SPECIAL REPORT

Legionnaires' Disease at a Hotel in Missouri, 2015: The Importance of Environmental Health Expertise in Understanding Water Systems

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Abstract **During a Legionnaires' disease outbreak at a Missouri hotel in 2015, the Centers for Disease Control and Prevention assisted state and local health departments to identify possible sources and transmission factors and to recommend improvements to water management. We performed an environmental assessment to understand the hotel's water systems and identify areas of risk for *Legionella* amplification and transmission. We obtained samples from the pool, spa, and potable water systems for *Legionella* culture. In the potable water system, we noted temperatures ideal for *Legionella* amplification and areas of water stagnation. Additionally, we found inadequate documentation of pool and spa disinfection and maintenance. Of 40 water samples, *Legionella pneumophila* serogroup 1 that matched the sequence type of one available clinical isolate was recovered from five sink and shower fixtures. A comprehensive environmental assessment proved crucial to identifying maintenance issues in the hotel's water systems and underscored the need for a water management program to reduce Legionnaires' disease risk.**

Introduction

Legionnaires' disease (LD) is a severe pneumonia caused by the bacterium *Legionella*. Approximately 9% of cases are fatal (Dooling et al., 2015). The rate of reported LD cases in the U.S. rose nearly 300% from 2000–2014, likely due to a number of factors (e.g., an increase in susceptible populations, aging infrastructure leading to increased opportunities for *Legionella* growth, increased awareness with improved testing and reporting) (Garrison et al., 2016). *Legionella* is found in freshwater sources. It amplifies in manmade water systems (e.g., spas, potable water systems, cooling towers) and disseminates via aerosolized droplets (Fields, 1996).

In a review of LD outbreaks reported to the Centers for Disease Control and Prevention (CDC) during 2000–2014, 85% of outbreaks were caused by problems that effective water management could have prevented. Hotels and resorts accounted for 44% of outbreaks in this analysis (Garrison et al., 2016). Inadequate water system maintenance creates conditions favorable for *Legionella* amplification, including tepid water temperatures (77–108 °F), low residual disinfectant levels, water stagnation, and the presence of free-living protozoa, biofilm, scale, and sediment (Centers for Disease Control and Prevention [CDC], 2017). Changes in water pressure and water quality due to external factors, such as construction or water main breaks, have also been associated with amplification of *Legionella* in building water systems (Mermel, Josephson, Giorgio, Dempsey, & Parenteau, 1995). An industry standard published in 2015 described measures to reduce the risk of *Legionella* amplification and transmission in building water systems through use of water management programs (ASHRAE, 2015).

In-depth knowledge of facility water systems is critical for LD prevention and outbreak response. Key components of facility water systems include source water (i.e., from a municipal water treatment plant, private well, or other source), cold water distribution, heating, hot water distribution, wastewater elimination, and disinfectant treatment (CDC, 2017). An environmental assessment,

which includes measurement of water quality parameters (i.e., disinfectant levels, pH, temperature) and water sampling for *Legionella*, can help identify factors that can lead to *Legionella* amplification and transmission.

Trained environmental health specialists with knowledge of industry standards are needed to evaluate facility water system maintenance procedures, develop and implement *Legionella* environmental sampling plans, measure water quality parameters, advise on *Legionella* remediation options (i.e., hyperchlorination or superheating and flushing), and provide technical direction for the development of a water management program. Environmental health specialists can also use fundamental industrial hygiene principles such as engineering controls, work practice modifications, and administrative operations to understand and guide water management interventions.

We describe an LD outbreak associated with a Missouri hotel, the initial public health investigation, and the subsequent comprehensive environmental assessment, underscoring the need for environmental health specialists trained in current industry standards to recommend control efforts and support development of a water management program to reduce the risk of future LD cases.

