Distribution System Water Quality and Its Relationship to Building Water Quality – Is a Chlorine Residual Enough?

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Outline of Today’s Talk

What happens to WQ from the distribution System to the tap

- Microorganisms in water
- Role of disinfectant residual in drinking water
- Water quality in buildings and how to maintain it to protect public health – *Legionella* and Legionnaires’ disease control
- Role of public water suppliers and building managers
- Q&A
Review the basics

Microbiological control – goal is to reduce **fecal pathogens** that may occur in source water to an acceptable level

- *Giardia, Cryptosporidium*, enteric viruses, *Salmonella, Shigella*, others

Starts with SW protection, then treatment, then final disinfection and out to the DS.

Chlorination of water supplies has been very effective in controlling waterborne disease from fecal pathogens.
Changing Character of US WBDOs

• Early 1900s, majority of WBDOs were due to typhoid fever
• Bacterial WBDOs were controlled with chlorination (1908)
• 2006 - typhoid cases 0.1 per 100,000 people (only 353 cases) with most in international travelers

Microorganisms

• Not possible to test for pathogens of concern so rely on surrogates
• Total coliforms and *E. coli* are used as an indicator of microbiological water quality (>100 yr)
• While TC bacteria (not EC) can regrow after treatment in DSs, but other fecal pathogens (*Crypto, Giardia, enteric viruses*) cannot
  o They require an animal host in which to reproduce
  o When removed or inactivated through the treatment process they do not regrow in water
Emerging Drinking Water Pathogens

- **Not fecal in origin**, do not correlate with occurrence of total coliforms/ *E. coli*
- Live in the environment
- Do not rely on human or animal host to reproduce
- Not monitored in source or treated water
- If monitored one expects to find them at low levels
Where Do Emerging Drinking Water Pathogens Come From?

- Mother Nature
  - Thousands of microbial species in source water
- Decrease through treatment but many species found in finished water
- Toughest species left after disinfection – includes opportunistic pathogens (e.g., legionellae and mycobacteria)
- Microbial ecosystem established in DS biofilms – especially distal ends
  - *Legionella*, nontuberculous mycobacteria (NTM), *Pseudomonas aeruginosa*, *Naegleria fowleri*
Why Should We be Concerned about Opportunistic Pathogens? Read the Headlines!

Brain-Destroying Amoeba Rattles Louisiana Parish: What You Should Know

4th Patient Dies, 15 Infected at Greenville Memorial Hospital Linked to Contaminated Tap Water

VA under scrutiny after Legionnaires' cases in Pittsburgh

Philly is Hot Spot for Disease Striking Women
“Discovered” in 1976 at PA hotel outbreak
  • On research team in 1980 at UVM developing an animal model of the pathology of LD

• Common in the environment, found in treated DW in low concentrations

• Can grow at elevated temperatures, survives and multiplies in hot water heaters (25-50°C, [77-122°F])
• Becomes established in premise plumbing biofilms and is difficult to eradicate

• Colonize pipes, tanks, faucets, showerheads, cooling towers, etc.

• Outbreaks linked to all types of water features (pools, spas, showers, hot tubs, AC, ice makers, potting soils, windshield washer)
What is Legionellosis?

• Legionellosis is a respiratory disease caused by *Legionella* bacteria
• Can cause a serious type of pneumonia (Legionnaires’ disease, LD), or
• a less serious infection called Pontiac fever (mild flu-like symptoms)
Who is at risk?

Immunocompromised  Smokers  Older adults (>50)

About a quarter of cases have no known risk factors

Babies?
Where does Legionella grow?

Can grow at elevated temperatures and survive and multiply in hot water heaters (25-50°C, [77-122°F])
Legionella Transmission

Inhalation

(“Going down the wrong pipe”)

Aspiration

“Water is safe to drink but not breathe.....”
- Jen Clancy, PhD, MS Law
Legionella is a Serious Public Health Risk

• There are 8,000-18,000 cases a year
  o Perhaps 10 X cases unrecognized

• The fatality rate of Legionnaires’ disease during an outbreak is 5-30% but can be as high as 50% in hospital settings

• $434,000,000 cost to treat in US yearly

• 217% increase over 10 years in reported cases (CDC)
Legionnaires' Disease Is On The Rise
2000–2015*

*National Notifiable Diseases Surveillance System
Why are Emerging Drinking Water Pathogens Emerging Now?

