment processes, interim requirements are also detailed.

- Within 1 year of this treatment standard coming into effect:

- A municipality, whose water system uses surface water or a groundwater source that is known to be influenced by surface water (GUDI), must provide to the Department a detailed plan regarding how their system will attain full compliance;
    - Note: For the purposes of GUDI determination, any well that is known to be constructed in contravention of present day well construction standards, and the well is serving a municipal water system, the well will be considered as GUDI unless determined otherwise in a hydrogeological assessment;

- Full parameter testing and analysis is required for raw and treated water as per the chemical, physical and microbiological parameters stated in the Guidelines for Canadian Drinking Water Quality;

- Within 2 years of this treatment standard coming into effect, facilities using groundwater sources that have failed Step 1 of the GUDI Screening, as stated in the 'Protocol for Determining Groundwater Under the Direct Influence of Surface Water', must determine whether any well within the water supply is influenced by surface water and provide to the Department individual well assessment documents (See Steps 2 & 3 of the 'Protocol for Determining Groundwater Under the Direct Influence of Surface Water');

    - For facilities that have been determined to be under the influence of surface water, the responsible municipality must provide to the Department a detailed plan regarding how their system will attain full compliance with this treatment standard;

    - Full parameter testing and analysis is required for raw and treated water as per the chemical, physical and microbiological parameters stated in the Guidelines for Canadian Drinking Water Quality;

- Prior to April 01, 2008, all construction and operational systems must be in place to meet the requirements of this treatment standard.

Treatment Standards

The purpose of having a treatment standard is to set the minimum parameters that are recognized for water treatment and distribution facility operations in which to maintain public health protection. The safe, clean water supply is addressed by the implementation of the multi-barrier approach. This includes:

- source water protection;
- effective treatment and disinfection process operations;
- effective distribution system operation and water quality maintenance;
- quality control - sampling, testing and monitoring.

Research and field work results support optimizing particle removal from water treatment facilities to maximize public health protection from microbial contamination. This treatment standard considers utilizing two specific treatment processes, filtration and disinfection, in which to achieve the level of health protection. This treatment standard identifies specific parameter values, record keeping and reporting requirements. For facilities that are not presently meeting this standard, interim requirements have also been determined and included in this document.

General Requirements

- Filtration is required for all surface water treatment facilities;
- Treatment facilities are required to have a minimum of two filters to ensure that unfiltered water does not enter the water distribution system;
- Treatment facilities are required to have a minimum of two disinfection units to ensure that non-disinfected water does not enter the water distribution system;
- Within the combination of utilizing both the filtration and disinfection processes at a water treatment facility covered by this standard, the following treatment efficiencies must be met:
    - Treatment must be sufficient to ensure 99.9% inactivation or removal of *Giardia lamblia* cysts (3-Log Removal);
    - Treatment must be sufficient to ensure 99.99% inactivation or removal of viruses (4-Log Removal);
    - Disinfection must address a minimum of 0.5 log removal when used in conjunction with filtration.
        - Note: In order to ensure that required levels of disinfection are achieved, this standard uses the concept of the disinfection concentration (C) multiplied by the actual time (T) that the finished water is in contact with the disinfectant which is known as CT for log removal.

Filtration Requirements

- *Turbidity Monitoring Requirement:*
    - Continuous monitoring is required for individual filters and for the combined filtered water with measurements taken at no more than five-minute intervals;
    - Continuous or grab sample monitoring at least once/day is required for raw water, taken just prior to the location of the coagulation chemical addition point;
    - Continuous or grab sample monitoring of the distribution system is required as per facility approval;
    - Continuous or grab sample monitoring of the filtered water directed to waste is required.

- *Filter Turbidity Values:*

- A turbidity value of 0.2 NTU must be achieved on at least 95% of the measurements or at least 95% of the time based on each calendar month and taken by continuous monitoring;
- A turbidity value must not exceed 0.2 NTU for more than 12 consecutive hours;
- A turbidity value must never exceed 1.0 NTU;
- A turbidity value of the water directed to waste following a backwash cycle must be less than 0.5 NTU prior to returning filter to normal operation.

- *Distribution Turbidity Values:*
  - An aesthetic objective turbidity value of 5.0 NTU or less must be achieved on distribution system sampling based on each calendar month;
  - Sampling and testing frequency is the same as for bacteriological sampling requirements as stated in the Guidelines for Monitoring Public Drinking Water Supplies or as stated in the Approval To Operate for the facility.

- *Filter Operation Requirements:*
  - Filters must be capable to direct filtered water to waste immediately following a backwash for a period of time until the filtrate turbidity value is below 0.5 NTU;
  - Filters must be controlled in such a manner as to remove an individual filter from service if the turbidity exceeds either 0.2 NTU for 12 consecutive hours or if the turbidity exceeds 1.0 NTU at any time;
  - Filters must be equipped with alarm and instrumentation capabilities;
  - Standard operational procedures must be developed, implemented and communicated to all operations staff.

Disinfection Requirements

- *Chlorine Residual Monitoring Requirement:*
  - Continuous monitoring is required for finished water leaving the treatment facility with measurements taken at no more than five-minute intervals;
  - Continuous monitoring is required, with measurements taken at no more than five-minute intervals, of the water leaving a water storage structure within a water distribution system;
  - Grab sample monitoring of the distribution system is required.

