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Dr. Miller's Two-Step Super-Shock Disinfection Procedure for *Legionella* Removal from Building Potable Water Premise Plumbing Systems

Background/Overview

Legionella pneumophila, the causative agent of Legionnaire's disease, is a water-borne bacterium that is part of normal surface water ecosystems where it grows within free-living protozoa (typically amoebae) in water-surface biofilm slime layers. While *Legionella* are periodically released into the water as planktonic bacteria where they can be transmitted to humans when released into the air as aerosol droplets, the reservoir for growth remains securely within its protected niche inside of the protozoa and within the biofilm matrix. These Legionella-containing biofilms are frequently extended into building plumbing systems when Legionella, other bacteria, and protozoa enter the building in the incoming cold water supply. *Legionella* is a warm water-loving bacterium, so most of the Legionella are found in biofilms within the hot water loop within buildings, wherever the temperature is appropriate (i.e. not too hot but not too cold). With energy saving policies and scalding protection in buildings that limit the hot water temperatures, *Legionella* has many locations that are favorable to grow, especially in the dead-legs off of the hot water loop going to the faucets and showerheads. It has been well-documented that *Legionella* growing in amoebae in these biofilms are a challenge to control as a result of their relative resistance to the common super-heat and chemical (i.e. hyper-chlorination) control measures generally used for this purpose[1].

As a result of this resistance, simple super-heat or hyper-chlorination procedures typically produce only short-term, temporary removal of *Legionella* from these established premise plumbing biofilms in the water distribution system. With the biofilm chemical architecture still in place post-disinfection, along with some of the microbiology (including *Legionella* and amoebae) hidden deep in some biofilms, and isolated in untreated dead-legs, these biofilms are quickly re-populated, leading to a return to an infectious risk for the building occupants. Thus, the procedure described below is a two-step process, that uses a sequential super-chlorination **(step one)** to disinfect the premise plumbing biofilm, and "burn" out much of the chemical slime matrix of the biofilm architecture, which is then immediately followed by a super-heat and flush **(step two)** to complete the disinfection of the disrupted biofilm. These two steps are designed to be synergistic, so that they work together to eliminate the *Legionella*, along with some of the biological and chemical conditions that contributed to its proliferation. Special attention will be paid to the **dispersal and targeting** of both disinfection exposure steps to achieve flushing of every nook and cranny of the building, that is to say, every possible dead-leg (e.g. faucets and showerheads) within the plumbing system. **The long-term success of this two-step protocol depends on its thoroughness, and how well the details of protocol are followed to completion.**

Step One - Hyper-Chlorination Procedure

When free in the water, *Legionella* are as susceptible as other bacteria to the chlorine in the water as a primary disinfectant from the municipality. However, this residual chlorine (0.5-1.0 mg/L) has little ability to penetrate within the mass of organic slime of the biofilm, and also within the protective niche of the amoebae. Thus, the primary chlorine disinfectant in the water has limited ability to control *Legionella* proliferation in premise plumbing systems once it gets a foothold. Thus, a hyper-(super)-chlorination procedure is required for *Legionella*-biofilms. Generally, chlorine is added near the point of cold water entry into the building, trying to achieve **25-50 mg/L throughout the building (especially in the hot water loop), for a period of two hours.** Check the chlorine levels at 1 hour and adjust the chlorine addition accordingly. Since it is important to get adequate chlorine into the hot water loop, monitoring of chlorine coming out of the hot water tank will be critical. If levels are below 25 mg/L, additional chlorine needs to be added. The **final part** of the hyper-chlorination procedure is the **chlorine dispersal**, exposing all areas of the premise plumbing. This will require **turning on all of the faucets and showerheads in the entire facility** in order to expose the *Legionella* biofilm to a slow, but continuous, **flow of hyper-chlorinated water for two hours.** This should include the **cold water** and the **hot water** (in fact, especially the hot water!). Interestingly, it is this dispersal step that is often incomplete, resulting in disinfection failures and *Legionella* re-growth. At the end of the two-hour flush, the chlorine addition should be stopped and the chlorine flushed out of the system with fresh water to all of the faucets and showerheads. This hyper-chlorination procedure is tedious because of the need for continuous flushing with the chlorine, especially in buildings that are still occupied, such as hospitals where these *Legionella* biofilms are especially concerning. The faucets and showerheads also need to be well-marked with signs to avoid accidental chlorine exposure. Nevertheless, **carrying out the procedure completely is essential for success**.

