



Andreas Wagner, CIH, ROH
Golder Associates Inc.
awagner@golder.com
+1 904-305-7830

Assessing and Mitigating *Legionella* in Building Water Systems of Assisted Living Facilities

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Agenda

- Defining the Problem
- Pathogenic Bacteria
- Risk Assessment Techniques
- Remediation and Control Measures
- Two Case Studies

ALF

“Housing facility for people with disabilities or for adults who cannot or choose not to live independently.”

Defining The Problem

- Biofilm causes up to 85% of all Healthcare Acquired Infections (HAIs)
- Slimy agglomeration of living and dead microorganisms, often adhered to mineral scale
- Highly resistant to antimicrobial treatment; need to break membranes
- Becoming more virulent



Defining The Problem

- Water conditions that tend to promote the growth of *Legionella* include:
 - Stagnation
 - Temperature: 68 – 122 °F (20 – 50 °C)
 - pH between 5.0 and 8.5
 - < 0.5 ppm residual Chlorine
 - Sediment / scale / biofilm
 - Other microorganisms such as algae, flavobacteria, and Protozoa which supply essential nutrients and can harbor the organism



Factors affecting *Legionella* colonization and proliferation

Risk Assessment Techniques

- Review of water systems
- Identifying potential risk areas or equipment
- Developing a water sampling plan
- Local State health department may want to approve the plan
- Measure temperature, pH, and residual chlorine levels
- Conduct *Legionella* sampling
- Recommend appropriate mitigation procedures

Risk Assessment Techniques

- **Environmental Sampling:**

- Focus is on water and biofilm and not air
- Personal protective equipment usually not necessary unless significant risk to airborne exposure exists (e.g., contaminated active cooling towers)
- Targeted sampling vs random sampling
- Proximal vs distal locations
- High Risk vs Low Risk locations
- Hot water (HW) vs cold water (CW) vs mixed
- First-draw (pre-flush) vs flushed (post-flush) sampling



Sterile swabs



250 mL or 1 L Sterile bottle with Sodium Thiosulfate preservative

Remediation and Control Measures

- **Thermal and Flush (Thermal Pasteurization)**
 - Min 70 °C (158 °F) for 24 hours and flush for 20-30 min
 - Remove dead-legs first to avoid re-seeding
 - Temporary measure only
 - Recolonization can occur within weeks to months after treatment
 - Healthcare concerns regarding scalding
 - Flooding concerns

Remediation and Control Measures

- **Mechanical**

- Cooling towers: drift eliminators and location
- Removal of aerators; dead legs
- Regular inspection and maintenance
- Point-of-use (POU) filters
- Water softeners
- Installing/boosting circulating pumps
- ***FLUSHING!***



Remediation and Control Measures

- **Chemical**

- No one-size-fits-all approach
- Options include Chlorine, Monochloramine, Chlorine Dioxide, Copper-Silver Ionization, UV, and Ozone
- Most disinfectants don't provide for a total kill of bacteria
- In most buildings, risk associated with premise plumbing may be addressed without additional treatment
- Remove dead-legs first to avoid re-seeding
- Permanent control measure once implemented properly
- Added concern regarding disinfection byproducts

Remediation and Control Measures

- **Water Management Plan (WMP)**
 - Analysis of all building water systems
 - Identify risk areas
 - Monitoring and sampling
 - Control limits and corrective actions
 - Flushing and disinfection programs
 - Documentation and record keeping
 - Validation



Case Studies

- Two ALFs located in Northeast Florida
- *Legionella* Risk Assessment (LRA) were triggered due to suspected legionellosis cases
- Facility owners had no experience with *Legionella* and no WMP
- Both facilities were of recent construction
- Local health department involved
- Both facilities required installation of a Chlorine Dioxide secondary disinfection system

Case Study 1

- **History:**
 - In early 2014, four cases of LD were reported by local health department, suspected to be linked to the facility
 - Limited sampling by another consultant and the health department indicated the presence of *Legionella pneumophila* serogroup 1 in potable water
 - Facility flushed its water system with 170°F water (thermal pasteurization) as an initial response
 - Previous unconfirmed single case of LD in 2012?
 - Golder retained to conduct a LRA in May 2014.