- *Free Chlorine Residual Values and Sampling Requirements:*
  - The disinfection process must be operated in such a manner as to ensure that a 0.2 mg/L minimum free chlorine residual is achieved throughout the water distribution system;
  - The maximum free chlorine residual of water delivered to consumers is 4.0 mg/L;
  - Sampling and testing frequency for chlorine residual monitoring of the distribution system is the same as for bacteriological sampling requirements as stated in the Guidelines for Monitoring Public Drinking Water Supplies.

- *Disinfection Requirements:*
  - Disinfection shall contribute a minimum of 0.5 log removal/inactivation for *giardia lamblia*;
  - Disinfection equipment must be operated in such a manner as to prevent non-disinfected water from entering a distribution or storage facility;
  - Water systems must be equipped with alarm capabilities to notify operations staff if the disinfection process fails to operate properly;
  - Standard operational procedures must be developed, implemented and communicated to all operations staff.

Record Keeping Requirements

- All turbidity data must be recorded to determine treatment efficiencies and trending analysis;
- All incidents of turbidity measurements above 1.0 NTU must be detailed with a description of any actions taken and reported to NSDEL;
- Disinfection application data (dosage and CT determinations) and chlorine residual data at the treatment facility and in the distribution system must be recorded;
- All incidents of free chlorine residual measurements below 0.2 mg/L in the distribution system must be detailed with a description of any actions taken and reported to NSDEL;
- All incidents of suspected and/or confirmed disease outbreaks attributed to the water system must be documented.

Reporting Requirements

- Water quality and analysis reports are to be provided to the Department upon

request and/or as is identified in the facility Approval To Operate;

- The facility must meet all emergency reporting requirements as established by the Department or any other regulatory body;
- The Boil Water Advisory Protocol and Communication Plan as stated in the Guidelines for Monitoring Public Drinking Water Supplies must be adhered to;
- Immediate notification, to Nova Scotia Environment and Labour, of a health-related adverse water quality situation is required.

Interim Requirements For Facilities Not Meeting The Surface Water Treatment Standard

- For surface water sources and known GUDI systems - within 1 year of the effective date of this standard, the municipality must provide for the installation and operation of disinfection equipment that has an automatic shut-off operation capability in order to prevent non-disinfected water from entering a distribution system. For facilities where GUDI has been determined, this requirement must be met within 2 years of the effective date of this standard;
- Sampling of the distribution system for bacteriological monitoring must be increased in frequency by double those stated in facility Approval To Operate;
    - For facilities without an identified frequency requirement for bacteriological monitoring, the requirement will be double the frequency at the current accepted sampling locations and shall be no less than double those stated in the Guidelines for Monitoring of Public Water Supplies;
    - Sampling must be adequate to appropriately characterize the distribution system;
- The minimum free chlorine residual in the distribution system is 0.4 mg/L;
- Distribution system sampling must be reported on a monthly basis;
- Distribution sampling locations must be indicated on a map that illustrates the current distribution system and a copy of the sampling location map is to be provided to the Department;
- Any changes to the sampling locations are to be approved by the Department;
- Standard operational procedures and emergency contingency plans must be developed, implemented and communicated to all staff for the interim period. These procedures and plans must be made available to Department staff upon request;
- The Boil Water Advisory Protocol and Communication Plan as stated in the appropriate section of the Guidelines for Monitoring Public Drinking Water Supplies must be adhered to;

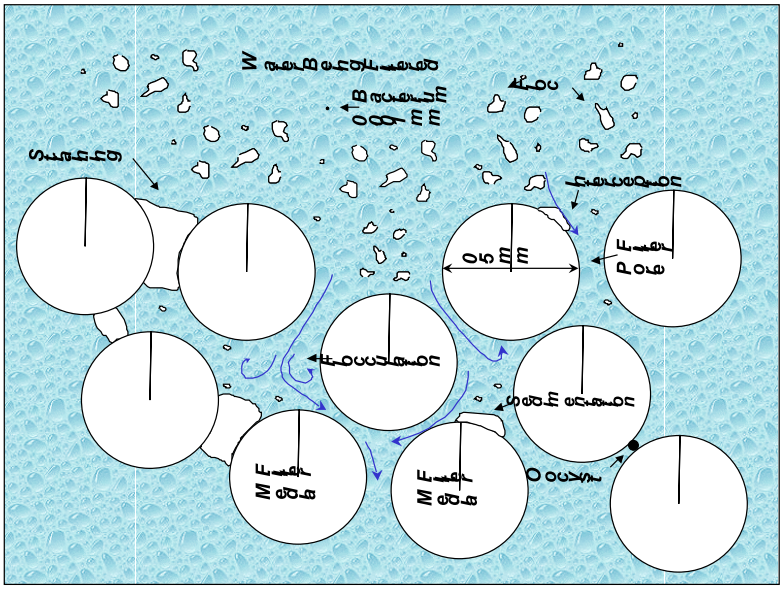
- Based on the Guidelines for Monitoring Public Drinking Water Supplies, if at any time the bacteriological parameters are not met, the system will be required to issue a boil water advisory. The boil water advisory will be removed by NSDEL in consultation with the Medical Officer of Health and the owner when all concerns regarding adverse water quality have been addressed as identified in the Guidelines.

