Drinking Water Disinfection

For Operators, Town Councils, and LSD Committees

Water Supply Sources

- Surface Water:
  - Water that runs off surfaces and collects in lakes and ponds
  - Surface water withdrawn using intake
- Groundwater:
  - Precipitation or surface water that has filtered through the soil to underlying aquifers
  - Groundwater withdrawn using well and pump

Surface Water Quality

- Affected by:
  - Rainfall intensity and duration
  - Soil composition
  - Slope of ground
  - Vegetation on the ground
  - Human activities and structures (agriculture, cities, industry, dams, deforestation and recreation.

Sources of Contamination

- At the source of supply
- At the treatment plant
- In storage systems or reservoirs
- In distribution systems:
  - Bacterial re-growth is common in dead end water mains
  - High sediment accumulation breeds bacteria – flushing is required
- Cross connections:
  - Cross connection can be deadly
  - Important to have a CCC program in place
- Infiltration:
  - Negative pressure can draw contaminants into pipe through any leaks that may be present
- Water main breaks:
  - Keep positive pressure in main before repairs
  - Ensure contaminants do not enter water main

Disinfection

- Goal of water disinfection is to kill and/or inactivate waterborne microorganisms that can cause illness or death
- Typical waterborne microorganisms of concern include
  - Bacteria
  - Viruses
  - Protozoa
- Dedicated disinfection step is required to inactivate the microorganisms

E. coli

- *E. coli* used as definite indicator of recent faecal contamination of water
- Maximum Allowable Concentration (MAC) : none detectable/100 mL sample
- *E. coli* can cause gastrointestinal issues such as vomiting, diarrhea – some can be life threatening
- Walkerton, Ont., 2000 - 2300 people fell ill, 7 died due to *E. coli* and *Campylobacter* contamination

Protozoa

- Some protozoa are pathogenic, can live in the gut of animals or humans
- Can enter drinking water through direct or indirect contamination with animal or human faeces
- *Giardia* and *Cryptosporidium* are protozoans that are most often associated with drinking water contamination and water borne illness
- The absence of *E. coli* in a sample does not necessarily mean that pathogenic protozoans are not present

Giardia and Cryptosporidium

- *Giardia*
  - *Giardia* causes the illness giardiasis; the illness is also known as beaver fever
  - Can result from contamination from beaver, muskrat or cattle faeces
  - Causes gastrointestinal symptoms such as diarrhea, vomiting, weight loss etc.
- *Cryptosporidium*
  - *Cryptosporidium* causes the illness cryptosporidiosis
  - Commonly caused by direct or indirect contamination with livestock
  - Causes gastrointestinal symptoms such as diarrhea, vomiting, weight loss etc.

Viruses

- Main form of contamination is through human faeces. Can be from sewage plant effluents, septic tank leakages, etc.
- Viruses common for water borne illness include Enterovirus, Norovirus and Rotavirus
- Symptoms from consuming contaminated water can include diarrhea, vomiting, dehydration, fever, headaches

Boil Water Advisories

- Boil Water Advisories (BWA) are put in place when there is a risk of or known contamination of the drinking water supply
- Typically are put in place when there are known issues with the disinfection system such as
  - Not enough disinfectant in the system
  - Mechanical failure
  - Changes in incoming water quality due to weather
  - Disturbance in distribution system

Boil Water Advisory Actions

- The community must be notified when a boil water advisory is initiated
- Consumers may be alerted through:
  - Local media outlets (e.g. radio, television, and newspapers)
  - Dropping-off notices in mailboxes
  - Placing warning signs on taps in public places (e.g. gas stations, restaurants, campgrounds, schools)
- For Boil Water Advisories lasting more than one month, remind residents monthly
- More information can be found here:
  - http://www.ecc.gov.nl.ca/waterres/quality/drinkingwater/pdf/bwa_instruct.pdf

Instructions to Provide to Consumers During a BWA

- Water for the following activities must be boiled:
  - Drinking
  - Preparing infant formula
  - Preparing juice and ice cubes
  - Washing fruits and vegetables
  - Cooking
  - Dental Hygiene
- Cold water taps should be used; do not consume water from hot water taps
- Hold water at a rolling boil for at least one minute
- Water can be boiled in a pot or kettle on a stove

Boil Water Advisories

- Newfoundland and Labrador have a code system for categorizing reasons for a BWA

