WATER QUALITY

Key Concepts
Cryptosporidium/Giardia
What are they?
- Small flagellated protozoan parasites → human pathogens
  - Small intestines
- Hardy cysts
  - Environmentally Stable
  - Survive up to 77 days in water

GIARDIA LAMBLIA

Dick Despommier © 1996


US CDC/Health Canada
GIARDIA LAMBLIA

- Most common intestinal protozoan in NA/worldwide
  - WHO: 200 million cases/year
  - Canada: 5-10%
    - Occurrence: 2 – 200 cysts/100 L up to 8700 cysts/100L

- Global disease
  - Developed countries
    - 2% adults
    - 6-8% children
  - Developing countries
    - 33% of people
GIARDIA LAMBLIA

- Infection rates
  - ‘ summer
  - US: 2X > June – October vs January – March

- Transmission
  - Fecal – Oral via Contaminated
    - Food
    - Water
  - Ingestion: 10 cysts

- Ingestion → Giardiasis
  - Self limiting
  - Immunocompromised


US CDC/Health Canada
GIARDIA LAMBLIA

- **Cysts**
  - Environmentally stable
  - Passed in faeces
  - Ingestion
    - Stomach acid triggers life cycle

- **Trophozoites**
  - 9-21 um long
  - 5-10 um wide
  - 2-4 um thick
  - Attaches to intestines

*Giardiasis (Giardia intestinalis)*

Contamination of water, food, or hands/fomites with infective cysts.

Trophozoites are all passed in stool but they do not survive in the environment.

Cysts

= Infective Stage

= Diagnostic Stage

US CDC/Health Canada
GIARDIA LAMBLIA

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US CDC/Health Canada
Giardiasis
(Giardia intestinales)

Contamination of water, food, or hands/objects with infective cysts.

1. Cysts
2. Infective Stage
3. Diagnostic Stage
4. Trophozoites
5. Cyst


US CDC

CY: Cysts; TR: Trophozoites; fl: Flagella

HydroQual Laboratories Ltd.
GIARDIA LAMBLIA

- Cross Canada Survey
  - 162 raw sewage samples
    - 52% contained cysts
    - 1 – 88,000 cysts/L
  - 1215 raw/treated drinking water samples
    - 10% contained cysts
    - 0.001 – 2 cysts/L

GIARDIA LAMBLIA

- Edmonton, Alberta
  - Raw water (1990 – 1996)
    - 8 – 193 cysts/100 L
  - 1997 – heavy spring run off
    - 2500 cysts/100 L of raw water
    - 24 cysts/1000 L of treated water → water advisory

- Minimum infective dose: 1- 10 cysts
  - ID\(_{50}\): 19 cysts

GIARDIA LAMBLIA

- Treatment methods
  - Chlorination
  - Filtration

- Standard treatment methods are effective during normal conditions

- May decrease during isolated events
  - Spring run off
  - Power outage

US CDC
What are they?
- Cryptosporidium → Hidden spores
- Protozoan parasites → human pathogens

Hardy Cysts
- Survive lengthy periods outside of host
- Environmentally stable
- Resistant to treatment
  - Specifically Chlorine based
  - Standard filtration → 99% removal
CRYPTOSPORIDIUM

- Global Disease
  - Developed → 1 - 4.5%
  - Developing → 3 - 20%
  - Immunocompromised
    - US → 3 - 20%
    - Africa/Haiti → 50 - 60%
- Daycares
- Swimming Pools

- Outbreaks
  - Canada - North Battleford, Saskatchewan (2001)
  - United States - Milwaukee (1993)
CRYPTOSPORIDIUM

- Transmission
  - Fecal - Oral
    - Person to person
    - Animal to person
    - Foodborne
    - Waterborne

- Ingestion → Cryptosporidiasis
  - Self limiting
  - Immunocompromised
CRYPTOSPORIDIUM

- **Cysts**
  - Environmentally Stable
  - Passed in faeces
  - Ingestion → Excystation

- **Sporozoites**
  - Attaches to the epithelial surface of the GI tract

CDC: www.marvistavet.com/html/body_cryptosporidium.html
CRYPTOSPORIDIOUM

- **Cryptosporidiosis**
  - Cysts
    - Environmentally Stable
    - Passed in faeces
    - Ingestion $\rightarrow$ Excystation