Backup Water Systems

- The purpose of a 'Backup Water System' is to serve as a resource in the event of a disruption of the normal water system supply, treatment and or distribution. The following parameters for a backup water system must be met:
  - A backup water system is only to be used on a temporary basis;
  - When a backup water system is used for supplying water for human consumption, the owner of the system must notify DEL and identify the anticipated period of time the system will be in service;
  - For backup systems that meet the requirements of this treatment standard, the water system may continue to operate as under normal circumstances until the main water system is ready to be put back into service;
  - For backup systems that do not meet the requirements of this treatment standard, the municipality must immediately initiate a 'Boil Water Advisory' as stated in the Guidelines for Monitoring Public Drinking Water Supplies;
  - Based on the Guidelines for Monitoring Public Drinking Water Supplies, the boil water advisory will be removed by NSDEL in consultation with the Medical Officer of Health and the owner when all concerns regarding adverse water quality have been addressed as identified in the Guidelines.

Filtration

In most water treatment facilities filtration is typically the final unit treatment process relative to the physical removal of microbial pathogens. Filtration is a physical process whereby the particles are trapped by the media to prevent them from passing through and into the finished water. The following diagram illustrates the physical removal of particulate matter by a filter:



As the filtration process is typically the last barrier where microbial pathogens can be physically removed, each filter must be monitored. Particle removal through a water treatment process can be monitored and assessed by various methods including turbidity, particle counting, and microscopic particulate analysis (MPA). However, because turbidity monitoring is the most common method of assessing particle removal in surface water systems, turbidity is the parameter required by this standard from which to monitor and safeguard against biological contamination of the water into the distribution system.

The standard operating procedures developed for the effective, efficient and compliant operation of the filtering process will provide a level of continuity in the operation. It is critical that the procedures be properly communicated and accessed by the operations staff. In order to evaluate and provide comment on the system operation, these procedures must be made available to Department staff upon request.

The maximum log removal value for filtration processes is 2.5 log removal to meet CT requirements and a minimum of 0.5 log removal based on the disinfection process. The

log removal values for several types of filtration processes are indicated in the following table:

Expected Log Removals By Filtration		
Type of Process	**Giardia Cysts**	**Viruses**
Conventional Filtration	2.5	2.0
Direct Filtration	2.0	1.0
Slow Sand Filtration	2.0	2.0
Diatomaceous Earth Filtration	2.0	1.0
Membrane Filtration	2.5	2.0
Natural Filtration *	To Be Determined	

***** Groundwater systems which have been assessed as being under the influence of surface water (GUDI) may also be determined to have a level of natural filtration. The parameters for applying the level of natural filtration achieved will be identified in the Groundwater Treatment Standard with the associated expected log removal as it relates to meeting the CT requirements.

Note: *Alternate Filtration Processes* - For any new and/or alternative method of filtration which is not identified in the table, the method will be considered acceptable provided that the alternate filtration process has been shown to achieve performance levels that when combined with disinfection the finished water meets quality parameters of this standard.

Disinfection

Disinfection is the final barrier in the treatment process and it is responsible for inactivating any microbial pathogens that pass through previous unit processes. Disinfection is the most important step in any water treatment process. New microbial challenges and increased knowledge of disinfection byproducts makes it essential that the design of new and/or upgraded waterworks and the maintenance of these facilities reflect current knowledge, technologies and practices.

In cases where chlorine is used as the primary disinfectant, the CT value needs to be calculated by taking into consideration pH and temperature of the water and the free chlorine residual.

All water treatment facilities must include disinfection to guard against microbial contamination of the water. Disinfection processes must be approved and meet industry standards.

Regardless of the primary disinfection process utilized, the water distribution system must maintain a minimum free chlorine residual level in order to provide an appropriate level of safety to the consumer.

Note: *Alternate Disinfection Processes* - The application of alternative disinfectants is acceptable provided that the formation of disinfection byproducts is minimized and the alternate disinfectant has been shown to achieve the level of disinfection that is required with chlorination. Notwithstanding the use of alternative disinfectants, it will be necessary to maintain a disinfectant residual throughout the distribution system as indicated in the standard.

Log Removal

In order to ensure that required levels of disinfection are achieved, this standard uses the concept of the disinfection concentration (C) multiplied by the actual time (T) that the finished water is in contact with the disinfectant. This calculated value is used in reference to the log removal tables for *giardia lamblia* and/or viruses removal/inactivation. The table values are based on several factors including: pH, temperature, chlorine residual and mixing. The ratio of CT with the table value should be greater than 1.0 in order to effectively address the removal/inactivation of the *giardia* and viruses. This is known as CT for log removal.

To ensure that the different parameters and their effect on the disinfection process are best addressed, it is recommended that the calculation be based on:

- the lowest temperature expected of the water when contacted by the disinfectant;
- the highest pH value;
- the lowest expected residual at the furthest most measuring point from the chemical application; and
- the least effective mixing of the chemical in the water - Baffling Factor.

NOTE: Typically, *giardia* inactivation requirements are more difficult to achieve than the virus requirements. A calculation can be performed based on the log removal values of viruses. However, the CT requirements of this standard will depend on CT calculations to be performed using the log removal values for *giardia*.

CT Calculation

CT values for log removal of *giardia* are identified in the tables attached to this standard. To determine if a system meets the log removal requirements the calculated concentration time ratio must be equal to or greater than one (the value identified).

