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  • Surface water withdrawn using intake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  • Groundwater withdrawn using well and pump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:
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

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

¹ENVC 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

• $\text{Cl}_2 + \text{H}_2\text{O} \rightarrow \text{HOCl} + \text{HCl}$
  
  (Hypochlorous Acid) + (Hydrochloric Acid)

• Dissociation

  $\text{HOCl} \leftrightarrow \text{H}^+ + \text{OCl}^-$
  
  (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

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<th>pH</th>
<th>Log Inactivation</th>
<th>pH</th>
<th>Log Inactivation</th>
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<td>44 87 131 174 218 261</td>
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</tbody>
</table>
Calculating CT

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

<table>
<thead>
<tr>
<th>Baffling Factor</th>
<th>Inlet/Outlet</th>
<th>Intra-basin Baffles</th>
<th>Mixing</th>
<th>Notes</th>
<th>Schematic</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3</td>
<td>Single or multiple unbaffled inlets and outlets</td>
<td>None</td>
<td>Minimal</td>
<td>Short circuiting and stagnation are likely to occur</td>
<td><img src="image" alt="Schematic" /></td>
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<tr>
<td>0.5</td>
<td>Single or multiple baffled inlets and/or outlets</td>
<td>Some</td>
<td>Moderate</td>
<td></td>
<td><img src="image" alt="Schematic" /></td>
</tr>
<tr>
<td>0.7</td>
<td>Perforated inlet baffle, outlet weir, perforated launderers</td>
<td>Serpentine, perforated</td>
<td>Superior</td>
<td></td>
<td><img src="image" alt="Schematic" /></td>
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<tr>
<td>1</td>
<td>n/a</td>
<td>n/a</td>
<td>Total</td>
<td>Plug-flow</td>
<td><img src="image" alt="Schematic" /></td>
</tr>
</tbody>
</table>
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