Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/watres

Temperature diagnostic to identify high risk areas and optimize *Legionella pneumophila* surveillance in hot water distribution systems

Emilie Bédard [a,b,*], *Stéphanie Fey* [a], *Dominique Charron* [a], *Cindy Lalancette* [b], *Philippe Cantin* [c], *Patrick Dolcé* [d], *Céline Laferrière* [e], *Eric Déziel* [b], *Michèle Prévost* [a]

[a] *Department of Civil Engineering, Polytechnique Montréal, Montréal, QC, Canada*
[b] *INRS-Institut Armand-Frappier, Laval, QC, Canada*
[c] *Centre d'expertise en analyse environnementale du Québec, Québec, QC, Canada*
[d] *Department of Medical Microbiology and Infectious Diseases, Centre Hospitalier Régional de Rimouski, Rimouski, QC, Canada*
[e] *Department of Microbiology and Immunology (Infection Control), CHU Ste-Justine, Université de Montréal, Montréal, QC, Canada*

ARTICLE INFO

Article history:
Received 21 September 2014
Received in revised form
22 December 2014
Accepted 5 January 2015
Available online 13 January 2015

Keywords:
Legionella pneumophila
Premise plumbing
Viable but not culturable (VBNC)
Thermal control
Temperature profile
Culturability

ABSTRACT

Legionella pneumophila is frequently detected in hot water distribution systems and thermal control is a common measure implemented by health care facilities. A risk assessment based on water temperature profiling and temperature distribution within the network is proposed, to guide effective monitoring strategies and allow the identification of high risk areas. Temperature and heat loss at control points (water heater, recirculation, representative points-of-use) were monitored in various sections of five health care facilities hot water distribution systems and results used to develop a temperature-based risk assessment tool. Detailed investigations show that defective return valves in faucets can cause widespread temperature losses because of hot and cold water mixing. Systems in which water temperature coming out of the water heaters was kept consistently above 60 °C and maintained above 55 °C across the network were negative for *Legionella* by culture or qPCR. For systems not meeting these temperature criteria, risk areas for *L. pneumophila* were identified using temperature profiling and system's characterization; higher risk was confirmed by more frequent microbiological detection by culture and qPCR. Results confirmed that maintaining sufficiently high temperatures within hot water distribution systems suppressed *L. pneumophila* culturability. However, the risk remains as shown by the persistence of *L. pneumophila* by qPCR.

* *Corresponding author*. NSERC Industrial Chair in Drinking Water, Polytechnique Montréal, P.O. Box 6079 Station Centre-ville, Montréal, QC, Canada H3C 3A7. Tel.: +1 514 340 4711x3711.
E-mail address: emilie.bedard@polymtl.ca (E. Bédard).
http://dx.doi.org/10.1016/j.watres.2015.01.006
0043-1354/

1. Introduction

Legionella pneumophila (*Lp*) is an opportunistic pathogen that can proliferate in hot water distribution systems (HWDS) of large buildings, such as health care facilities (HCFs), where it can cause waterborne nosocomial pneumonias. Although its optimal growth temperature lies between 25 and 42 °C (Yee and Wadowsky, 1982), *Lp* has been isolated from water systems at temperatures up to 60 °C (Martinelli et al., 2000), and in cold water systems with temperatures below 20 °C (Arvand et al., 2011). The presence of *Lp* in HCFs water systems is well demonstrated, with reports of 10–50% positive hot water samples taken from taps and showers in Europe and the United States (Arvand et al., 2011; Bargellini et al., 2011; Martinelli et al., 2000; Serrano-Suarez et al., 2013; Stout et al., 2007). Risk characterization of water sources remains uncertain because of the lack of reliable dose–response models (Buse et al., 2012) and therefore the difficulty to define an acceptable level of *Lp* contamination that would minimize risk. While the level of positivity for *Legionella* in health care facilities (HCF) HWDS has been proposed as a reliable predictive risk factor (Best et al., 1983; Lin et al., 2011), the specificity and sensitivity of the 30% positivity cut-off point has been recently questioned (Allen et al., 2012, 2014; Pierre et al., 2014).