The following example calculations are based on:

1. water temperature of **10°C**;
2. pH of water is **7.0**;
3. free chlorine residual of **1.2** mg/L;
4. complete mixing - baffling factor of **1.0**; and
5. actual contact time between the point of chemical application and the first user is **45** minutes.

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

CT = 1.2 x 45 x 1.0

CT = 54

Example 1: Based on the log requirements, to achieve 3-log removal of *giardia lamblia* cysts using only disinfection, the value must be taken from the tables attached to this standard. Based on the free residual concentration, the water temperature of 10°C and the water pH of 7.0, the value used for determining if CT will provide for 3-log removal is **114**.

Therefore, the actual CT for this system is:

CT = 54 / 114

CT = **0.47** (must equal 1 or greater)

This indicates the system does not meet the CT requirements.

Example 2: To illustrate how the addition of a filtration process improves the capacity to meet the standard, if the system had conventional multi-media filtration, the CT disinfection requirement would be to meet 0.5 log removal, or using the value of 36 (taken from the table).

Therefore, the CT for the system is:

CT = 54 / 36

CT = **1.5**

This would indicate that the system does meet the CT requirements of the standard.

Notes:

- CT Log Removal Tables are attached to this treatment standard;
- This standard addresses CT for chlorine only. As noted on Page 10, alternate disinfectants must achieve the level of disinfection as required with chlorination. Other disinfectant treatment methods such as chlorine dioxide,

ozone, chloramination and ultra violet each have specific calculations to achieve the required CT Log Removal.

CT Log Removal For Giardia Lamblia At 0.5°C Degrees

	pH < 6.0						pH 6.5						pH 7.0						pH 7.5					
Free Cl_2	Giardia Log Removal @ 0.5° C						Giardia Log Removal @ 0.5° C						Giardia Log Removal @ 0.5° C						Giardia Log Removal @ 0.5° C					
Residual	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0
0.4	23	46	69	91	114	137	27	54	82	109	136	163	33	65	98	163	163	195	40	78	117	155	193	232
0.6	24	47	71	94	118	141	28	56	84	112	140	168	33	67	100	167	167	200	40	80	120	159	199	239
0.8	24	48	73	97	121	145	29	57	86	115	143	172	34	68	103	171	171	205	41	82	123	164	205	246
1.0	25	49	74	99	123	148	29	59	88	117	147	176	35	70	105	175	175	210	42	84	127	169	211	253
1.2	25	51	76	101	127	152	30	60	90	120	150	180	36	72	108	179	179	215	43	86	130	173	216	259
1.4	26	52	78	104	129	155	31	61	92	123	153	184	37	74	111	184	184	221	44	89	133	177	222	266
1.6	26	52	79	105	131	157	32	63	95	126	158	189	38	75	113	188	188	226	46	91	137	182	228	273
1.8	27	54	81	108	135	162	32	64	97	129	161	193	39	77	116	193	193	231	47	93	140	186	233	279
2.0	28	55	83	110	138	165	33	66	99	131	164	197	39	79	118	197	197	236	48	95	143	190	238	286
2.2	28	56	85	113	141	169	34	67	101	134	168	201	40	81	121	202	202	242	50	99	146	195	243	292
2.4	29	57	86	114	143	172	34	68	103	137	171	205	41	82	124	206	206	247	50	99	149	199	248	298
2.6	29	58	88	117	146	175	35	70	105	139	174	209	42	84	126	210	210	252	51	101	152	203	253	304
2.8	30	59	89	119	148	178	36	71	107	142	178	213	43	86	129	214	214	257	52	103	155	207	258	310
3.0	30	60	91	121	151	181	36	72	109	145	181	217	44	87	131	218	218	261	53	105	158	211	263	316

	pH 8.0						pH 8.5						pH < 9.0					
Free Cl_2	Giardia Log Removal @ 0.5° C						Giardia Log Removal @ 0.5° C						Giardia Log Removal @ 0.5° C					
Residual	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0
0.4	46	92	139	185	231	277	55	110	165	219	274	329	65	130	195	260	325	390
0.6	48	95	143	191	238	286	57	114	171	228	285	342	68	136	204	271	339	407
0.8	49	98	148	197	246	295	59	118	177	236	295	354	70	141	211	281	352	422
1.0	51	101	152	203	253	304	61	122	183	243	304	365	73	146	219	291	364	437
1.2	52	104	157	209	261	313	63	125	188	251	313	376	75	150	226	301	376	451
1.4	54	107	161	214	268	321	65	129	194	258	323	387	77	155	232	309	387	464
1.6	55	110	165	219	274	329	66	132	199	265	331	397	80	159	239	318	398	477
1.8	56	113	169	225	282	338	68	136	204	271	339	407	82	163	245	326	408	489
2.0	58	115	173	231	288	346	70	139	209	278	348	417	83	167	250	333	417	500
2.2	59	118	177	235	294	353	71	142	213	284	355	426	85	170	256	341	426	511
2.4	60	120	181	241	301	361	73	145	218	290	363	435	87	174	261	348	435	522
2.6	61	123	184	245	307	368	74	148	222	296	370	444	89	178	267	355	444	533
2.8	63	125	188	250	313	375	75	151	226	301	377	452	91	181	272	362	453	543
3.0	64	127	191	255	318	382	77	153	230	307	383	460	92	184	276	368	460	552

Notes:

1) Always reference the highest pH value expected for the water to be treated.

