CHALLENGES & OPTIONS WHEN DESIGNING A SMALL POTABLE WATER SYSTEM

EOCP Environmental Operators Certification Program

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OBJECTIVE

This presentation focuses on options and challenges for designing a small drinking water system, specifically using surface water or *GUDI (ground water under the direct influence of Surface Water)*.

This applies to:

- Drinking Water
- Potable Water
- Domestic Water

PS: This presentation is not intended to provide or replace any legislative laws or guidelines for Drinking water treatments

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AGENDA

- Types of water sources & contaminants
- Types of water systems
- Treatment of Surface water and *GUDI (ground water under the direct influence of Surface Water)*
  - Multi barriers approach to Drinking water Safety
  - 4-3-2-1-0 approach to *drinking water treatment*
  - LT2ESWTR strategy
- Challenges and options for designing a small drinking water systems
- Conclusion

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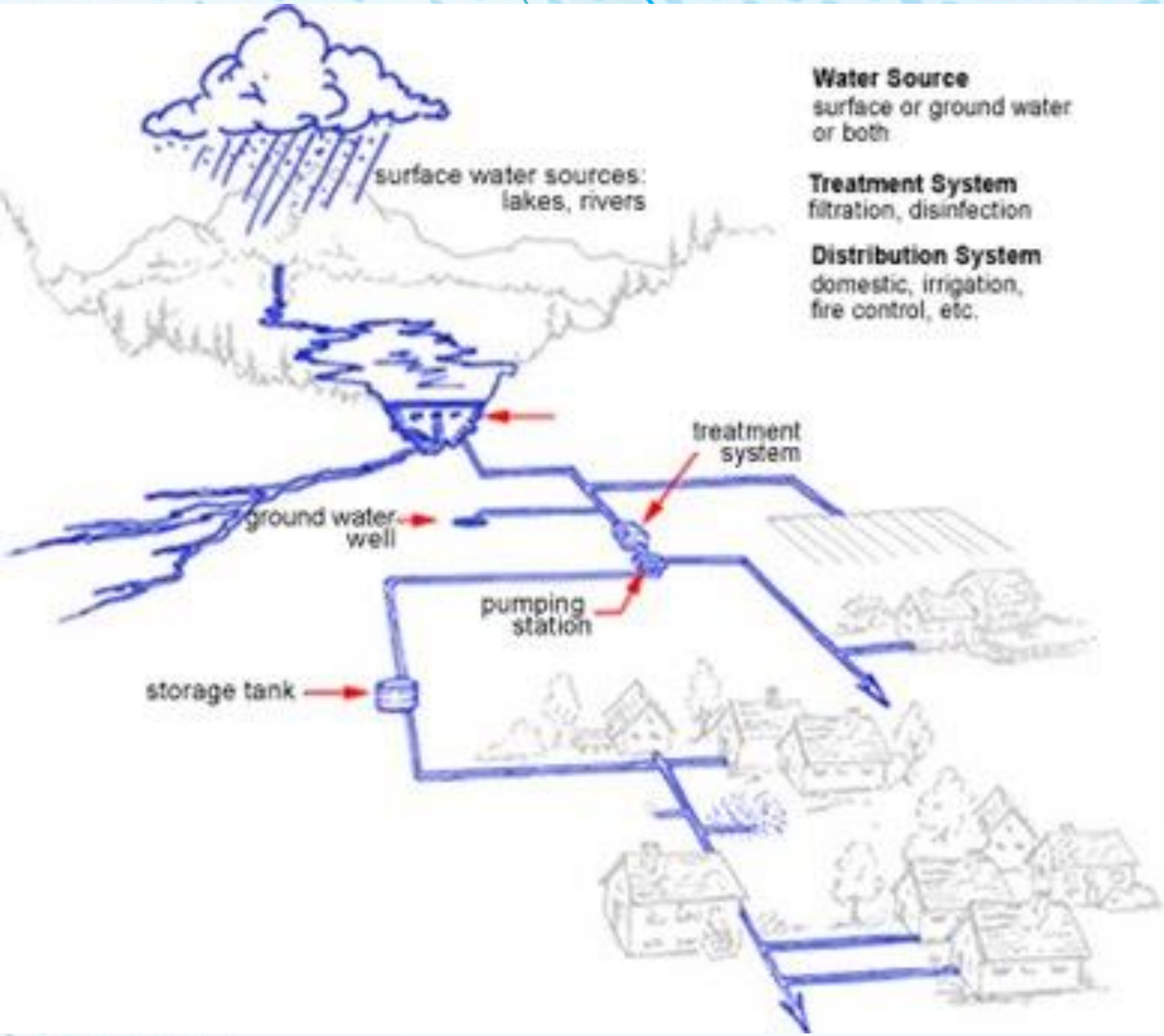
Types of Water Sources & Contaminates