Engineered environments provide special conditions for the selection, amplification, and dissemination of opportunistic and emerging pathogens

- DW biofilms in tanks, pipes premise plumbing
- Nitrification (monochloramine used to disinfect DW to lower DBPs and provide longer residual, can set up nitrogen cycle)
- “Microbiology of the built environment”
  - Selects for these organisms to establish and proliferate
Opportunistic Premise Plumbing Pathogens (OPPPs)

• Addressing OPPPs poses a logistical challenge
  o Community water systems are designed and regulated to treat pathogens in the water treatment train and control them from leaving the facility
  o OPPPs reside and multiply in building water systems
  o BUT they get into premise plumbing from the water supply
    ▪ Escape treatment
    ▪ Enter through main breaks, cross connections, low pressure events

• Responsibility?
What do we want?

- Present
- In a form that reduces the chances of biological growth, but
- Only one component of a multifaceted control strategy

How much disinfectant is enough?
Secondary Disinfection Regulations - Nationwide

Residual must be “detectable”
Numerical limit < 0.2 mg/L
Numerical limit ≥ 0.2 mg/L

Diversity of state approaches reflects unsettled science

0.5 mg/L
## Review of State Regulations

### How states define detectable

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<tr>
<th>Detectable is</th>
<th># States</th>
<th>States and definitions</th>
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<td>Undefined</td>
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</tr>
<tr>
<td>Defined &amp; different from min</td>
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<td>DE (0.04 mg/L, Free), IA (0.1 mg/L, Free and Total)</td>
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<tr>
<td>defined as same as min required</td>
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<td>GA, IN, MN, NE, NV, NJ,</td>
</tr>
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</table>

### How states regulate DS residual

<table>
<thead>
<tr>
<th>Approach</th>
<th># States</th>
<th>States</th>
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</thead>
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<tr>
<td>Must be detectable (detectable might not be defined)</td>
<td>26</td>
<td>AK, AZ, AR, CA, CT, HI, ID, ME, MD, MA, MI, MS, NH, NM, NY, ND, OR, RI, SC, SD, UT, VA, WA, WI, WY</td>
</tr>
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<td>Numeric minimum for total chlorine, &lt; 0.2 mg/L</td>
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<td>MN, NV, NJ, PA, VT</td>
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<tr>
<td>Numeric minimum for total chlorine, ≥ 0.2 mg/L</td>
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<td>AL, CO, DE, FL, GA, IL, IN, IA, KS, KY, MO, MT, NC, NE, OH, OK, TN, TX, WV</td>
</tr>
<tr>
<td>Numeric minimum for total chlorine, ≥0.5 mg/L</td>
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<td>LA</td>
</tr>
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</table>

The majority of states do not define detectable or have numeric residual requirements.
Water quality at the point of use
The Path from Treatment to Customer

• Water quality – both chemical and microbiological – changes as water moves
  • From treatment through distribution to building water systems and
  • Through building water systems to points of use

• Major causes of degraded water quality (loss of residual, growth of organisms, formation of disinfection byproducts) in distribution systems
  • Biofilms in pipes, tanks, surfaces
  • Stagnation (particularly dead ends and storage)
  • Ingress of microbes in main breaks, cross connections and low pressure incidents

• Same issues in buildings
Water Quality Deterioration in Distribution Systems

- **Biofilm growth**
- **Stagnation**
- **Residual loss**
- **Ingress**

**Decay Rate**

**Time and Distance**

Importance of Control in Distribution and Building Water Systems

• US drinking water related illnesses and outbreak data (CDC, 2009-2010)

• Large outbreaks (many cases) related to fecal pathogens and distribution system defects

• Numerous outbreaks related to operation of building water systems
Building Water Systems

• Water supplier is no longer legally responsible for water quality in the building pipes (exception is the Lead and Copper Rule)

• Most building owners do not know
  • that water quality degrades in their plumbing,
  • that they are responsible for the WQ or
  • how to operate their system to maintain WQ
What Makes Building Plumbing Unique

• Building plumbing has all of the same WQ issues as the distribution system
  o ONLY TO A GREATER EXTENT

• Lack of professionals with the knowledge to recognize, prevent or mitigate WQ problems when they arise in building plumbing

• No U.S. DW regulations that address WQ degradation in building plumbing systems*
Issues that Make Building Plumbing Unique - and Can Lead to WQ Problems

- High SA to V ratio
- Materials
- Water age (LEED)
- Extreme temperatures
- Low to no disinfectant residual
- Bacterial regrowth
- High variable velocities
- Proximity to service lines
- Cross connections
- Aerosol exposure

Report, National Academy of Sciences, 2006
How can we prevent Legionnaires’ Disease?