2) Always reference the lowest temperature expected for the water to be treated.

3) CT Log Removal may be better achieved by calculating based on operational variables such as through pH adjustment, lower flow rates, or chlorine residual maintenance.

4) By following points 1 and 2 your CT calculation will provide the least room for error with your disinfection application.

CT Log Removal For Giardia Lamblia At 5°C Degrees

	pH < 6.0						pH 6.5						pH 7.0						pH 7.5					
Free Cl_2	Giardia Log Removal @5°C						Giardia Log Removal @5°C						Giardia Log Removal @5°C						Giardia Log Removal @5°C					
Residual	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0
0.4	16	32	49	65	81	97	20	39	59	78	98	117	23	46	70	93	116	139	28	55	83	111	138	166
0.6	17	33	50	67	83	100	20	40	60	80	100	120	24	48	72	95	119	143	29	57	86	114	143	171
0.8	17	34	52	69	86	103	20	41	61	81	102	122	24	49	73	97	122	146	29	58	88	117	146	175
1.0	18	35	53	70	88	105	21	42	63	83	104	125	25	50	75	99	124	149	30	60	90	119	149	179
1.2	18	36	54	71	89	107	21	42	64	85	106	127	25	51	76	101	127	152	31	61	92	122	153	183
1.4	18	36	55	73	91	109	22	43	65	87	108	130	26	52	78	103	129	155	31	62	94	125	156	187
1.6	19	37	56	74	93	111	22	44	66	88	110	132	26	53	79	105	132	158	32	64	96	128	160	192
1.8	19	38	57	76	95	114	23	45	68	90	113	135	27	54	81	108	135	162	33	65	98	131	163	196
2.0	19	39	58	77	97	116	23	46	69	92	115	138	28	55	83	110	138	165	33	67	100	133	167	200
2.2	20	39	59	79	98	118	23	47	70	93	117	140	28	56	85	113	141	169	34	68	102	136	170	204
2.4	20	40	60	80	100	120	24	48	72	95	119	143	29	57	86	115	143	172	35	70	105	139	174	209
2.6	20	41	61	81	102	122	24	49	73	97	122	146	29	58	88	117	146	175	36	71	107	142	178	213
2.8	21	41	62	83	103	124	25	49	74	99	123	148	30	59	89	119	148	178	36	72	109	145	181	217
3.0	21	42	63	84	105	126	25	50	76	101	126	151	30	61	91	121	152	182	37	74	111	147	184	221

	pH 8.0						pH 8.5						pH < 9.0					
Free Cl_2	Giardia Log Removal @5°C						Giardia Log Removal @5°C						Giardia Log Removal @5°C					
Residual	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0
0.4	33	66	99	132	165	198	39	79	118	157	197	236	47	93	140	186	233	279
0.6	34	68	102	136	170	204	41	81	122	163	203	244	49	97	146	194	243	291
0.8	35	70	105	140	175	210	42	84	126	168	210	252	50	100	151	201	251	301
1.0	36	72	108	144	180	216	43	87	130	173	217	260	52	104	156	208	260	312
1.2	37	74	111	147	184	221	45	89	134	178	223	267	53	107	160	213	267	320
1.4	38	76	114	151	189	227	46	91	137	183	228	274	55	110	165	219	274	329
1.6	39	77	116	155	193	232	47	94	141	187	234	281	56	112	169	225	281	337
1.8	40	79	119	159	198	238	48	96	144	191	239	287	58	115	173	230	288	345
2.0	41	81	122	162	203	243	49	98	147	196	245	294	59	118	177	235	294	353
2.2	41	83	124	165	207	248	50	100	150	200	250	300	60	120	181	241	301	361
2.4	42	84	127	169	211	253	51	102	153	204	255	306	61	123	184	245	307	368
2.6	43	86	129	172	215	258	52	104	156	208	260	312	63	125	188	250	313	375
2.8	44	88	132	175	219	263	53	106	159	212	265	318	64	127	191	255	318	382
3.0	45	89	134	179	223	268	54	108	162	216	270	324	65	130	195	259	324	389

Notes:

1) Always reference the highest pH value expected for the water to be treated.

2) Always reference the lowest temperature expected for the water to be treated.

3) CT Log Removal may be better achieved by calculating based on operational variables such as through pH adjustment, lower flow rates, or chlorine residual maintenance.

4) By following points 1 and 2 your CT calculation will provide the least room for error with your disinfection application.