Water Source
surface or ground water
or both
Treatment System
filtration, disinfection
Distribution System
domestic, irrigation,
fire control, etc.
surface water sources:
lakes, rivers
treatment
system
ground water
well
pumping
station
storage tank

The Earth’s Water

There’s a reason we call it the “Blue planet”.

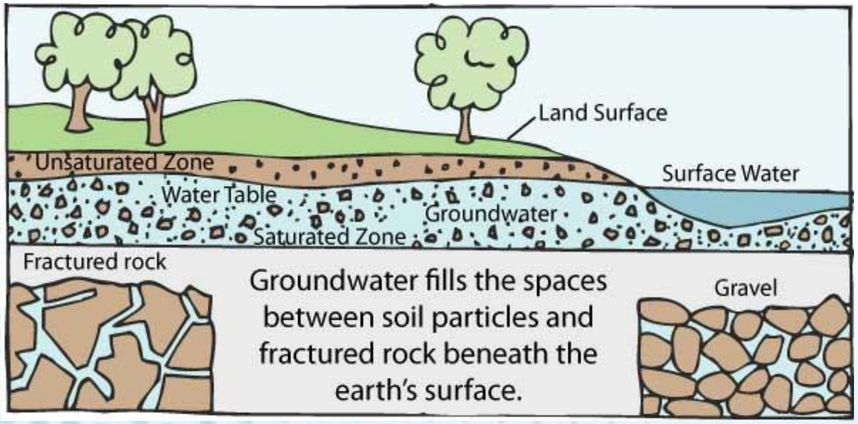
About 71% of the Earth´s surface is covered by water.

The amount of water is always the same.

Different states (liquid, solid or gas) and different conditions.

What is Groundwater?

Groundwater is the water found underground in the cracks and spaces in soil, sand and rock. It is stored in, and moves slowly through, geologic formations of soil, sand and rocks called **aquifers**.



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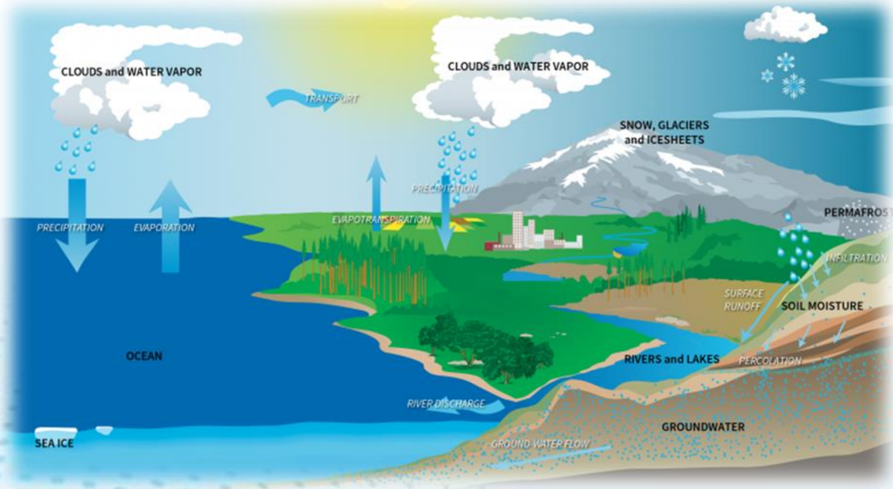
What is Surface Water?



Surface Water is water that resides in a river, lake or fresh water wetland.