Methods

Initial Outbreak Investigation

In April and June 2015, two LD cases confirmed by *Legionella* urinary antigen testing were reported among persons who had stayed in the same Missouri hotel. Local public health officials conducted an environmental assessment of all water systems; however, because spas are a common source of hotel-related outbreaks (Dooling et al., 2015), control efforts initially were focused solely on disinfection of the pool and spa. At the time, water samples were not collected from other building water systems for *Legionella* testing.

In October 2015, a third guest at the same hotel died of LD, prompting further investigation by state public health officials. After review of the initial environmental assessment, a total of five environmental samples were collected from the pool, spa, spa filter, water heater, and a tank associated with the heating, ventilation, and air-conditioning (HVAC) system. *Legionella* testing of these samples at an Environmental *Legionella* Isolation Techniques Evaluation (ELITE) member laboratory (www.cdc.gov/legionella/elite.html) was negative. The state health department requested CDC's assistance for the environmental investigation.

Epi-Aid Environmental Assessment

In November 2015, CDC epidemiology and laboratory staff joined state and local epidemiology and environmental health staff to interview the building owner, maintenance employees, and pool/spa contractors. They performed a detailed environmental assessment of the hotel, including a review of

- facility blueprints and survey of the facility (i.e., occupancy rates, number of buildings and floors);
- sources of water (i.e., potable water, spa, cooling towers, decorative fountains); premise plumbing system components (i.e., where and how water flows through buildings [water heaters, storage tanks, and point-of-use sites such as showers and sink fixtures]);
- changes in municipal disinfectant use;
- water system maintenance records;
- water management program;
- water quality parameters; and
- factors external to the building such as construction and water main breaks.

The team identified potential sites of *Legionella* amplification and transmission using a standardized environmental assessment form (CDC, 2015) and hand-drawn water system diagrams provided by hotel staff.

Epi-Aid Water Quality Measurement and Environmental Sampling

During the assessment, the team examined water quality parameters (e.g., pH, temperature, disinfectant levels) at sites near the water entry into the building (proximal) and along the water distribution system at point-of-use (medial and distal) to identify areas of risk for *Legionella* growth. We noted all aerosol-generating devices (e.g., showers, faucets, spa) that represented potential points of exposure and measured the abovementioned water parameters. Because of the recent change in municipal disinfection (from chlorine to monochloramine), total chlorine levels were measured at selected sites (CDC, 2018a; Fields, 1996; U.S. Environmental Protection Agency, Office of Water, 2016).

Using knowledge of the facility's water distribution and water quality parameters, along with epidemiologic data, the team developed a water sampling plan for *Legionella* that included sites throughout the hot water distribution systems and associated heaters, storage tanks, and hot water returns (CDC, 2018a; Kozak, Lucas, & Winchell, 2013). Improperly maintained spa filters can serve as a source of *Legionella* growth; therefore, we also obtained biofilm swabs of filter housings identified in the spa and pools (CDC, 2018b; Garrison et al., 2016).

Water samples and biofilm swabs were processed at CDC's *Legionella* Laboratory. *Legionella* isolates were characterized by serogroup and sequence typing (Lück, Fry, Helbig, Jarraud, & Harrison, 2013).

Results

Epi-Aid Environmental Assessment

The hotel's two buildings were constructed in 1989 and in February–August 2015, respectively, and are connected independently to the municipal water supply. No interruptions to the potable water system were reported during the more recent construction. The assessment focused on the older building, where all guest rooms possibly associated with LD cases were located. This building had 3 floors with 79 guest rooms arranged around a central atrium overlooking an unenclosed pool and spa. A 4.5-ft wall separated the pool and spa from the elevator, front desk, and surrounding rooms.

The municipal water facility used a chlorine disinfection system until August 2015 but changed to monochloramine disinfection in September 2015 to meet federal drinking water standards. Heated water from the water heater was stored in a hot water storage tank and traveled through riser pipes and a recirculating loop to deliver and collect water from the guest room sinks and showers/bathtubs on each floor. Thermostatic mixing valves were located on sinks and showers of the guest rooms. The potable water system relied on municipal disinfection. By design, the HVAC system did not aerosolize water (i.e., it was not a cooling tower or evaporative condenser) and thus likely did not pose a risk for *Legionella* transmission.