Case Study 1

- **Important Building Information:**
 - Opened in 2010; 4 floors, with an “H” configuration and three designated wings, and 185 one or two bedroom units
 - Memory care units located in one wing on two floors
 - Late 2012/early 2013 an influx of silt and debris was reported within the potable water system, thought to be associated with adjacent construction activities
 - Two onsite boilers with four 257-gallon capacity hot water heaters set at 140 °F
 - Water softener system was installed in March 2013
 - Potable water supplied by CPVC piping through multiple vertical risers
 - One main water supply line that had free chlorine levels ranging from 0.73 to 0.85 ppm.

Case Study 1

- **Initial Findings:**
 - Several dead-legs identified
 - Free chlorine concentrations in the CW and HW were below 0.5 ppm
 - Faucet aerator screens or shower head screens showed evidence of significant debris accumulation and biofilm in nearly all inspected locations
 - Flushing also revealed sediment and cloudy water in isolated locations
 - An expansion tank in the mechanical room without a purge valve
 - No flushing in vacant units and ice makers in fridges turned off

Case Study 1

- **Initial Findings continued:**
 - Temperature: CW was over 80 °F; HW never exceeded 115 °F at fixtures even after 5 min. flushing (Note: HWR levels in the Mechanical Room were at 140 °F)
 - Distal points from the Mechanical Room were more problematic, leading to suspicion of poor flow/mixing in the HWR system.
 - HWR circuits inspected showed no flow conditions (lines were at ambient T)
 - HWR system appeared to have never been balanced as circuit setters were all at ½-open position

Case Study 1

- **Initial Findings continued:**
 - Culture Analysis:
 - No positive results for incoming water and mechanical room locations (0/8)
 - 95 % positive for potable water samples (21/22), ranging from <1 CFU/mL to 2,940 CFU/ml
 - Higher *Legionella* concentrations detected in first draw sample, indicative of localized amplification which correlated with visual assessment
 - Flush sample results were also positive for *Legionella* inferring a systemic colonization, higher in the hot water system than the cold

Case Study 1

- **Recommendations:**
 - Immediate hyperchlorination of potable water system, followed by aggressive flushing
 - Removal and replacement of all sink aerators and showerheads (including flex hose)
 - Installing POU filters
 - Removal of all dead legs
 - Balancing of HWR system, including 100 circuit setters
 - Implement a routine flushing program
 - Develop and implement a site-specific WMP

Case Study 1

- **Problems ...**
 - Facility retained a local water treatment company and ordered POU filters on showers only to minimize occupant exposure while long term remediation options were developed
 - Sink aerators were replaced and a rigorous routine flushing schedule started
 - Immediate hyperchlorination of potable water system, followed by aggressive flushing was not done
 - Facility moved forward with installing a chlorine dioxide secondary water treatment system in July 2014, concurrent with plumbing system modifications – completed by September 2014
 - Water treatment company took over monitoring, including sampling program
 - Facility did not develop or implement a WMP

Case Study 1

- **More Problems ...**
 - Periodic water sampling performed by water treatment company over the next 12 months revealed a generally declining number of samples positive for *Legionella* coupled with reduced concentrations of *Legionella* in the positive samples.
 - However, in June 2015 sampling results indicated an increase of positive samples and concentrations
 - In July 2015, additional cases of residents hospitalized with pneumonia were reported and subsequent testing confirmed at least one case of LD

Case Study 1

- **Next Steps:**
 - Golder was reengaged in July 2015 to perform additional onsite assessments and sampling services
 - Initial assessment revealed systemic colonization (27% positives; 20/75) within the cold and hot water systems
 - 57% positives on pre-flush samples (13/23)
 - Hyperchlorination was performed in August 2015
 - Almost 1/3 of the circuits setters were still not functioning properly
 - Decision was made to streamline HWR system by removing the room-by-room hot water recirculation pipe work (completed January 2016)

