WATERBASED PATHOGENS: THE HIDDEN THREAT IN OUR WATER SUPPLY SYSTEMS

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Emerging Pathogens in Water Workshop

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WATERBORNE PATHOGENS

- Waterborne disease transmitted through ingestion of contaminated water, frequently fecal material
- Examples: *E. coli*, *Salmonella*

Rod-shaped *Escherichia coli* bacteria 0157:H7
WATERBORNE PATHOGENS

- Source water treated to remove them
- Indicators used to demonstrate their presence e.g., fecal coliforms
- Utilities routinely monitor for waterborne pathogens using indicators
- Can normally only find way into distribution systems via intrusion events
- Normally found within distribution systems for transient periods of time
WATERBASED PATHOGENS

- Originate in water and spend all or part of their life cycle in water
- Can grow, metabolize and reproduce in water
- Examples
  - *Legionella*
  - *Pseudomonas aeruginosa*
  - *Mycobacterium*
  - *Naegleria fowleri*
  - *Aeromonas* suspected of being waterbased, but not proven to be
Mycobacterium avium
Mycobacterium avium

- A cause of respiratory infections in the immuno-compromised
- Cause of hot tub lung disease
- Most resistant bacterial vegetative form to common water disinfectants (chlorine, UV light)
- Grows in the biofilm in drinking water chlorinated distribution systems
Pseudomonas aeruginosa

- Recent research has shown a 95% reduction in hospital cases and elimination of deaths by placement of 0.22 micron filter on the taps.
- 1,200 deaths from tapwater/yr in U.S.
Legionella spp.

- Name acquired after 1976 outbreak at a convention of the American Legion
- Ideal growth range: 35-46°C
- Can survive 55°C
## Legionellosis

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Legionnaire’s Disease</th>
<th>Pontiac Fever</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incubation Period</td>
<td>2-10 days</td>
<td>5 hrs–3 days</td>
</tr>
<tr>
<td>Duration</td>
<td>Weeks</td>
<td>2-5 days</td>
</tr>
<tr>
<td>Case-Fatality rate</td>
<td>Depends on susceptibility</td>
<td>No deaths</td>
</tr>
<tr>
<td></td>
<td>Nosocomial cases 40-80%</td>
<td></td>
</tr>
<tr>
<td>Attack rate</td>
<td>0.1-5% of the general population</td>
<td>Up to 95%</td>
</tr>
<tr>
<td></td>
<td>0.4-14% in hospitals</td>
<td></td>
</tr>
<tr>
<td>Symptoms</td>
<td>Anorexia, malaise, fever, chills, lethargy, vomiting, diarrhea</td>
<td>Fever, chills, vomiting, diarrhea</td>
</tr>
</tbody>
</table>
Legionellosis

- Legionnaires disease caused by *L. pneumophila*

- *Legionellosis* is attributed to inhalation of aerosols from devices like cooling towers, hot tubs, indoor fountains, and domestic plumbing systems

- *Legionella* is thermotolerant
**Naegleria fowleri**

- Thermophilic – 25 to 30 °C optimal, but can grow at 44-45 °C
- Only pathogenic species of *Naegleria* are thermotolerant
- Cysts can tolerate 51 to 65 °C
- Cysts survive poorly at 0 °C
- Cysts and trophozites and cysts are sensitive to drying
**Life Stage Determining Factors**

Water Temperature
Type and Availability of Food
Water pH
Water Activity

**Time Line:**
Organisms can excyst and encyst within hours and can go back and forth between stages easily.
**Naegleria fowleri**

* Causes Primary amoebic meningoencephalitis (PAM)

* *N. fowleri* is found in hot springs and other warm bodies of water.

* Disease contraction via the nasal cavity.

* Young children and older individuals are most susceptible. 98% mortality.

* Over 400 cases worldwide.
**Naegleria fowleri**

- Two outbreaks documented with drinking water
  - Adelaide, Australia
  - Central Arizona

- In 2002, two children in the Phoenix Metropolitan area died from *N. fowleri* infections. No known exposure except drinking water.