CT Log Removal For Giardia Lamblia At 10°C Degrees

	pH < 6.0						pH 6.5						pH 7.0						pH 7.5					
Free Cl_2	Giardia Log Removal @ 10°C						Giardia Log Removal @ 10°C						Giardia Log Removal @ 10°C						Giardia Log Removal @ 10°C					
Residual	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0
0.4	12	24	37	49	61	73	15	29	44	59	73	88	17	35	52	69	87	104	21	42	63	83	104	125
0.6	13	25	38	50	63	75	15	30	45	60	75	90	18	36	54	71	89	107	21	43	64	85	107	128
0.8	13	26	39	52	65	78	15	31	46	61	77	92	18	37	55	73	92	110	22	44	66	87	109	131
1.0	13	26	40	53	66	79	16	31	47	63	78	94	19	37	56	75	93	112	22	45	67	89	112	134
1.2	13	27	40	53	67	80	16	32	48	63	79	95	19	38	57	76	95	114	23	46	69	91	114	137
1.4	14	27	41	55	68	82	16	33	49	65	82	98	19	39	58	77	97	116	23	47	70	93	117	140
1.6	14	28	42	55	69	83	17	33	50	66	83	99	20	40	60	79	99	119	24	48	72	96	120	144
1.8	14	29	43	57	72	86	17	34	51	67	84	101	20	41	61	81	102	122	25	49	74	98	123	147
2.0	15	29	44	58	73	87	17	35	52	69	87	104	21	41	62	83	103	124	25	50	75	100	125	150
2.2	15	30	45	59	74	89	18	35	53	70	88	105	21	42	64	85	106	127	26	51	77	102	128	153
2.4	15	30	45	60	75	90	18	36	54	71	89	107	22	43	65	86	108	129	26	52	79	105	131	157
2.6	15	31	46	61	77	92	18	37	55	73	92	110	22	44	66	87	109	131	27	53	80	107	133	160
2.8	16	31	47	62	78	93	19	37	56	74	93	111	22	45	67	89	112	134	27	54	82	109	136	163
3.0	16	32	48	63	79	95	19	38	57	75	94	113	23	46	69	91	114	137	28	55	83	111	138	166

	pH 8.0						pH 8.5						pH < 9.0					
Free Cl_2	Giardia Log Removal @ 10°C						Giardia Log Removal @ 10°C						Giardia Log Removal @ 10°C					
Residual	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0
0.4	25	50	75	99	124	149	30	59	89	118	148	177	35	70	105	139	174	209
0.6	26	51	77	102	128	153	31	61	92	122	153	183	36	73	109	145	182	218
0.8	26	53	79	105	132	158	32	63	95	126	158	189	38	75	113	151	188	226
1.0	27	54	81	108	135	162	33	65	98	130	163	195	39	78	117	156	195	234
1.2	28	55	83	111	138	166	33	67	100	133	167	200	40	80	120	160	200	240
1.4	28	57	85	113	142	170	34	69	103	137	172	206	41	82	124	165	206	247
1.6	29	58	87	116	145	174	35	70	106	141	176	211	42	84	127	169	211	253
1.8	30	60	90	119	149	179	36	72	108	143	179	215	43	86	130	173	216	259
2.0	30	61	91	121	152	182	37	74	111	147	184	221	44	88	133	177	221	265
2.2	31	62	93	124	155	186	38	75	113	150	188	225	45	90	136	181	226	271
2.4	32	63	95	127	158	190	38	77	115	153	192	230	46	92	138	184	230	276
2.6	32	65	97	129	162	194	39	78	117	156	195	234	47	94	141	187	234	281
2.8	33	66	99	131	164	197	40	80	120	159	199	239	48	96	144	191	239	287
3.0	34	67	101	134	168	201	41	81	122	162	203	243	49	97	146	195	243	292

Notes:

1) Always reference the highest pH value expected for the water to be treated.

2) Always reference the lowest temperature expected for the water to be treated.

3) CT Log Removal may be better achieved by calculating based on operational variables such as through pH adjustment, lower flow rates, or chlorine residual maintenance.

4) By following points 1 and 2 your CT calculation will provide the least room for error with your disinfection application.

CT Log Removal For Giardia Lamblia At 15°C Degrees

	pH < 6.0						pH 6.5						pH 7.0						pH 7.5					
Free Cl_2	Giardia Log Removal @ 15°C						Giardia Log Removal @ 15°C						Giardia Log Removal @ 15°C						Giardia Log Removal @ 15°C					
Residual	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0
0.4	8	16	25	33	41	49	10	20	30	39	49	59	12	23	35	47	58	70	14	28	42	55	69	83
0.6	8	17	25	33	42	50	10	20	30	40	50	60	12	24	36	48	60	72	14	29	43	57	72	86
0.8	9	17	26	35	43	52	10	20	31	41	51	61	12	24	37	49	61	73	15	29	44	59	73	88
1.0	9	18	27	35	44	53	11	21	32	42	53	63	13	25	38	50	63	75	15	30	45	60	75	90
1.2	9	18	27	36	45	54	11	21	32	43	53	64	13	25	38	51	63	76	15	31	46	61	77	92
1.4	9	18	28	37	46	55	11	22	33	43	54	65	13	26	39	52	65	78	16	31	47	63	78	94
1.6	10	19	28	37	47	56	11	22	33	44	55	66	13	26	40	53	66	79	16	32	48	64	80	96
1.8	10	19	29	38	48	57	11	23	34	45	57	68	14	27	41	54	68	81	16	33	49	65	82	98
2.0	10	19	29	39	48	58	12	23	35	46	58	69	14	28	42	55	69	83	17	33	50	67	83	100
2.2	10	20	30	39	49	59	12	23	35	47	58	70	14	28	43	57	71	85	17	34	51	68	85	102
2.4	10	20	30	40	50	60	12	24	36	48	60	72	14	29	43	57	72	86	18	35	53	70	88	105
2.6	10	20	31	41	51	61	12	24	37	49	61	73	15	29	44	59	73	88	18	36	54	71	89	107
2.8	10	21	31	41	52	62	12	25	37	49	62	74	15	30	45	59	74	89	18	36	55	73	91	109
3.0	11	21	32	42	53	63	13	25	38	51	63	76	15	30	46	61	76	91	19	37	56	74	93	111