Surface Water is naturally replenished by precipitation and naturally lost through discharge to the oceans, evaporation, evapotranspiration and groundwater recharge

Raw Surface Water and GUDI

- **GUDI** is an acronym for Groundwater Under the Direct Influence of surface **water**.
- It refers to situations where microbial pathogens can travel from surface **water** through an aquifer to a **water** well.

Types of Water Systems

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Types of Water Systems (Owned by Federal Government or First Nation Communities)

- **Large Systems:** Serve more than 5000 people
- **Small Systems:** Serve between 501 to 5000 people
- **Very Small Systems:** Serve between 26 to 500 people
- **Micro-Systems:** Serve up to and including 25 people

Treatment of Surface Water & GUDI

Water Treatment

Water treatment is any process that makes water more acceptable for a specific end-use.

Water treatment removes contaminants and undesirable components, or reduces their concentration so that the water becomes fit for its desired end-use.

In North America Potable water demand per person varies from 66 -100 Gallons per day

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Raw Surface Water & GUDI

Typical Water Analysis

- High Turbidity and TSS
- Moderate TDS (300-1000 ppm)
- Moderate hardness (50-100 ppm)Fe, Mn (low, <0.1 ppm)
- High organic matter level (TOC, COD)
- Moderate level of suspended solids (TSS = 5-15 ppm and < 5 ppm for GUDI)
- High bacteria and viruses level

Potential Problems

- Scaling
- Odor
- Bacteria growth, viruses

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Multi Barriers Approach to Water Safety

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Multi Barriers Approach

Five types of barriers are commonly used in the provision of drinking.

Hazard	Barrier	Typical Risk Management Approach
Pathogens Chemical contaminants Radionuclides	Source protection	Watershed protection plan Upgraded sewage treatment Choice of water source
Pathogens Disinfection by-products Chemical contaminants	Treatment	Water quality standards Chemically assisted filtration Disinfection
Infiltration Pathogen regrowth	Distribution system	Chlorine residual System pressure Capital maintenance plan
Undetected system failures	Monitoring	Automatic monitors Alarms and shut-offs Logbooks, trend analyses
Failure to act promptly on system failure Failure to communicate promptly with health authorities and the public	Response	Emergency response plans Boil water advisories (orders)

4-3-2-1-0 Approach to Treatment

4-3-2-1-0 Approach to Water Treatment (What)

- 4-log reduction in viruses
- 3-log reduction in cryptosporidium and giardia lamblia
- 2-treatment barriers minimum (example chlorine + filtration);
- ≤ 1 NTU turbidity
- 0 total coliforms & fecal coliforms (bacteria)

Log reduction relates to the percentage of microorganisms physically removed or inactivated by a given process.

- 1-log reduction = 90%
- 2-log reduction = 99%
- 3-log reduction = 99.9%
- 4-log reduction = 99.99%

4-3-2-1-0 Approach to Water Treatment (How)

4 log inactivation of viruses

- Can be achieved by using filtration and or chlorine disinfection.
- Filters must be NSF61/53 certified and should have LOG credits. There are some disposable cartridge filters on the market hat meet these criteria. Ultrafilter (UF) membranes also have LOG credits, however it’s not always practical to use UF systems for small treatment facilities due to their design and operational complexities.
- Viruses can also be easily inactivated with the use of chlorine. The common practice of maintaining 0.5 mg/L of free chlorine for 20 minutes is adequate in most cases.

3 log removal or inactivation of giardia lamblia and cryptosporidium protozoa

- This can be achieved by many of the same means used for virus reduction.
- Technologies such as barrier filters with LOG credits,
  UV and chlorination are effective for this.

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4-3-2-1-0 Approach to Water Treatment (How)

2 treatment barriers minimum (example chlorine + filtration)

- It is recognized that effective treatment for all microbial risks by a single treatment barrier is not effective.
- A minimum dual barrier of treatment is required for all surface water to reduce the risk of microbial or health threats to drinking water.

≤ 1 NTU turbidity

- In order for any type of disinfection to be effective, turbidity (a measure of clarity correlated to the amount of organics in the water) must be ≤ 1NTU (Nephelometric Turbidity Unit).
- This is often achieved through the use of filters

0 total coliforms & fecal coliforms (bacteria)

LT2ESWTR strategy

LT2ESWTR strategy

LT2ESWTR addresses the health effects associated with *Cryptosporidium* in surface water used as a drinking water supply.