- **Sporozoites**
  - Attaches to the epithelial surface of the GI tract $\rightarrow$ illness

Image credits: CDC; jhyoung.myweb.uga.edu
Cryptosporidium

- **Prevalence**
  - Wastewater → 3.3 - 20,000/L
  - Surface waters receiving agricultural or wastewater discharges → 0.006 - 2.5/L
  - Pristine surface water → 0.02 - 0.08/L
  - Drinking water → 0.006 - 4.8/L
  - Recreational water → 0.66 - 500/L

Cryptosporidium

- Cross Canada Survey
  - 162 raw sewage samples
    - 11.1% contained oocysts
    - 1 - 120/L
  - 1215 raw/treated drinking water sample
    - 6.4% contained oocysts
    - 0.001 - 0.005 oocysts/L

- Canada
  - 1 - 100 oocysts/100 L up to 10 300 oocysts/100 L

- Infection: ID$_{50}$: 132 oocysts

Wallis et al., 1995 Risk assessment for waterborne giardiasis and cryptosporidiasis in Canada. Unpublished report to Health Canada

CDC; jhyoung.myweb.uga.edu

Health Canada
What does this mean?
- The Canadian Drinking Water Guidelines
  - Do not require analysis
- Analysis is recommended
  - Human pathogen
  - Due Diligence
  - Important to assess the source water to determine the number of organisms present
- Efficacy of treatment
- Dictate treatment level
  - Spring runoff
CRYPTOSPORIDIUM & GIARDIA

- Testing methods
  - USEPA method 1623.1
    - Filtration
    - Elution/Concentration
    - Immuno-magnetic separation (IMS)
    - Fluorescence staining
    - Enumeration

- Factors affecting recovery rates
  - Methodology
    - Previous methods → 10% recovery
    - New method → 50-60% recovery
  - Turbidity/Matrix interference
    - Addition of dispersants
Cyanobacterial Toxins - Microcystin-LR
What are they?
- Blue-green algae
- Form in shallow, warm slow moving or still water
- Cells → cyanobacterial toxins
  - Neurotoxins → anatoxins
  - Hepatotoxins → microcystins
  - Skin irritants
  - Other toxins
What are they?

- Blue-green algae

- Form in shallow, warm slow moving or still water

- Cells → cyanobacterial toxins
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  - Hepatotoxins → microcystins

- Skin irritants
- Other toxins
MICROCYSTIN

- Occurrence of Blooms
  - Hot summer Months
  - Prevalent in prairies

- Cyanobacterial bloom formation
  - physical (temperature, turbidity)
  - chemical (availability of macronutrients, e.g. phosphorous)
  - biological factors (competition for nutrients)
  - Year around
MICROCYSTIN - HEPATOTOXINS

- Common - Microcystin-LR
  - Microcystis aeruginosa and other blue-green algae.

- Highly stable toxin → chemical structure
  - Water
  - Temperature fluctuations
  - Changes in water chemistry

- Most toxic → LD$_{50}$ of 50 µg/kg bodyweight.
MICROCYSTIN - HEPATOTOXINS

- The Canadian Drinking Water Guideline
  - The maximum acceptable concentration (MAC) for the cyanobacterial toxin microcystin-LR in drinking water is 0.0015 mg/L (1.5 ug/L).

- World Health Organization
  - 1.0 ug/L
MICROCYSTIN - HEPATOTOXINS

- Occurrence - Cyanobacterial
  - Most common genera in Canada
    - Anabaena, Aphanizomenon, Microcystis, Oscillatoria and Nodularia

- Toxicity
  - Temporal
  - Spatial

- 50-75 % of bloom isolates → Toxins
- No obvious way of determining bloom toxicity

Finnish Institute of Marine Research

Estuarine, Coastal and Shelf Science, March (2006); 67(1-2): 108 - 122
MICROCYSTIN

Prevention

What to do

- Nutrient deprivation through good watershed management.
- Addition of chemicals to reduce nutrient availability (e.g. ferric sulphate to precipitate phosphorous).