BWA Code	Description	Number in Place[1]
A	No disinfection system	32
B1	Off because of taste & odour	6
B2	Off because of perceived health risk of chlorination	1
B3	Off because of lack of funds to operate	12
C1	Off due to maintenance or mechanical failure	36
C2	Off due to lack of chlorine or other disinfectant	1
D1	Water distribution maintenance/repair	19
D2	Cross-connection discovered	8
D3	Inadequately treated water sent to dist. System	5
E1	Not meeting CT requirement	28
E2	Cl2 not detectable in distribution system	47
E3	Insufficient residual in system with other disinfectant	0
F3	Total Coliforms in repeat sampling	9
F2E/F4/F5	E. Coli detected	2/0/1
F6	Viruses detected	0
F7	Protozoa detected	0
G	System compromised due to disaster	0
H	Waterborne disease contamination	0

[1]ENVC BWA Summary, July 14, 2016

Boil Water Advisories – SOPs

- Department of Municipal Affairs and Environment have developed Standard Operating Procedures (SOPs) that can be used to as resources for lifting BWAs
- Can be found online:

http://www.mae.gov.nl.ca/waterres/quality/drinkingwater/sopbwa.html

- Other resources available including fact sheets on disinfection

Primary vs Secondary Disinfection

- Primary disinfection is the removal, inactivation or destruction of pathogenic organisms.
- Newfoundland and Labrador requires CT = 6 mg/L for primary disinfection
- Secondary disinfection is the maintenance of a disinfectant residual within the distribution system to prevent bacterial regrowth
- Newfoundland and Labrador requires a detectable free chlorine residual throughout the distribution system
- Typically primary and secondary disinfection are performed in one step

Common Disinfectant Chemicals

- Chlorine is the most common chemical used for disinfection of drinking water
- Maintains residual in distribution system to prevent biological regrowth
- Readily available
- Relatively inexpensive
- Typically added using:
  - Sodium hypochlorite (liquid)
  - Calcium hypochlorite (powder)
  - Chlorine gas
- All chemicals used in drinking water treatment must be NSF 60 Certified

The Chemistry of Chlorination

- $Cl_2 + H_2O \longrightarrow HOCl + HCl$

  (Hypochlorous Acid) + (Hydrochloric Acid)

- Dissociation

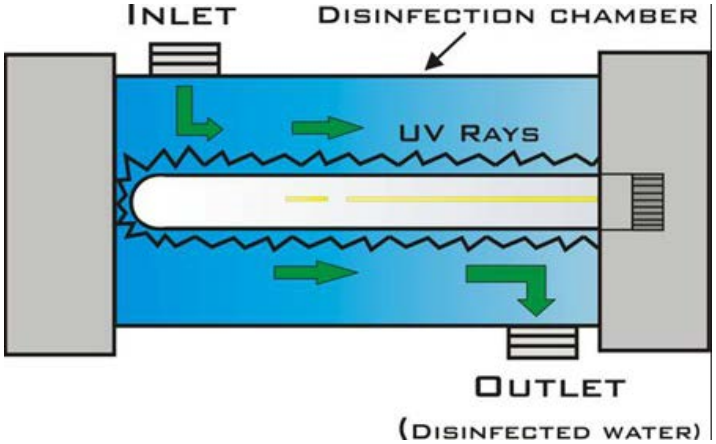
  $HOCl \longleftrightarrow H^+ + OCl^-$

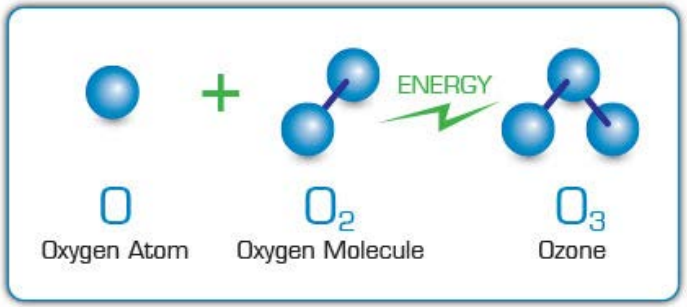
  (Hypochlorite Ion)

- Balance of HOCl to OCl^- dependant on pH

Alternative Disinfectants

- Other forms of disinfection can be used:
- Primary Disinfection:
  - Ozone
  - Ultraviolet (UV)
  - Chlorine Dioxide
- Secondary Disinfection
  - Chloramines





What is CT?

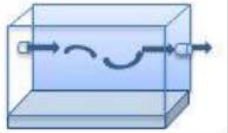
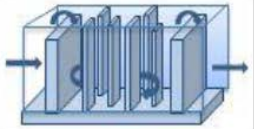
- Product of chlorine residual and time
- Concentration x time
- Pathogens are inactivated through exposure to a certain dose applied over a given amount of contact time
- Used to determine efficacy of disinfection practices
- CT required in Newfoundland: 6 mg·min/L

CT Log Inactivation Values (in mg.min/L) for *Giardia* using free chlorine at 0.5°C