Log removal credits for treatment barriers

- Log removals credits for *Giardia* and *Cryptosporidium* are adapted from the removal credits established by the U.S. EPA as part of the "Long Term 2 Enhanced Surface Water Treatment Rule" (LT2ESWTR) (U.S. EPA, 2006b) and the "Long Term 1 Enhanced Surface Water Treatment Rule" (LT1ESWTR) Disinfection Profiling and Benchmarking Guidance Manual (U.S. EPA, 2003).

- Alternatively, log removal rates can be established on the basis of *demonstrated performance or pilot studi*es. The physical log removal credits can be combined with the disinfection credits to meet overall treatment goals.

Example: 3M's BLA series, 1um membrane cartridge filters were approved for drinking water at a camp ground site in Alberta

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Cryptosporidium and Giardia removal credits for various treatment technologies meeting the turbidity values specified in the Guidelines for Canadian Drinking Water Quality -1

Treatment barrier	*Cryptosporidium* removal credit-2	*Giardia* removal credit-3
Conventional filtration	3 log	3 log
Direct filtration	2.5 log	2.5 log
Slow sand filtration	3 log	3 log
Diatomaceous earth filtration	3 log	3 log
Microfiltration and ultrafiltration	Demonstration and challenge testing-4	Demonstration and challenge testing-4
Nanofiltration and reverse osmosis	Demonstration and challenge testing-4	Demonstration and challenge testing-4

1- Health Canada 2012 b
2- Values from the LT2ESWTR (U.S. EPA, 2006a), p. 678
3-Values based on review of Schuler and Ghosh, 1990, 1991; AWWA, 1991; Nieminski and Ongerth, 1995; Patania et al., 1995; McTigue et al., 1998; Nieminski and Bellamy, 2000; U.S. EPA 2003; DeLoyde et al., 2006; Assavasilavasukul et al., 2008
4-Removal efficiency demonstrated through challenge testing and verified by direct integrity testing.

Challenges & Options when designing a small drinking water System

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Source Water Quality Data Challenges

- Availability of water quality data

- If the source water analysis is not reliable and not based on multiple samples taken before designing a small WTP, it could lead to a non-compliant design that does not meet the Guidelines for Canadian Drinking Water Quality.

Must have info to design a small DWTP using Surface water or GUDI

Parameter	Treated Water (Not to be used as guildeines)
- Source of Water	
- Turbidity	<1
- Existing treatment if any	
- TOC	<3 or <5
- DOC	<3 or <5
- Color	<3-5
- Temperature	
- Iron	<0.3 ppm
- Manganese	<0.05ppm

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Pre Treatment Selection

- Treatment for TOC and slime producing bacteria
- Prefiltration to finer filtration for turbidity reduction
- TOC must be taken into account because chlorination in the presence of high TOC would produce Trihalomethane (THM).
- Ground water and GUDI can have slime producing bacteria that present challenge for downstream equipment.
- Chemical treatment such as Hypochlorite dosing to take care of slime & for TOC reduction

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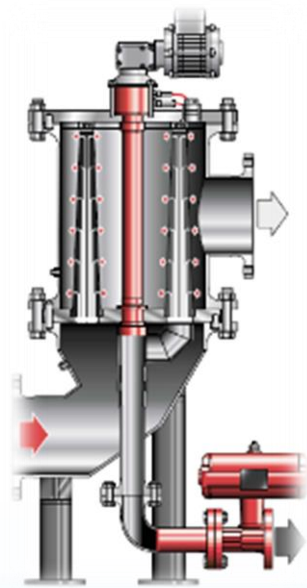
Self-Cleaning Filters for Pre-Filtration