	pH 8.0						pH 8.5						pH < 9.0					
Free Cl_2	Giardia Log Removal @ 15°C						Giardia Log Removal @ 15°C						Giardia Log Removal @ 15°C					
Residual	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0
0.4	17	33	50	66	83	99	20	39	59	79	98	118	23	47	70	93	117	140
0.6	17	34	51	68	85	102	20	41	61	81	102	122	24	49	73	97	122	146
0.8	18	35	53	70	88	105	21	42	63	84	105	126	25	50	76	101	126	151
1.0	18	36	54	72	90	108	22	43	65	87	108	130	26	52	78	104	130	156
1.2	19	37	56	74	93	111	22	45	67	89	112	134	27	53	80	107	133	160
1.4	19	38	57	76	95	114	23	46	69	91	114	137	28	55	83	110	138	165
1.6	19	39	58	77	97	116	24	47	71	94	118	141	28	56	85	113	141	169
1.8	20	40	60	79	99	119	24	48	72	96	120	144	29	58	87	115	144	173
2.0	20	41	61	81	102	122	25	49	74	98	123	147	30	59	89	118	148	177
2.2	21	41	62	83	103	124	25	50	75	100	125	150	30	60	91	121	151	181
2.4	21	42	64	85	106	127	26	51	77	102	128	153	31	61	92	123	153	184
2.6	22	43	65	86	108	129	26	52	78	104	130	156	31	63	94	125	157	188
2.8	22	44	66	88	110	132	27	53	80	106	133	159	32	64	96	127	159	191
3.0	22	45	67	89	112	134	27	54	81	108	135	162	33	65	98	130	163	195

Notes:

1) Always reference the highest pH value expected for the water to be treated.

2) Always reference the lowest temperature expected for the water to be treated.

3) CT Log Removal may be better achieved by calculating based on operational variables such as through pH adjustment, lower flow rates, or chlorine residual maintenance.

4) By following points 1 and 2 your CT calculation will provide the least room for error with your disinfection application.

CT Log Removal For Giardia Lamblia At 20°C Degrees

	pH < 6.0						pH 6.5						pH 7.0						pH 7.5					
Free Cl_2	Giardia Log Removal @ 20°C						Giardia Log Removal @ 20°C						Giardia Log Removal @ 20°C						Giardia Log Removal @ 20°C					
Residual	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0
0.4	6	12	18	24	30	36	7	15	22	29	37	44	9	17	26	35	43	52	10	21	31	41	52	62
0.6	6	13	19	25	32	38	8	15	23	30	38	45	9	18	27	36	45	54	11	21	32	43	53	64
0.8	7	13	20	26	33	39	8	15	23	31	38	46	9	18	28	37	46	55	11	22	33	44	55	66
1.0	7	13	20	26	33	39	8	16	24	31	39	47	9	19	28	37	47	56	11	22	34	45	56	67
1.2	7	13	20	27	33	40	8	16	24	32	40	48	10	19	29	38	48	57	12	23	35	46	58	69
1.4	7	14	21	27	34	41	8	16	25	33	41	49	10	19	29	39	48	58	12	23	35	47	58	70
1.6	7	14	21	28	35	42	8	17	25	33	42	50	10	20	30	39	49	59	12	24	36	48	60	72
1.8	7	14	22	29	36	43	9	17	26	34	43	51	10	20	31	41	51	61	12	25	37	49	62	74
2.0	7	15	22	29	37	44	9	17	26	35	43	52	10	21	31	41	52	62	13	25	38	50	63	75
2.2	7	15	22	29	37	44	9	18	27	35	44	53	11	21	32	42	53	63	13	26	39	51	64	77
2.4	8	15	23	30	38	45	9	18	27	36	45	54	11	22	33	43	54	65	13	26	39	52	65	78
2.6	8	15	23	31	38	46	9	18	28	37	46	55	11	22	33	44	55	66	13	27	40	53	67	80
2.8	8	16	24	31	39	47	9	19	28	37	47	56	11	22	34	45	56	67	14	27	41	54	68	81
3.0	8	16	24	31	39	47	10	19	29	38	48	57	11	23	34	45	57	68	14	28	42	55	69	83

	pH 8.0						pH 8.5						pH < 9.0					
Free Cl_2	Giardia Log Removal @ 20°C						Giardia Log Removal @ 20°C						Giardia Log Removal @ 20°C					
Residual	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0
0.4	12	25	37	49	62	74	15	30	45	59	74	89	18	35	53	70	88	105
0.6	13	26	39	51	64	77	15	31	46	61	77	92	18	36	55	73	91	109
0.8	13	26	40	53	66	79	16	32	48	63	79	95	19	38	57	75	94	113
1.0	14	27	41	54	68	81	16	33	49	65	82	98	20	39	59	78	98	117
1.2	14	28	42	55	69	83	17	33	50	67	83	100	20	40	60	80	100	120
1.4	14	28	43	57	71	85	17	34	52	69	86	103	21	41	62	82	103	123
1.6	15	29	44	58	73	87	18	35	53	70	88	105	21	42	63	84	105	126
1.8	15	30	45	59	74	89	18	36	54	72	90	108	22	43	65	86	108	129
2.0	15	30	46	61	76	91	18	37	55	73	92	110	22	44	66	88	110	132
2.2	16	31	47	62	78	93	19	38	57	75	94	113	23	45	68	90	113	135
2.4	16	32	48	63	79	95	19	38	58	77	96	115	23	46	69	92	115	138
2.6	16	32	49	65	81	97	20	39	59	78	98	117	24	47	71	94	118	141
2.8	17	33	50	66	83	99	20	40	60	79	99	119	24	48	72	95	119	143
3.0	17	34	51	67	84	101	20	41	61	81	102	122	24	49	73	97	122	146