Case Study 1

- **Final Monitoring Results:**
 - Periodic water sampling since the hyperchlorination event in August 2015, coupled with HWR system modifications, resulted in a significant decrease in the number of samples with detectable levels of *Legionella* and reduced concentrations of Legionella when detected
 - Overall < 2% (9/508) samples had detectable *Legionella* vs. 27% (20/75) pre hyperchlorination
 - Only 1 positive (1/210, < 0.5%) in the last 5 sampling rounds since completion of plumbing modifications

Case Study 1

- **WMP Control Limits:**

Processing Step	Operating Range	Critical Limit
Hot Water Storage Tanks	130 - 140°F	120 - 160°F
Distal Outlet Hot Water Temp.	110 - 120°F	105 - 125°F
Cold Water Booster Pumps	On	Off
Hot Water Recirculation Pumps	On	Off
ClO ₂ at Distal Outlets	0.3 - 0.6 mg/L	0.2 - 0.8 mg/L
Incoming Cold Water Chlorine	0.5 – 2.0 mg/L	0.2 – 4.0 mg/L

Case Study 2

- **History:**
 - In June 2017, one case of LD was reported by local health department, suspected to be linked to the facility
 - Limited sampling by another consultant retained initially by the Facility indicated the presence of *Legionella* pneumophilia in 80% of potable water samples collected (16/20) and measured chlorine levels at below 0.1 ppm
 - Facility also conducted hyperchlorination the day after the initial sampling
 - Significant debris and poor water flow in many areas was observed during the hyperchlorination event
 - Also removed most aerators from sinks and shower heads and installed POU filters in all occupied units and most of the unoccupied units
 - Golder retained to conduct a LRA in July 2017

Case Study 2

- **Important Building Information:**
 - Opened in late 2016 and was in operation less than a year
 - Two floors, with 90 units consisting of one or two bedroom units; 4 wings
 - Memory care units located in one wing on ground floor
 - Concerns regarding two oversized water softeners which reportedly “off-line” but filled with water for as long as six months prior to coming online.
 - 10 gas fired instantaneous tankless HW heaters, 7 set at 115 °F (residential) and 3 set at 140 °F (kitchen)
 - No thermostatic mixing valves at point of use fixtures, resulting in difficulties maintaining uniform HW temperatures in the HWR system
 - One main water supply line that had free chlorine levels ranging from 1.5 – 2 ppm

Case Study 2

- **Important Building Information continued:**
 - Building was not flushed prior to occupancy because there was no water meter installed?
 - Debris influx noted during Facility start-up and reportedly may have contributed to one of the hot water recirculation pumps failing
 - Redundant piping was installed in the first floor of the Facility in the Memory Care wing for future expansion purposes
 - The potable water distribution system was reportedly balanced at the time of turnover to current owner?

Case Study 2

- **Initial Findings:**
 - A total of 24 dead-legs in Memory Care units identified, almost 1,000 linear feet of dead leg piping (120 CFU/mL *Legionella*)
 - Free chlorine concentrations in the CW and HW were well below 0.5 ppm with water softeners on line
 - Some faucet aerator screens and shower head screens showed evidence of debris accumulation and biofilm
 - Two expansion tanks associated with the HW heaters did not have a purge valve
 - No flushing in vacant units

Case Study 2

- **Initial Findings continued:**
 - Temperature: CW was over 80°F; HW never exceeded 109°F at fixtures even after 3 min. flushing (Note: HW heaters were set to 115°F)
 - Four flow balancing/circuit setting devices located at distal points in the four wings within the interstitial space of the first floor ceilings
 - All three of the inspected devices were at identical settings of 6, inferring the system may not have been balanced
 - A commercial ice machine in the kitchen which had a charcoal filter installed tested positive for *Legionella* <1 CFU/ml)
 - Decorative fountain (not in use) located in courtyard of the Facility

Case Study 2

- **Initial Findings continued:**
 - Culture Analysis:
 - Only 5% (3/60) samples collected during Golder's initial LRA were positive:
 - One of the water softeners (< 1 CFU/mL)
 - One of two commercial ice machines (< 1 CFU/mL)
 - Dead leg piping in Memory Care (120 CFU/mL)
 - No positives (0/20) of post-hyperchlorination sampling

