Challenges in Maintaining Drinking Water Quality at Hospitals and Other Large Buildings

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Every building is a dead-end

- Variety of reactive pipe materials that interact with disinfectant and bacteria
  - PVC, PEX, Galvanized, Copper, Brass, Solder, Old Lead
  - Old plumbing versus new
- Variety of plumbing configurations, installation practices (good/bad), and maintenance (good/bad)
- Variety of water use patterns affect *Water Age*
  - Flow: Continuous Turbulent $\rightarrow$ Long Stagnation
  - Temperature, Redox Potential, pH, Disinfectant Residual: Highly Variable

Variable end water quality possible between:
- Floors
- Water Outlets
- Hot and Cold water

"Representative" sampling?
Hospitals deserve increased attention

- A recent outbreak of hospital-acquired pneumonia in Pittsburg, from waterborne *Legionella* bacteria, caused
  - Several fatalities and lawsuits
  - Congressional investigation
  - Extensive press coverage and criticism
  - Closer look at microorganisms in hospital water

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http://www.cnn.com/2012/12/13/health/legionnaires-hospital-water/
Hospitals deserve increased attention

**VA hospital knew human error caused Legionnaires' outbreak**

Internal documents obtained last January by CBS News also indicated the Pittsburgh VA was failing to properly monitor and maintain its water system’s Legionella prevention equipment, and that officials were told by a water treatment company that the hospital had legionella bacteria because "systems not being properly maintained."


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<thead>
<tr>
<th>Ice machines were source of Legionnaires', May 2, 2014</th>
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<th>Legionnaires’ Disease Outbreak Linked to Hospital’s Decorative Fountain, January 9, 2012</th>
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<td><a href="http://www.shea-online.org/View/ArticleId/124/Legionnaires-Disease-Outbreak-Linked-to-Hospital-s-Decorative-Fountain.aspx">http://www.shea-online.org/View/ArticleId/124/Legionnaires-Disease-Outbreak-Linked-to-Hospital-s-Decorative-Fountain.aspx</a></td>
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Ice machines (ingestion) • Faucets (ingestion/inhalation) • Showerheads (inhalation) • Decorative fountains (inhalation)
**Legionella is one opportunistic pathogen**

*Legionella pneumophila*

- Pontiac fever
- Pneumonia, even death to susceptible individuals with risk factors
- Primary cause of waterborne disease in the USA
- No enforceable regulations
- MCLG = 0, TT, listed on CCL3
- No consensus on endpoints for remediation

http://en.wikipedia.org/wiki/Legionella_pneumophila
Objectives

- Develop a sampling plan to monitor water quality in hospitals and potentially other large buildings
- Implement sampling plan in a hospital which was interested in participating
- Another hospital had already been sampled (different sampling plan), data were revisited
- Both hospitals chose to install in-building disinfection
- Understand implications of in-building disinfection:
  - End water quality before/after
  - Regulatory requirements after
Case Study 1: Hospital Before In-building Disinfection

• Buildings A & B - Eight floors per building
• Receives treated surface water
  (pH = 8.6, Alkalinity = 75 mg/L as CaCO₃, free chlorine = 1 mg/L)
• Sample water faucets at 10 selected nurse break rooms of A & B:
  - once every few months (on-going)
  - 250 mL of first-draw water and
    1 L of flushed water (3 min)
  - hot water and cold water
  - water chemistry
Case Study 1: Hospital Before In-building Disinfection

- Initially sampled 40 showerheads from available patient/staff bathrooms:
  - depended on accessibility during visits
  - microbiological parameters in biofilms
  - 120 showerheads to be analyzed in total before/after in-building disinfection (on-going)
Case Study 1: Sampling Plan

Variability between:
- Buildings
- Among Floors
- Within Floors

Variability between:
- Buildings
- Floors
- First Draw and Flushed Water
- Hot and Cold Water

Building A

Building B
Case Study 1: Collection of Tap Water

On-site Water Parameters:
• pH
• Temp.
• Chlorine

Laboratory: Inorganic trace elements:
• ICP-MS
• ICP-AES
Case Study 1: Collection of Showerheads

**Microbiological Parameters**
(cultural assays and molecular):

- *Legionella* bacteria in biofilms
- Other pathogens (not discussed herein)
Case Study 1: Temperature variability

- Maintaining high enough hot water temperature to inactivate/kill pathogens is a first line of defense.

- Not achieved in hot, first-draw water.

- Flushed hot water warmer than first-draw hot water.

- Tempering valves
Temperature cannot control *Legionella* and prevent scalding concurrently.

Hospital hot water in range that *Legionella* like.