Notes:

1) Always reference the highest pH value expected for the water to be treated.

2) Always reference the lowest temperature expected for the water to be treated.

3) CT Log Removal may be better achieved by calculating based on operational variables such as through pH adjustment, lower flow rates, or chlorine residual maintenance.

4) By following points 1 and 2 your CT calculation will provide the least room for error with your disinfection application.

CT Log Removal For Giardia Lamblia At 25°C Degrees

	pH < 6.0						pH 6.5						pH 7.0						pH 7.5					
Free Cl_2	Giardia Log Removal @ 25°C						Giardia Log Removal @ 25°C						Giardia Log Removal @ 25°C						Giardia Log Removal @ 25°C					
Residual	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0
0.4	4	8	12	16	20	24	5	10	15	19	24	29	6	12	18	23	29	35	7	14	21	28	35	42
0.6	4	8	13	17	21	25	5	10	15	20	25	30	6	12	18	24	30	36	7	14	22	29	36	43
0.8	4	9	13	17	22	26	5	10	16	21	26	31	6	12	19	25	31	37	7	15	22	29	37	44
1.0	4	9	13	17	22	26	5	10	16	21	26	31	6	12	19	25	31	37	8	15	23	30	38	45
1.2	5	9	14	18	23	27	5	11	16	21	27	32	6	13	19	25	32	38	8	15	23	31	38	46
1.4	5	9	14	18	23	27	6	11	17	22	28	33	7	13	20	26	33	39	8	16	24	31	39	47
1.6	5	9	14	19	23	28	6	11	17	22	28	33	7	13	20	27	33	40	8	16	24	32	40	48
1.8	5	10	15	19	24	29	6	11	17	23	28	34	7	14	21	27	34	41	8	16	25	33	41	49
2.0	5	10	15	19	24	29	6	12	18	23	29	35	7	14	21	27	34	41	8	17	25	33	42	50
2.2	5	10	15	20	25	30	6	12	18	23	29	35	7	14	21	28	35	42	9	17	26	34	43	51
2.4	5	10	15	20	25	30	6	12	18	24	30	36	7	14	22	29	36	43	9	17	26	35	43	52
2.6	5	10	16	21	26	31	6	12	19	25	31	37	7	15	22	29	37	44	9	18	27	35	44	53
2.8	5	10	16	21	26	31	6	12	19	25	31	37	8	15	23	30	38	45	9	18	27	36	45	54
3.0	5	11	16	21	27	32	6	13	19	25	32	38	8	15	23	31	38	46	9	18	28	37	46	55

	pH 8.0						pH 8.5						pH < 9.0					
Free Cl_2	Giardia Log Removal @ 25°C						Giardia Log Removal @ 25°C						Giardia Log Removal @ 25°C					
Residual	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0
0.4	8	17	25	33	42	50	10	20	30	39	49	59	12	23	35	47	58	70
0.6	9	17	26	34	43	51	10	20	31	41	51	61	12	24	37	49	61	73
0.8	9	18	27	35	44	53	11	21	32	42	53	63	13	25	38	50	63	75
1.0	9	18	27	36	45	54	11	22	33	43	54	65	13	26	39	52	65	78
1.2	9	18	28	37	46	55	11	22	34	45	56	67	13	27	40	53	67	80
1.4	10	19	29	38	48	57	12	23	35	46	58	69	14	27	41	55	68	82
1.6	10	19	29	39	48	58	12	23	35	47	58	70	14	28	42	56	70	84
1.8	10	20	30	40	50	60	12	24	36	48	60	72	14	29	43	57	72	86
2.0	10	20	31	41	51	61	12	25	37	49	62	74	15	29	44	59	73	88
2.2	10	21	31	41	52	62	13	25	38	50	63	75	15	30	45	60	75	90
2.4	11	21	32	42	53	63	13	26	39	51	64	77	15	31	46	61	77	92
2.6	11	22	33	43	54	65	13	26	39	52	65	78	16	31	47	63	78	94
2.8	11	22	33	44	55	66	13	27	40	53	67	80	16	32	48	64	80	96
3.0	11	22	34	45	56	67	14	27	41	54	68	81	16	32	49	65	81	97

Notes:

1) Always reference the highest pH value expected for the water to be treated.

2) Always reference the lowest temperature expected for the water to be treated.

3) CT Log Removal may be better achieved by calculating based on operational variables such as through pH adjustment, lower flow rates, or chlorine residual maintenance.

4) By following points 1 and 2 your CT calculation will provide the least room for error with your disinfection application.

Date: December 2002

Original Approved by
Nova Scotia Environment and Labour