Free Cl_2 Residual	pH < 6.0						pH = 6.5						pH = 7.0						pH = 7.5					
	Log Inactivation						Log Inactivation						Log Inactivation						Log Inactivation					
	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3
0.40	23	46	69	92	115	137	27	54	81	108	135	163	33	65	98	130	163	195	40	79	119	158	198	237
0.60	24	47	71	94	118	141	28	56	84	112	140	169	33	67	101	134	168	200	40	80	120	160	200	239
0.80	24	48	72	96	120	145	29	57	86	114	143	172	34	68	102	136	170	205	41	82	123	164	205	246
1.00	25	49	74	98	123	148	29	59	89	118	148	176	35	70	105	140	175	210	42	84	126	168	210	253
1.20	25	51	77	102	128	152	30	60	90	120	150	180	36	72	108	144	180	215	43	86	129	172	215	259
1.40	26	52	78	104	130	155	31	61	92	122	153	184	37	74	111	148	185	221	44	89	134	178	223	266
1.60	26	52	78	104	130	157	32	63	95	126	158	189	38	75	113	150	188	226	46	91	137	182	228	273
1.80	27	54	81	108	135	162	32	64	96	128	160	193	39	77	116	154	193	231	47	93	140	186	233	279
2.00	28	55	83	110	138	165	33	66	99	132	165	197	39	79	119	158	198	236	48	95	143	190	238	286
2.20	28	56	84	112	140	169	34	67	101	134	168	201	40	81	122	162	203	242	50	99	149	198	248	297
2.40	29	57	86	114	143	172	34	68	102	136	170	205	41	82	123	164	205	247	50	99	149	198	248	298
2.60	29	58	87	116	145	175	35	70	105	140	175	209	42	84	126	168	210	252	51	101	152	202	253	304
2.80	30	59	89	118	148	178	36	71	107	142	178	213	43	86	129	172	215	257	52	103	155	206	258	310
3.00	30	60	90	120	150	181	36	72	108	144	180	217	44	87	131	174	218	261	53	105	158	210	263	316

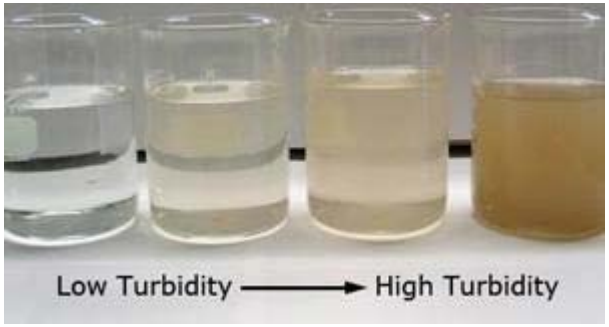
Calculating CT

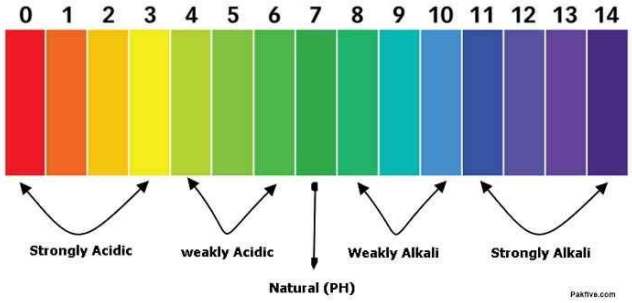
- Multiply free chlorine residual at end of contact chamber by the time that chlorine was in contact with water (by baffle factor)

Baffling Factor	Inlet/Outlet	Intra-basin Baffles	Mixing	Notes	Schematic
0.3	Single or multiple unbaffled inlets and outlets	None	Minimal	Short circuiting and stagnation are likely to occur	
0.5	Single or multiple baffled inlets and/or outlets	Some	Moderate		
0.7	Perforated inlet baffle, outlet weir, perforated launders	Serpentine, perforated	Superior		
1	n/a	n/a	Total	Plug-flow	

Factors Impacting Chlorination

- pH
  - Ideal pH for chlorination is less than 7.0
- Temperature
  - Lower temperatures slow chlorine activity
- Turbidity
  - Can hide pathogens from disinfectant contact
- Concentration
  - Higher dose increases chlorine in system
- Chlorine demand
  - Organic matter, iron, manganese etc. can consume chlorine