We know how to control *Legionella* in building water systems

- Keep the cold water cold (below 20°C, 68°F) and the hot water hot (60°C, 140°F) – watch out for scalding
- Keep the water moving, avoid stagnation
- Maintain plumbing fixtures, clean hot water tanks
- Understand the building water system and how to manage it effectively (HACCP plans)
  - Identify hazards, monitor critical control points, verify that the metrics you’ve established to maintain good WQ are being met, and fix the system when problems arise
  - May require additional water treatment to maintain WQ
- Manage building water quality
Building Water Management Plans

HACCP
Focus for Managing Building WQ

Sediment
Temperature
Water Age
disinfectant Residual

*Keep the cold water cold and the hot water hot, keep the water moving and the system clean*
What Do We Know?

• WQ received from utility is good most of the time
• In a building it can degrade rapidly
• We know the diseases it can cause
  o Legionnaires’ disease is #1
• We can prevent this from happening by understanding and managing building WQ
Resources on Building WQ

- ASHRAE
  - ASHRAE Guideline 12-2000 - Minimizing the Risk of Legionellosis Associated with Building Water Systems
  - Revision Standard 188, Prevention of Legionellosis Associated with Building Water Systems
- CDC
Resources on Building WQ

• National Sanitation Foundation
  o NSF Standard 444 - Prevention of Injury and Disease Associated with Building Water Quality, due for ballot in 2018
  o 2-day training course on HACCP planning
    o developed and taught by Aaron Rosenblatt
  o NSF 453 Cooling Towers - Treatment, Operation and Maintenance to Prevent Legionnaires' Disease, public comment just closed
• Water Research Foundation
  o 2 workshops on research needs for building plumbing
    ▪ Pruden (2013) and LeChevallier (2015)
  o WRF 4664: “Customer Messaging on Plumbing System Issues”

• EPA grants:
  o “Impacts of Water Conservation on Water Quality in Premise Plumbing and Water Distribution Systems”
    ▪ $4 million
    ▪ 2 awards – Drexel/ESPRI and VA Tech/Michigan State
Roles and Responsibilities of Water Suppliers and Building Managers
For utilities: Distribution System Improvement Variables (AWWA Partnership for Safe Water)

- Disinfectant residual
- Cross connection control
- Customer complaints
- Disinfection byproduct control
- Energy management
- External corrosion control
- Internal corrosion control
- Flushing
- Hydrant & valve maintenance
- Main breaks

- Nitrification
- Pipe rehabilitation and replacement
- Inorganic accumulation control
- Pressure management
- Security and online monitoring
- Storage tank O&M
- Water age management
- Water loss control
- Water sampling and response
Building Water System Control

Assessment and Measurement

- Water safety planning
  - Water system configuration
  - Water system uses
  - Partnership and ownership
- Water quality surveillance
  - At the building water system point of entry
  - At key distal locations
  - How much does water quality degrade between the POE and distal location?
  - Residual concentration
  - Temperature
  - Flow

Key Control Strategies

- Keep cold water cold and hot water hot
- Flushing
  - Pipes and faucets
  - Water heater tank
  - Treatment devices
- Supplemental disinfection
  - Chlorine Chloramine
- Treatment efficacies differ widely; treatment systems must account for building water conditions (intermittent flow, range of uses, nitrification)
Water Utilities can play a Unique Role

- Water quality experts
  - Plumbing is different, issues similar
- Know their large customers
- Can provide outreach and education on WQ maintenance
- Relationship does not have to end at the meter
Distribution System Water Quality and Its Relationship to Building Water Quality – Is a Chlorine Residual Enough?
Building water quality is entering a new era.....
June 2, 2017
Memorandum

Requirement to Reduce *Legionella* Risk in Healthcare Facility Water Systems to Prevent Cases and Outbreaks of Legionnaires’ Disease (LD)
The requirement: Health care facilities must have a water management plan

Healthcare facilities are expected to comply with CMS requirements to protect the health and safety of its patients. Those facilities unable to demonstrate measures to minimize the risk of LD are at risk of citation for non-compliance with the CMS Conditions of Participation. Accrediting organizations will be surveying healthcare facilities deemed to participate in Medicare for compliance with the requirements listed in this memorandum, as well, and will cite non-compliance accordingly.
6 MI officials criminally charged in Flint water crisis

Six current and former Michigan and Flint health officials, including Director of Health & Human Services Nick Lyon, were criminally charged with involuntary manslaughter on 6/14/2017 for their roles in the city's water crisis suspected of being responsible for an outbreak of LD that led to 12 deaths.
Thank you
Questions?