Control of *Legionella* risks in health care facilities (HCFs) is addressed and regulated through guidance documents (Bartram et al., 2007; BSR/ASHRAE, 2013; CDC, 2003; HSE, 2013; République Française, 2010a). System characterization and environmental monitoring are among the first steps to establish a water safety plan or to evaluate the operational risk in hot water distribution systems (HWDSs), especially in HCFs (BSR/ASHRAE, 2013; Department of Health (DH) and Estates and Facilities Division, 2006; République Française, 2010b; WHO, 2011). Recent guidelines stress the need to properly manage hydraulics to ensure homogenous temperature and biocidal control in all areas of the HWDS (CSTB, 2012), and system balancing under varying demand should be verified.

Although a multitude of possible system architectures are encountered, a simplified schematic of a hot water distribution system (HWDS) can be established (Fig. 1) and should include: the number and characteristics of key systems components such as the calorifiers, reheating units and reservoirs, the distribution systems including principal, subordinate and tertiary flow and return loops and point-of-use devices (tertiary terminal end). A schematic and characterization of each HWDS within a premise must be established independently (BSR/ASHRAE, 2013; HSE, 2013; République Française, 2010a). This data is the foundation for interpreting monitoring results and identifying high risk areas.

A summary of the key elements from selected regulations and guidelines to implement temperatures control of *Lp* in large buildings, and when available, in HCFs is provided as supplementary material (Table S1). Approaches to control *Lp* in hot water distribution systems (HWDSs) vary considerably, but all guides include objectives or obligations for optimal operating temperatures at critical points in the distribution systems. Also commonly specified are construction and operational standards, such as minimizing stagnation (recirculation loops, elimination of hydraulic and physical dead ends, etc.), recommendations on the use of devices and materials not promoting bacterial proliferation (construction material, flow, temperature, etc.) and requirements for microbiological monitoring in relation to pre-established criteria that define corrective actions.

In France, recently strengthened regulations determine mandatory minimum temperature and *Legionella* monitoring at defined critical control points: 1) hot water outlet and reservoir when present; 2) return loop; and 3) representative points-of-use considered at risk (farthest from the water heater or serving vulnerable patients) but the number of sampling points to be monitored is not specified (République Française, 2005,

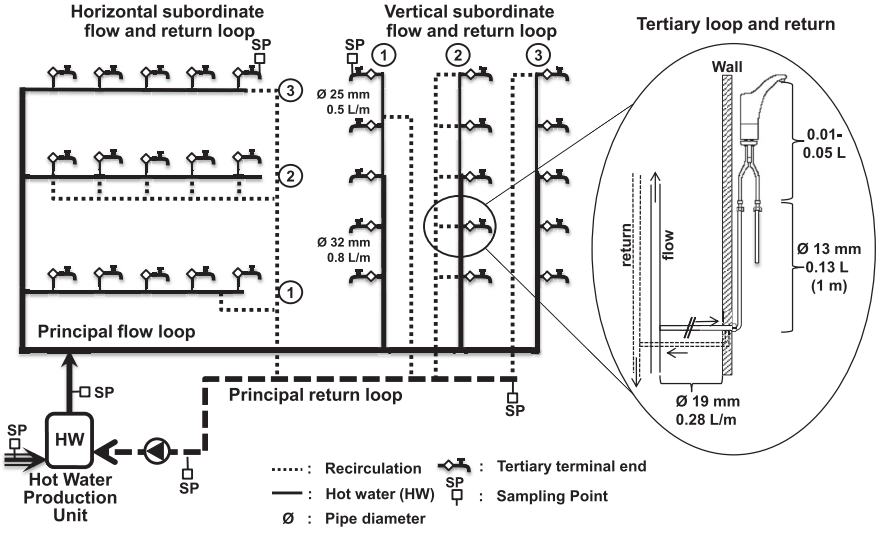

Fig. 1 – Hot water distribution system general schematic including temperature control points. Three different types of vertical and horizontal distribution systems are represented: ① recirculation before the last tap; ② recirculation connected after each device; ③ recirculation connected after the last device.