Step Two - Super-Heat & Flush Procedure

The hyper-chlorination procedure is mostly successful in eliminating the *Legionella* from buildings in the short-term, but often there is a re-colonization by *Legionella*, often within a few months. Despite the aggressive nature of the hyper-chlorination, there are often dead-legs in the plumbing that don't get adequately hyper-chlorinated, or areas of extensive biofilm slime that don't experience a complete kill of *Legionella*, or *Legionella* that survive within chlorine-resistant encysted amoebae or other encysted protozoa. Any surviving *Legionella* can then re-populate the biofilm once amoebae re-colonization is established. Also, new *Legionella* and amoebae can enter the building with the incoming cold water.

Thus, there is a **2nd Step** for **Dr. Miller's Protocol,** a **Super-Heat and Flush Procedure**, which is to follow-up **immediately** (same day or the next day) after the chlorine has been flushed out of the plumbing, This is also a well-documented procedure for disinfecting building plumbing systems to remove *Legionella*.[1] The procedure is similar to hyper-chlorination, but **heat** is used as the disinfecting agent/condition. This procedure specifies that the hot water temperature be **increased to 70° C (160° F)**, and then all of the faucets and showerheads are flushed with the super-hot water for **60 min.** (Note: **Experience has shown that this exposure time of 60 min and at a temperature of 70° C (160° F) is important to get complete kill of *Legionella*, even within the disrupted biofilm architecture from the hyper-chlorination of Step One.)** As with the chlorine disinfection (Step One), the water flow through each faucet does not need to be

fast, but hot water needs to be **continually moving** through the faucets and showerheads, in order for sufficient heat to penetrate to the base of the biofilm during the 60 minute exposure..

The rationale for this 2nd step is that the hyper-chlorine first step, as an oxidizing agent, will "burn out" much of the slime biofilm matrix, and remove or disrupt some of this blanket of thermal insulation, as well as, removing the structural architecture that would serve as foundation for new biofilm formation. This hyper-chlorination makes the remaining *Legionella* and amoebae more exposed to the super-hot temperatures and makes them an easier target for killing. And switching to heat in the 2nd Step is also less damaging to the plumbing than would be a repeat hyper-chlorination.

Doing the 2nd step heat-flush immediately after the chlorine flush can also be a good use of staff, since the people in place to carry out the chlorine flush will be there to carry out the 2nd step heat flush. Additionally, after the chlorination step, the chlorine needs to be flushed out of the pipes. This cold water flushing can be done while waiting for the water temperature of the hot water to increase to the required 160° F.

After completion of the required 30-60 minutes of heat flush, the temperature of the hot water is returned to normal (although there should be a discussion among the members of the building's *Legionella* Water Management Team concerning what "normal hot water temperature" should be:

For optimal control of *Legionella* growth, hot water temperature in the hot water tank should be maintained at 140° F (60° C), while the **temperatures at the faucet should be as close to 125° F (52° C) as possible.**

Validation of the Effectiveness of the Two-Step Procedure - Immediate and Future

A complete building-wide ***Legionella* testing** should be done within a day or two after completion of the **Two-Step Procedure,** in order to validate the immediate effectiveness of the disinfection in the removal of the *Legionella*. Future testing should then be done quarterly for a year in order to document the **lack** of *Legionella* re-colonization (i.e. re-growth). In the absence of any new *Legionella* colonization, annual testing in the future is then adequate, or whatever frequency is recommended by the *Legionella* Water Management Team.

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[1]Lin, Y.E, J.E. Stout, V.L. Yu, and R.D. Vidic. Disinfection of water distribution systems for *Legionella*. Sem. Resp. Infect. *13*: 147-159 (1998).