Bedard et al., 2013

Edwards et al., 2010
Case Study 1: Disinfectant variability

- Water entering the hospital loses much of its chlorine disinfectant within the hospital.
- First-draw water has less disinfectant than flushed water.
- Hot water has less disinfectant than cold water.
- Are these levels sufficiently protective against pathogens?
Case Study 1: *Legionella* bacteria in showerhead biofilms

- Some showerheads with less HPC counts (results not shown) tested positive
- Others with more HPC counts tested negative

9/40 positive
*L. pneumophila* serogroup 1 [qPCR]
Many hospitals nation-wide opt to proactively control pathogens by adding “in-building” disinfection
In-building disinfection

→ Thermal disinfection
Example: ASHRAE Guideline 12-2000
  • Water always stored at > 60°C in water heater
    > 51°C in hot water lines
  • Different instructions after outbreaks or for periodic thermal disinfection

→ Chemical Disinfection
  • Chlorine
  • Chloramine
  • Chlorine dioxide
  • Copper-silver ionization
  • UV irradiation
  • Ozone

All methods have expected advantages/disadvantages
  • EPA is preparing review document
  • Water Research Foundation Report # 4379
Copper-Silver Ionization is one option

- Adds copper ions (Cu\(^{+2}\)) and silver ions (Ag\(^{+}\)) to water → biocides
- Only a fraction of copper and silver will remain in free ionic form depending on water chemistry
Case Study 2: Hospital with copper-silver ionization in hot water to control *Legionella*

- 6 faucets - biofilm swabs
- 4 faucets - first draw water and flushed water (1 min), hot only
- Microbiological parameters in swabs
- Metallic contamination and water chemistry in bulk water
- Before/after copper-silver ionization
Case Study 2: *Legionella* bacteria in faucet biofilms

Activation of Cu-Ag unit

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+ means positive *L. pneumophila* [by culture]

- Initial results optimistic
- Longer-term data are needed
Case Study 2: Copper in water

- Copper from ionization unit and from plumbing
- Copper levels variable between taps. Typically within desired ranges, but occasionally:
  - Some higher than Cu Action Limit (first-draw and flushed water)
  - Some lower than manufacturer target range in first-draw water
Case Study 2: Silver in water

Silver (mg/L)

Hot water, 12/18/2012

First Draw  Flushed (1 min)

0.00  0.05  0.10  0.15  0.20

Silver from ionization unit only
Silver levels variable between taps. Typically within desired ranges, but occasionally:
- One tap higher than Ag secondary MCL in first-draw water
- Some taps lower than Ag target range in first-draw water
Undesirable staining

- Staining observed after 2 months from Cu-Ag system activation in Case Study 1
- Ag levels in water within target range during sampling, with only one exception
Undesirable staining
Undesirable staining

- Consulting firm removed stains with aggressive cleaner (hydrofluoric acid)
Undesirable staining

• Consulting firm removed stains with aggressive cleaner (hydrofluoric acid)

• XRD Analysis at EPA to identify precipitate
Undesirable staining

XRD Pattern

Intensity (Counts)

2θ(°) Co(Kα)
Undesirable staining

- AgCl identified as cause of staining
- Calcite and Quartz also identified (as expected)
In-building water treatment may alter the incoming water quality (intended and unintended)

How should it be monitored to ensure the safety of water?
Safe Drinking Water Act (SDWA) Provisions

A public water system (PWS):
- Service connections ≥ 15, or
- Individuals served ≥ 25

A PWS is not regulated if:
- It has distribution and storage facilities, but
- Does not have any collection and treatment facilities

Hospitals that receive water from a PWS:
- Are subject to SDWA if they have their own additional treatment facilities
SDWA also applies to other large buildings

Public Water Systems

Community Water Systems
- Municipal systems
- Nursing homes
- Apartment Complexes

Transient Non-Community
- Campgrounds
- Gas stations

Non-transient Non-Community
- Hospitals
- Schools/daycares

Schools, nursing homes, apartment complexes, casinos/resorts, etc. that meet the PWS definition, if they add their own in-building water “treatment”
SDWA requirements: Case Study 1

• Hospital had pre-existing softener for hot water line (not considered “treatment” under SDWA)

• In 2014 hospital activated Copper-Silver Ionization System for hot and cold water

→ Non-Transient Non-Community (NTNC) PWS no longer exempt from SDWA requirement
### SDWA requirements: Case Study 1

**Primacy Agency**
- Determined that based on specific treatment:
  - Cu and Ag need to be monitored and reported
  - No LCR, no Legionella, no TCR, no DBP testing required

**Water Utility**
- Operator in responsible charge
- Visit hospital 3 times/week to collect water samples for Cu and Ag (hot and cold water based on vendor recommendations)
- Monthly operating reports to the State

**Hospital**
- Daily grab monitoring for Cu
- Maintenance/proper operation of unit in coordination with water utility (monthly cleaning of metallic bars, replace/maintain valves/flow meters, etc.)

**Vendor**
- Advise on and check maintenance/proper operation of unit
- Replace metallic bars in flow cells
Summary

- *Legionella* colonized hospital showerheads, disinfectant residual was not sufficient and hot water temperature was not high enough
- Variability between first-draw and flushed water, hot and cold water, different floors and different buildings
- Hospital case study will be continued for longer-term

- Hospitals choose to proactively control possible disease outbreaks by selecting from a variety of “in-building” disinfection methods
- These may alter end drinking water and potentially affect primary or secondary drinking water contaminants- Cu/Ag ionization example presented here

- “In-building” treatment triggers requirements under the SDWA
- State of Ohio recently regulated a hospital with Cu-Ag ionization
- Other States’ interpretation of SDWA may vary
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