- The organism was detected in the drinking water system and appeared to be the source. The drinking water system used only groundwater and was not disinfected.
Acanthamoeba

- Numerous anywhere microorganisms are found
- Feed on
  - Bacteria
  - Fungi
  - Other protozoa
  - Cyanobacteria
Acanthamoeba spp.

- At least 20 species
- Infections in humans include
  - A. astronyxis
  - A. castellanii
  - A. cubertsoni
  - A. castellanii
  - A. polyphaga
Occurrence of *Acanthamoeba* in Surface Waters

- Found in most surface waters, fresh waters also detected occasionally in marine
- Reservoir spillway in South Carolina
  - 10 to 20 amoeba/100 ml in May
  - ~200 amoeba/100 ml peaking in July
Acanthamoeba and Legionella spp.

- Complex relationship
- Replication of *Legionella* in water distribution systems requires *Acanthamoeba* (Declerck et al., 2009. Microbiol. Res. 104:593-603)
- Lives within amoebae
Within distribution systems

Amoeba → Bacteria

Endosymbiotic relationship develops

Enhanced virulence of both organisms

Enhanced resistance of bacteria to disinfectants

Cl₂
Endosymbionts of Acanthamoeba

Legionella pneumophila
Mycobacterium avium
Burkholderia picketti
Vibrio cholerae
Francisella tularensi
Chlamydia pneumoniae
Rickettsiales
Listeria monocytogenes
Aeromonas

- Best known is *Aeromonas hydrophila*
- Two problems
  - ingestion results in gastroenteritis
  - contact with open wounds causes bacterial septicemia
- Only suspected of being waterbased
STUDY BY PABLOS et al., 2009
(J. Food Microbiol. 135:158-164)

- 132 drinking water samples
- 3.8% positive for waterborne coliform indicators
- 38% positive for Aeromonas
WATER DISTRIBUTION SYSTEMS AS LIVING ECOSYSTEMS

- Cultural heterotrophnic plate counts up to 100,000 per ml
- Total counts (AODC) up to 1 million per ml
- Autotrophic populations: e.g., Denitrificans and sulfur oxidizers
- Defined groups of bacteria with multiple modes of nutrition
SCOTT & PEPPER (2010)

- Phylogenetic analysis of potable water within six distribution systems via cloning and sequencing of community DNA
  - Methylobacterium
  - Aeromonas
  - Mycobacterium
  - Pseudomonas spp.
### Candidate Contaminate List 3 (Sept. 2009)

<table>
<thead>
<tr>
<th>Bacteria/Agents</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Adenovirus</strong></td>
</tr>
<tr>
<td><strong>Contaminate</strong></td>
</tr>
<tr>
<td><strong>List 3</strong></td>
</tr>
<tr>
<td><strong>(Sept. 2009)</strong></td>
</tr>
<tr>
<td><strong>Shigella sonnei</strong></td>
</tr>
<tr>
<td>Caliciviruses</td>
</tr>
<tr>
<td><strong>Campylobacter jejuni</strong></td>
</tr>
<tr>
<td><strong>Enterovirus</strong></td>
</tr>
<tr>
<td><strong>Escherichia coli (0157)</strong></td>
</tr>
<tr>
<td><strong>Helicobacter pylori</strong></td>
</tr>
<tr>
<td>Hepatitis A virus</td>
</tr>
<tr>
<td><strong>Legionella pneumophila</strong></td>
</tr>
<tr>
<td><strong>Mycobacterium avium</strong></td>
</tr>
<tr>
<td><strong>Naegleria fowleri</strong></td>
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<tr>
<td><strong>Salmonella enterica</strong></td>
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- Can live in distribution systems following water treatment
- No water utility ever monitors for waterbased pathogens
- Could be a source of endemic disease
WATERBASED PATHOGENS

● Influence of climate change on thermotolerant organisms
  - *Naegleria*
  - *Legionella*

● Influence of human engineered systems on water-based pathogens
  - reclaimed water
  - \( \approx 40 \) million gallons per day of effluent discharged into Santa Cruz
  - no information on incidence of water-based pathogens in groundwater
SUMMARY

- Waterbased pathogen impact on public health is unknown
- Indicators for waterbased pathogens needed
- Amoebic activity may be a useful indicator
- May result in major monitoring requirements for utilities