Automatic Strainers

Eaton Back-Washable Filters - Model 2596



HYDAC Backwashable Self-Cleaning Filter

Eaton Tubular Self -Cleaning Filters

Final Barrier Filter Selection

- Filtration is the best method to ensure <1 NTU turbidity
- 1um absolute or finer filtration is advised or mandated depending on the local or provincial guidelines.
- Cartridge type filters are available with LOG credits
- Point of entry (POE) and/or point of use (POU)
- Ultrafiltration (UF) for Turbidity reduction and LOG credits for Crypto, Giardia and virus
- Barrier filters should be NSF61/53 certified. Jurisdictional certification requirements should be considered

Cartridge Filtration

Membrane Filtration

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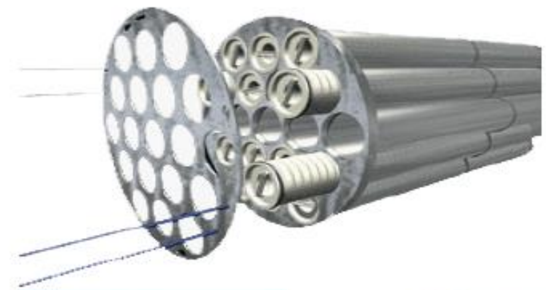
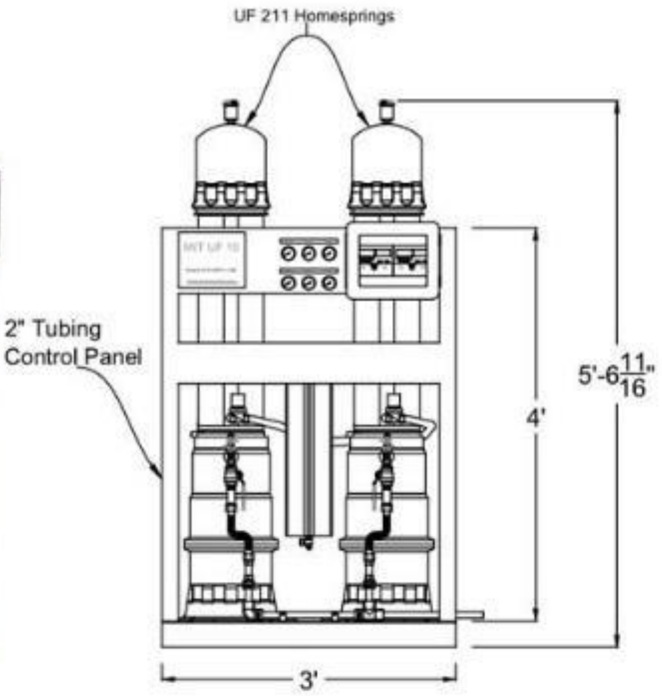
Cartridge type filters for Small DWTP

- Advantages:
  - For Future Process Flexibility: proactive installation of treatment to obtain 2.0 log removal credit for *Cryptosporidium* oocysts
- Challenges
  - Small facility footprint
  - No waste line connection
- Solution: **Cartridge Filtration**



Can treat up to 150,000 Gallons per day

Ultra Filtration for Small DWTP



5,000 to 250,000 gallons of water per day.

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Small Potable/Domestic Water Treatment Skid (Meets 4-3-2-1-0 requirements)

Hydro Project in BC

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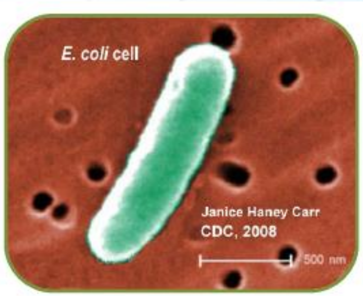
Designing the Disinfection System

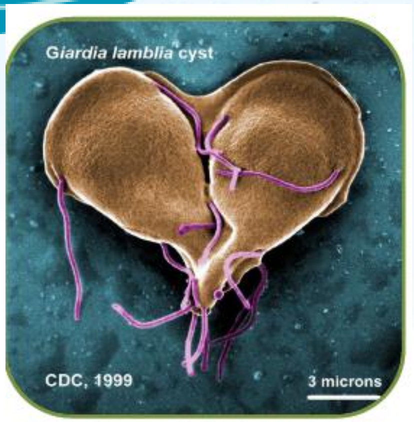
1. What method to use for disinfection
   UV vs chlorination or both