What not to do

- Addition of an algicide (copper sulphate - blue stone)
MICROCYSTIN

- Prevention
- Monitoring

- Drinking water supplies suspected or known to be susceptible to blooms should be routinely monitored for presence of cyanobacteria (identification or enumeration) and their toxins.
MICROCYSTIN

- Prevention

- Treatment Technology
  - Conventional water treatment processes
    - Successful → Removing cells
    - Partially successful → Removing/destroying toxins.
  - Combination treatment → Preferred
    - Conventional treatment + oxidant + biologically activated GAC
MICROCYSTIN - TESTING

- Protein Phosphatase Inhibition (PPI)
  - Highly sensitive
  - Not Specific
  - Screening tools

- Liquid chromatography mass spectroscopy (LC-MS)
  - Sensitive
  - Specific → identification of variants
  - Screening/Confirmatory tool
  - Expensive

Massachusetts Department of Environmental Protection
MICROCYSTIN - TESTING

- ELISA based method
  - Highly sensitive
  - Not Specific
  - Rapid (3 hours)
  - Screening tool

- Positive Drinking water results
  - Confirmation with LC-MS
Legionella
LEGIONELLA

- Gram negative bacterium
  - Water sources
  - 25°C - 45°C
- Human pathogens
  - Respiratory illness --> immunocompromised
- American Legion outbreak - 1976
  - 221 Infected → 34 deaths
LEGIONELLA – Legionnaires’ Disease

- Legionnaires’ disease
  - Inhalation
    - Droplets
    - Mist
    - Steam
- Symptoms
  - Fever
  - Chills
  - Headache
  - muscle pain
  - Respiratory
  - Vomiting
  - altered mental status
- 10-15% mortality rate
LEGIONELLA - Pontiac fever

- Pontiac fever causes a flu-like illness.
- Caused by inhalation of Legionella pneumophila.
- The symptoms include fever, lack of appetite, headache, and aching muscles.
- Pontiac fever is not associated with pneumonia. In most cases no treatment is required, and you will recover within two to five days.
- 50-80% attack rate after exposure.
Where is Legionella found?

- Ubiquitous
- Ground and surface water
- Plumbing systems
- Respiratory therapy
- Whirlpool baths and hot tubs,
- Humidifiers
- Cooling towers of large air-conditioning systems → IDEAL
Legionella - Ecology

- Survival
  - tap water
  - chlorinated and untreated water
  - stagnant water areas (water heaters, tanks, reservoirs)
  - Sediment, sludge and organic materials can harbor and promote growth
<table>
<thead>
<tr>
<th>Temperature Range</th>
<th>Condition</th>
<th>Environments</th>
</tr>
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<tbody>
<tr>
<td>70-100°C</td>
<td>Killed</td>
<td>Hot water, Warm water</td>
</tr>
<tr>
<td>60-70°C</td>
<td>Killed in time</td>
<td>Warm water, Spa pool, Heated pool, Cooling tower, Cold water</td>
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<tr>
<td>20-55°C</td>
<td>Multiplication</td>
<td>Warm water, Spa pool, Heated pool, Cooling tower, Cold water</td>
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<tr>
<td>0-20°C</td>
<td>Dormant</td>
<td>Cold water, Evaporative air cooler, Spray humidifier, Cold water main, Air cooling coil condensate</td>
</tr>
</tbody>
</table>
Legionella - Ecology

- Biofilms → difficult to remove
- Biofilms form as a thin layer of slime on surfaces in contact with water
- Able to grow in iron rich, oxygen low environments
- Incorporate other bacteria and protozoa that act as a shield to protect the Legionella from biocides
How do you test for Legionella?

- Swabs
  - Sludge, sediment, scale, shower heads, etc

- Water Samples
  - 1L sample needed in sterile/DNA free bottles
What test methods does HydroQual offer?

- DNA methods
  - Polymerase chain reaction (PCR)
    - Quick turn around time

- Culture methods
  - Viable Legionella
  - Identify serotype
    - 15 serotypes-type
      - 1,3 and 6 most severe
Legionella

- Prevention
  - Source Water maintenance (e.g. Water Safety Plan)
  - System design (i.e. dead legs)
  - Maintaining disinfection levels (i.e. 0.5 mg/L throughout the system)
Legionella

- Monitoring
  - Investigation of an outbreak
  - Validation of the effectiveness of control measures
  - Verification of the effectiveness of decontamination.
  - Recommended for cooling towers, hot tubs and water distribution systems (e.g. health care facilities)
THANK YOU

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