Technologies for *Legionella* Control: Scientific Literature Review

National Drinking Water Advisory Council (NDWAC) Meeting

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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)
- 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

[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^{o}C/ 95^{o}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 oC 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
- Independent external peer review – Jan. 2016
- Publish final document – Spring 2016