2. Issue with Disinfection by products (THM) if TOC is not taken care of at the front end

3. Calculating the Chlorine contact time (CT)

4. Issue of Chlorine escape/Maintaining the residual chlorine





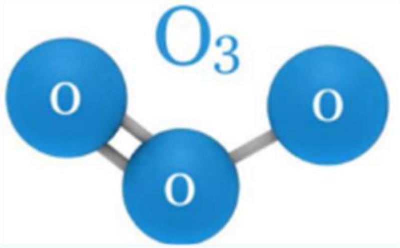


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Table 9. UV dose (mJ/cm 2) requirements for up to 4-log (99.99%) inactivation of Cryptosporidium and Giardia lamblia (oo)cysts (U.S. EPA, 2006a)

Log inactivation	UV dose (mJ/cm^2) requirements for inactivation	
	Cryptosporidium	Giardia
0.5	1.6	1.5
1	2.5	2.1
1.5	3.9	3
2	5.8	5.2
2.5	8.5	7.7
3	12	11
3.5	15	15
4	22	22

UV Dose requirement

LT2ESWTR Table IV-21. UV dose requirements for *Cryptosporidium*, *Giardia lamblia*, and virus inactivation credit

Log credit	*Cryptosporidium* UV dose (mJ/cm^2)	*Giardia lamblia* UV dose (mJ/cm^2)	Virus UV dose (mJ/cm^2)
0.5	1.6	1.5	39
1.0	2.5	2.1	58
1.5	3.9	3.0	79
2.0	5.8	5.2	100
2.5	8.5	7.7	121
3.0	12	11	143
3.5	NA	NA	163
4.0	NA	NA	186

CT Factor for Free Chlorine. CT= Residual concentration and contact time

CT Values for 3.0 log (99.9%) Inactivation of *Giardia* Cysts by Free Chlorine (Water Temperature of 15°C)

	pH						
Free Chlorine Residual (mg/L)	≤ 6.0	≤ 6.5	≤ 7.0	≤ 7.5	≤ 8.0	≤ 8.5	≤ 9.0
0.4	49	59	70	83	99	118	140
0.6	50	60	72	86	102	122	146
0.8	52	61	73	88	105	126	151
1.0	53	63	75	90	108	130	156
1.2	54	64	76	92	111	134	160
1.4	55	65	78	94	114	137	165
1.6	58	66	79	96	116	141	169
1.8	57	68	81	98	119	144	173
2.0	58	69	83	100	122	147	177
2.2	59	70	85	102	124	150	181
2.4	60	72	86	105	127	153	184
2.6	61	73	88	107	129	156	188
2.8	62	74	89	109	132	159	191
3.0	63	76	91	111	134	162	195

CT Values for Inactivation of Viruses by Free Chlorine

	Log Inactivation					
Temperature	2.0 Log		3.0 Log		4.0 Log	
°C	pH 6 - 9	pH 10	pH 6 - 9	pH 10	pH 6 - 9	pH 10
0.5	6	45	9	66	12	90
5	4	30	6	44	8	60
10	3	22	4	33	6	45
15	2	15	3	22	4	30
20	1	11	2	16	3	22
25	1	7	1	11	2	15

CT values for 99.9% (3 log) inactivation of Giardia by various disinfectants at 5°C and 20°C (pH 6-9) a,b				
Temperature (°C)	CT values			
	Free chlorine (Cl_2) -c	Chloramine (NH_2Cl)	Chlorine dioxide (ClO_2)	Ozone (O_3)
5	179	2200	26	1.9
20	67	1100	15	0.72

a: From U.S. EPA (1991).
b: Selected values adapted from Tables A.1-A.5 in Appendix A
c: pH 7.5, residual of 1 mg/L.

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Conclusion

- Before selecting a treatment methods, all available options and methods should be considered and discussed.
- It's important to educate ourselves with the latest and alternative technologies.
- Water treatment system design must not only meet the water quality guidelines set by regulators but also be user friendly and robust enough to deal with variable and sometimes unexpected operating situations.
- Companies and individuals experienced in designing and building these systems can be of great value to treatment plant stakeholders when designing, installing or modifying these systems.

THANK YOU!

Questions?

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