Technologies for *Legionella* Control: Scientific Literature Review

National Drinking Water Advisory Council (NDWAC)
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Overview

- EPA published the draft Legionella document on Oct. 21, 2015 and held a public meeting on Nov. 9, 2015. ([http://www2.epa.gov/dwsixyearreview/drinking-water-distribution-systems](http://www2.epa.gov/dwsixyearreview/drinking-water-distribution-systems))
- This is a technical document that States and the Veterans Health Administration (VHA) have requested to provide information on effective strategies for controlling *Legionella* in buildings
- The document will help protect public health by supporting states and building owners in making science-based risk management decisions regarding treatment and control of *Legionella*
Legionella Background

- *Legionella* bacteria are found naturally in the environment worldwide, usually in aquatic environments
- *Legionella* colonizes biofilms\(^1\) in premise plumbing
- Infection occurs primarily through inhalation or aspiration
  - Showerheads, faucets and hot tubs
  - Mist machines, decorative fountains and cooling towers
  - Respiratory therapy devices and humidifiers

\(^1\) Biofilms form when microbes stick to surfaces in aqueous environments and excrete a slimy, glue-like substance that can anchor them to all kinds of material.
Legionella: A Major Public Health Problem

- Legionellosis\(^2\) is a major health concern associated with drinking water
- CDC estimates 8,000 – 18,000 legionellosis hospitalizations occur in the U.S. annually, with up to a 30% fatality rate
- Hospitalization costs for Legionnaires’ disease are estimated at $433 million/year

\(^2\)Legionellosis is a form of atypical pneumonia caused by *Legionella* bacterial infection. The disease can occur in two forms: a pneumonia-like infection (Legionnaires’ Disease) or a flu-like illness (Pontiac fever).
Legionella: A Major Public Health Problem

• Waterborne disease outbreaks (2009-2012, reported by CDC)
  – 40 of 65 (62%) of the waterborne disease outbreaks caused by *Legionella*
  – 32 of 40 (80%) *Legionella* outbreaks caused by environmental conditions within water systems of buildings
Applicable Drinking Water Regulation

- **Surface Water Treatment Rule (SWTR) - 1989:**
  - Applies to surface water (SW) and ground water under direct influence of SW
  - MCLGs of zero for *Giardia*, viruses and *Legionella*
  - The SWTR presumes that compliance with the treatment technique (TT) requirements\(^3\) will control for *Legionella* in utilities

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\(^3\) TT requirements: Remove/inactivate *Giardia lamblia* and viruses before distribution; maintain a detectable residual disinfectant level in the distribution system.
Premise Plumbing Issues

• Premise plumbing refers to the pipes after the service connection line all the way to the tap, such as those in:
  – Hospitals, schools, businesses, and private buildings
• Premise plumbing conditions can lead to *Legionella* proliferation (e.g. water heating, long residence time, low disinfectant residual areas)
Legionella Document Overview

• EPA agreed to produce a technical document that compiles peer reviewed literature on technologies that control for *Legionella* in premise plumbing

• A multi-agency team participated in the data compilation, write up and review of the draft document
  – EPA (Regions, OGC, OPP & ORD), CDC, ASDWA, state representatives

• The document summarizes literature for each technology
  – Effectiveness against *Legionella*
  – Potential water quality issues
  – Operational requirements

• The document does not recommend any particular technology nor the addition/installation of treatment

• The document provides an overview of the regulatory context
Control Technologies

• Chlorine
  – Results of laboratory and pilot scale studies showed effectiveness but at wide range of dose and water quality conditions
  – Residual maintenance is important
  – Efficacy increases with increased temperature
  – Biofilms and inclusion of *Legionella* in amoeba shield organisms from chlorine
  – Potential water quality issues include disinfection byproducts (Trihalomethane (THM) and haloacetic acid (HAA)), taste and odors and corrosion
Control Technologies (Cont.)

• Monochloramine
  – Laboratory studies showed wide range of inactivation under varying water quality conditions
  – Efficacy increases with increased temperature
  – Several studies concluded chloramine is more effective at penetration of biofilms than chlorine
  – Potential water quality issues include disinfection byproduct formation (nitrosamines), nitrification, and corrosion
Control Technologies (Cont.)

• Chlorine Dioxide
  – Laboratory and pilot scale testing showed effectiveness at low doses (<1 mg/l)
  – Effective against Legionella shielded in amoebae and at penetrating biofilms
  – Literature reports successful applications of chlorine dioxide disinfection systems in hospitals
  – Efficacy increased with increased water temperature
  – Potential water quality issues include formation of chlorite and chlorate, taste and odors, and corrosion
Control Technologies (Cont.)

• Copper-Silver Ionization (CSI)
  – Laboratory studies indicate that copper ions (at 0.4 mg/L) and silver ions (at 0.04 mg/L) can reduce cultivability of Legionella
  – Literature reports successful applications in building water systems
  – Biofilms and inclusion of Legionella in amoeba shield the organism from CSI
  – Legionella strains appear to develop resistance to copper and silver
  – Potential water quality issues include high copper concentrations, and corrosion
Control Technologies (Cont.)

• UV Disinfection
  – Shown to be effective at decreasing and in some cases, eliminating *Legionella* from building water systems at low doses (40 mJ/cm²)
  – Only effective on water flowing through the reactor; when *Legionella* is already present in building water systems, supplemental treatment is required
  – Some UV reactors may not be tolerant of high temperatures (e.g. > 35°C/95°F) or certain chemical disinfectants
  – Iron, manganese, calcium and magnesium may affect the quartz lamp sleeves decreasing UV output
Control Technologies (Cont.)

• Ozone
  • Laboratory studies showed wide range of inactivation under varying water quality conditions
  • Decomposes quickly in water thus it is difficult to maintain a disinfectant residual
    – Particularly at higher temperatures
    – Second form of disinfection may be needed
  • Effects of biofilms and inclusion of *Legionella* in amoeba from ozone not well characterized
  • Potential water quality issues include formation of disinfection byproducts and corrosion
Other Control Technologies

• **Emergency Disinfection**
  – Superheat-and-Flush Disinfection
    • Involves raising the hot water temperature to 71-77 °C while flushing each outlet for at least 30 minutes
    • Has shown to be effective, particularly in hospital outbreak scenarios
    • Regrowth is an issue. May not provide long-term control unless combined with supplemental disinfection
  – Shock Hyperchlorination
    • Involves injecting elevated chlorine concentration (20-50 ppm) for a specific contact time
    • Success for control of Legionella has been mixed
    • Legionella can be protected within Acanthamoeba, which can survive chlorine concentrations of 50 ppm
Other Control Technologies (Cont.)

• Point-of-Use Filtration
  – Effectiveness demonstrated by several case studies
  – Dependent on pore size (≤ 0.2µm).
  – Depth filtration, including the use of silver-incorporated BAC filtration, not effective
  – Filters may clog and failure could lead to release of high levels of pathogens.
Preventative and Remediation Strategies

• Multi-barrier Approaches (e.g. Water Safety Plans, Water Management Plans, Hazard Analysis and Critical Control Points programs)
  – Approaches for protecting building water systems from hazards that may occur
  – Case studies show effectiveness for controlling growth of pathogens in building water systems
Next Steps

• Evaluate and revise the document based on public input – Nov./Dec. 2015
• Publish final document – Spring 2016