Case Study 2

- **Recommendations:**

- Increase set point temperature of residential HW heaters to 140°F
- Isolate or remove all dead leg piping sections located in the Memory Care units
- Consult with water softener manufacturer regarding chlorine reduction concern and only bring back on line after properly disinfecting/flushing
- Removal and replacement of all remaining sink aerators and showerheads (including flex hose) and Installing POU filters
- Clean and sanitize all ice makers according to the manufacturer's recommended guidelines; replace filters with non-carbon containing cartridges
- Install purge valves on the two expansion tanks
- Verify balancing of HWR system
- Develop and implement a site-specific WMP
- Implement a routine flushing program, especially for vacant units

Case Study 2

- **Follow-up Actions:**
 - Plumbing modifications were completed by September 2017
 - This included installing thermostatic mixing valves under all sinks
 - Initial hyperchlorination worked but concerns about possible rebound was raised by local health department based on Golder's initial LRA sampling results
 - A WMP was developed following the initial LRA

Case Study 2

- **Follow-up Sampling Results:**
 - Since the July 207 sampling, Golder has conducted a total of 8 additional sampling rounds, with the last one in April 2018
 - Results indicated a persistent presence of positive sample results, ranging from 2 – 50% positives per round or overall 13% positives (34/277)
 - Most positives are pre-flush samples, ranging from < 1 – 750 CFU/mL
 - Two main concerns were:
 - Water softener removing chlorine
 - Biofilm associated with flow controlling devices, including distal circuit setters, shut-off valves below each sink, and shower flow controllers

Case Study 2

- **Next Steps:**
 - Continued use of POU filters
 - In May 2018, Facility solicited competitive bids for secondary disinfection system
 - RFP did not specify Chlorine Dioxide system but all except one bid recommended it
 - Bids ranged significantly in costs from \$70,000 to > \$200,000 over 5 years; mostly lease options
 - System was installed in October 2018, with a baseline hyperchlorination completed just before turning system on
 - Water softeners were also replaced with correctly sized units

Case Study 2

- **On-going Monitoring Results:**
 - Baseline post hyperchlorination sampling conducted in November 2018 was 100% negative for treated systems (0/44)
 - One positive was the decorative fountain in the courtyard which Facility forgot try to shock (3 CFU/mL; 0.29 ppm Free Chlorine)
 - Conducted 1st round of sampling following 4 weeks of “normal operating” conditions of the Chlorine Dioxide System in January 2019 (results pending)
 - Recommended at least 2 “clean” rounds of sampling before discontinuing POU filters.

Conclusions

- ALFs pose some unique challenges, including highly susceptible population
- Recent standards and guidance documents may have put more emphasis on proactive risk management
- Information regarding and expertise in plumbing systems is key
- Incoming water with Free Chlorine of > 0.5 ppm may not be sufficient to control Legionella amplification
- Water softeners can remove significant chlorine!
- Construction activities nearby and/or improper commissioning of new facilities can pose a risk regarding sediment infiltration and bacteria amplification in water systems

Conclusions

- Challenge of budget constraints limiting proper assessments, especially related to sufficient sampling
- State health departments have inconsistent approaches and expectations regarding LRA and controls
- Clients expect immediate answers and controls
- Independent validation of any control plan should be conducted
- Periodic review and updates of WMP
- Potential health effects of disinfection byproduct beyond chlorite?
- Time from the initial reported case to “Normal Operating Conditions” can take a very long time (years!)

References

- EPA Office of Water: *Technologies for Legionella Control in Premise Plumbing Systems – Scientific Literature Review*, EPA 810-R-16-001, September 2016
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- 2015 AIHA Guideline: *Recognition, Evaluation, and Control of Legionella in Building Water Systems*
- ANSI/ASHRAE Standard: *188-2015 Legionellosis – Risk Management for Building Water Systems*
- CDC Tool Kit – *Developing a Water Management Program to Reduce Legionella Growth and Spread in Buildings – A Practical Guide to Implementing Industry Standards 13.2* (Version 1.1, June 5, 2017)

Questions?

Andreas Wagner, CIH, ROH
Principal and Practice Leader
awagner@golder.com

9428 Baymeadows Rd, Suite 400
Jacksonville, Florida 32256
+1 (904) 305-7830