TABLE **1**

Measured Water Parameters for Hotel A, Missouri, November 2015

Sample Site	Collected Specimen Types	Location Within Potable Water Distribution	Measured pH	Measured Temperature (°F)	Measured Total Chlorine (mg/L)	Measured Bromine (ppm)	*Legionella* (Serogroup, Sequence-Type [ST])
Spa[a]	Bulk water	–	7.8–8.2	100.7	–	4	
	Swab (water line)	–			–		
Spa filter, left[a]	Bulk sand	–	7.5–8.0	93.1	–		
Spa filter, right[a]	Bulk sand	–	7.5	97.9	–	4	
Spa jets	Swab	–			–		
Pool[a]	Bulk water	–	7.8–8.2	89.2	–	2	
	Swab (water line)	–			–		
Pool filter	Bulk sand	–	7.5–8.0		–		
Pool jets	Swab	–			–		
Basement toilet, near water main (cold water)[b]	None	Proximal	7.0–8.0	60.4	2.0		
Water heater[b]	Bulk water	Proximal	7.0	136.5	1.3		
Hot water storage tank[b]	Bulk water	Proximal	8.0–9.0	100.7	1.5		
Room 111 shower[b]	Swab	Medial					
	Bulk water	Medial	7.0	124.2	1.2		
Room 125 shower[b]	Swab	Distal					
	Bulk water	Distal	7.0–8.0	113.9	1.5		
Room 125 Jacuzzi tub faucet and jets[b]	Swab	Distal					
	Bulk water	Distal	Not measured	Not measured	Not measured		
Room 201 bathroom sink[b]	Swab	Distal					
Room 201 shower[b]	Swab	Distal					
	Bulk water	Distal	7.0	122.9	1.0		

continued ▸

Epi-Aid Water Quality Measurement and Environmental Sampling

The hotel did not have a water management program. Review of the spa's maintenance records revealed inadequate documentation of disinfection, drainage, and scrubbing. Bromine and calcium hypochlorite disinfectants were hand-fed by a private contractor for periodic disinfection of the spa and pool. Bromine levels were measured and found to be within acceptable ranges per standards for the spa but were low for the pool (Table 1) (CDC, 2018b). The spa had been drained and scrubbed and the sand filter changed after the third LD case was reported but before environmental sampling by state public health officials.

We identified unused guest rooms and an out-of-service water softener tank as sites of possible water stagnation within the potable water system. We found that some measured water temperatures at proximal and distal sites of water use were within the ideal range for *Legionella* amplification (77–108 °F) (Table 1). We noted heavy scale and sedimentation on most sink faucet aerators. Disinfectant was detectable throughout the system (Table 1).

We collected a total of 40 bulk and swab samples from the pools and spas, including the sand filters, jets, and water line; proximal, medial, and distal points in the potable water system; and the hot water storage tank (Figure 1). *Legionella pneumophila* serogroup 1 was recovered from five guest room sink