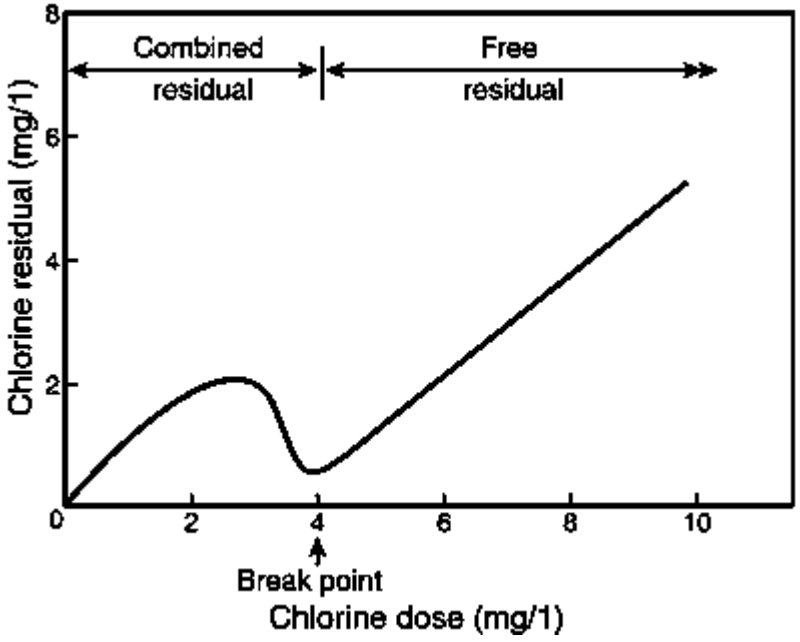


Calculating Chlorine Dose

- Need to know the flow rate and the feed rate to determine chlorine dosage
- Flow rate – typically in m^3/day or L/day
- Feed rate – typically in kg/day
- Dosage = (Feed rate x 1000)/Flow rate = mg/L
- Important to note expiry date on chemicals as the strength of chlorine can decline with age

Free vs Total Chlorine

- The amount of chlorine that is dosed at the plant is not equivalent to the amount of free chlorine residual
- Free chlorine is the chlorine that is available for disinfection in the distribution system
- Total chlorine is the sum of free chlorine and the chlorine that has already been consumed by chlorine demands



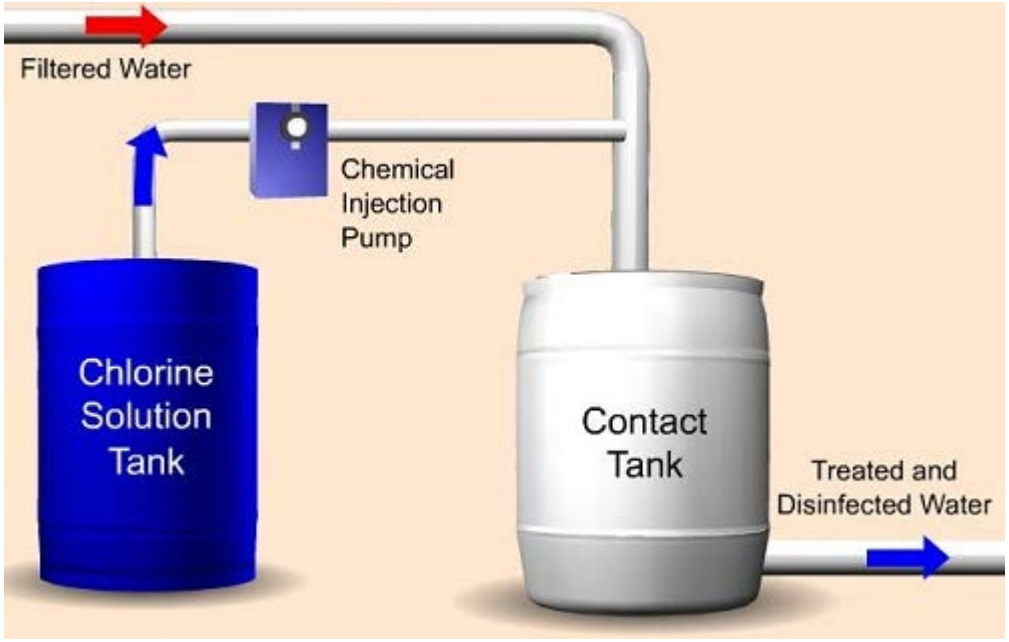
Measuring Chlorine Concentrations

- Field chlorine measurements typically measured using a handheld chlorine colorimeter
- DPD powdered reagent packet added to 10mL sample of water
- Test kits can be used for measuring both free and total chlorine
- Reagents have an expiry date, so make sure it is up to date
- Video on chlorine residual testing available at: https://www.youtube.com/user/NLWaterResources

Disinfection By-Products

- Disinfection By-Products (DBPs) are formed through reactions between a disinfectant and compounds in the water
- Two most common groups
- THMs- maximum allowable concentration (MAC) in drinking water of 0.10 mg/L
- HAAs- MAC = 0.08mg/L
- Can be controlled by reducing organic concentrations in the water before disinfection

Questions


Filtered Water
Chemical
Injection
Pump
Chlorine
Solution
Tank
Contact
Tank
Treated and
Disinfected Water