TABLE **1** continued

Measured Water Parameters for Hotel A, Missouri, November 2015

Sample Site	Collected Specimen Types	Location Within Potable Water Distribution	Measured pH	Measured Temperature (°F)	Measured Total Chlorine (mg/L)	Measured Bromine (ppm)	*Legionella* (Serogroup, Sequence-Type [ST])
Room 215 bathroom sink[b]	Swab	Distal					
	Bulk water	Distal	7.5	121.8	1.2		
Room 215 shower[b]	Swab	Distal					
	Bulk water	Distal	8.0	120.8	1.2		(1, ST763)
Room 219 bathroom sink[b]	Swab	Medial					(1, ST763)
	Bulk water	Medial	7.5	121.8	1.4		(1, ST763)
Room 219 shower[b]	Swab	Medial					
	Bulk water	Medial	7.0–8.0	108.8	0.4		
Room 310 bathroom sink[b]	Swab	Medial					
	Bulk water	Medial	7.5–8.0	107.6	1.4		(1, ST763)
Room 310 shower[b]	Swab	Distal					
	Bulk water	Distal	7.0–7.5	113.5	1.4		
Room 320 bathroom sink[b]	Swab	Medial					
	Bulk water	Medial	7.0–8.0	112.6	1.1–1.2		
Room 320 shower[b]	Swab	Medial					
	Bulk water	Medial	7.5–8.0	109.1	1.4		
Room 328 bathroom sink[b]	Swab	Medial					(1, ST763)
	Bulk water	Medial	8.0	115.2	1.2		
Room 328 shower[b]	Swab	Medial					
	Bulk water	Medial	8.0	112.8	1.2		

[a]Pool and spa water quality parameters for temperature: ≤104 °F; pH: 7.2–7.8; bromine: 3.0–8.0 ppm for the pool and 4.0–8.0 ppm for the spa (Centers for Disease Control and Prevention [CDC], 2016).

[b]Potable water quality parameters for temperature: water heater/storage tank = 140 °F, shower/sink hot water = 120–124 °F, shower/sink or other cold water = <68 °F; total chlorine: detectable, but ≤4.0 mg/L (U.S. Environmental Protection Agency, Office of Water, 2016); pH: 6.5–8.5 (CDC, 2017).

and shower fixtures. All environmental isolates matched the sequence type (ST763) of the only available clinical isolate, which had been obtained from the third infected guest.

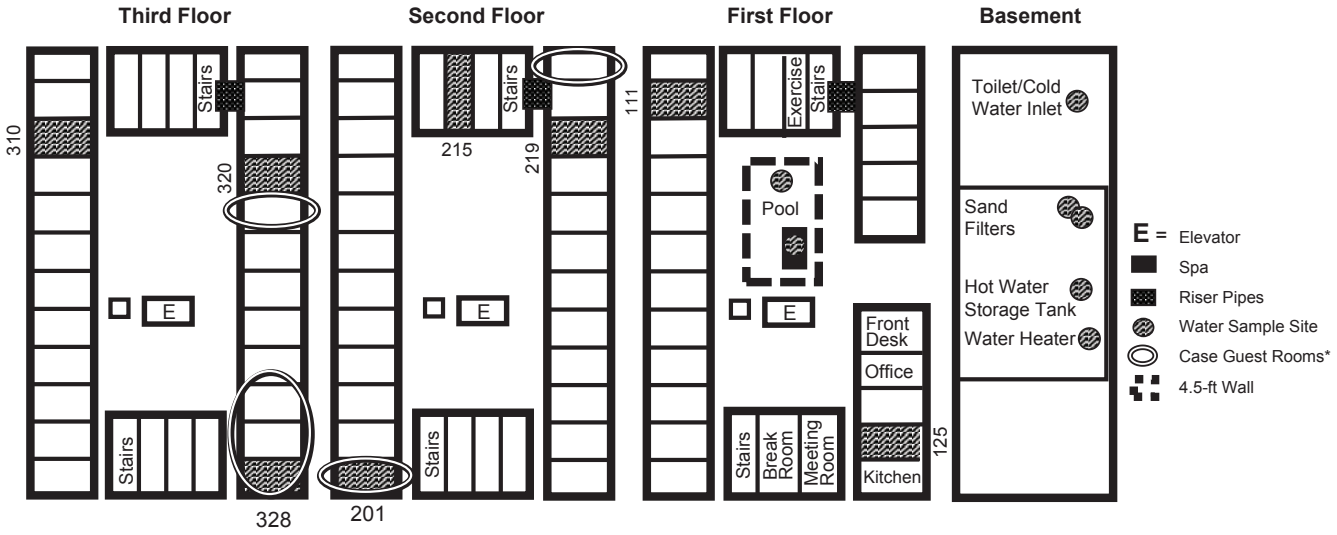
Discussion

LD outbreaks have been linked to inadequate water management (Garrison et al., 2016). Data from the environmental investigation suggest that the three infected guests likely were exposed to *Legionella* from the hotel's potable water system, although the incomplete documentation made it impossible to rule out an earlier deficiency associated with the spa. Temperatures optimal for *Legionella* amplification and areas of water stagnation in the potable water system might have increased the risk for *Legionella* growth. Lack of adequate maintenance documentation for the pool and spa and use of a hand-fed disinfection delivery system were inconsistent with CDC guidance for managing public aquatic facilities (CDC, 2018b). A water management program might have prevented these gaps in water system maintenance.

The absence of *Legionella* detection during the initial investigation might be a result of the small number of samples collected from the potable water system for testing and of disinfection of the spa before sampling. Subsequent sampling of 40 sites for *Legionella*, guided by a thorough environmental assessment of the potable water system, yielded *Legionella*.

FIGURE **1**

Building Schematic With Representative and Case Room Sampling Sites for Hotel A, Missouri, 2015



*Room locations for two cases were unknown; based on interviews, possible rooms of cases are circled.

To reduce the risk of *Legionella* amplification and transmission, the team recommended immediate hyperchlorination and/or superheating and flushing of the potable water system directed by a contractor specializing in *Legionella* remediation. Hotel staff were advised to eliminate low-flow areas by routinely flushing water fixtures in vacant rooms, to increase hot water temperatures outside the *Legionella* amplification range in the presence of thermostatic mixing valves (to prevent scalding), and to remove sedimentation from aerators (ASHRAE, 2015). We also recommended appropriate pool and spa maintenance with documentation to meet state and local environmental codes and installation of an automated disinfection delivery system (CDC, 2018b).

To reduce the risk of future cases, hotel staff were advised to develop and implement a water management program based on industry standards (ASHRAE, 2015) that would address maintenance gaps through the identification of control points, routine monitoring of control measures, and when necessary, corrective actions (CDC, 2017).

When LD clusters are identified, a comprehensive environmental assessment and water sampling should be considered for all potential sites of *Legionella* transmission as informed by case epidemiology. In this case, initially local public health officials considered spas to be the most likely source, and thus focused their investigation on spas. A more comprehensive environmental assessment with sampling from additional sites, however, ultimately revealed *Legionella* growth in the potable water system. A multidisciplinary team of environmental health specialists, epidemiologists, public health officials, and facility management staff is best equipped to identify all potential sources, develop a water sampling plan, measure parameters, and collect samples using appropriate techniques and then apply environmental interventions.

In circumstances where an environmental health specialist is unavailable, other public health staff (trained by or in consultation with an environmental health specialist) can perform environmental assessments and sampling based on industry standards. Furthermore, continual water quality monitoring and water sampling for *Legionella* can 1) help identify a source and/or factors promoting transmission during an outbreak, 2) confirm that reduction of the outbreak strain has occurred following remediation activities, and 3) establish a baseline to evaluate the effectiveness of an ongoing water management program.

Conclusion

Environmental health specialists play a key role in helping prevent LD. They will be called upon to assist health departments in building LD investigation capacity for timely identification of potential transmission sources and providing evidence-based prevention guidance tailored to specific buildings. Their expertise will be instrumental in supporting building owners and managers to develop and implement water management programs.

Therefore, it is important that environmental health specialists be trained to understand and appropriately apply the industry standards (Kunz & Cooley, 2016). In 2016, CDC and its partners developed a toolkit (CDC, 2017) to facilitate implementation of industry standards (ASHRAE, 2015). The toolkit describes step-by-step how to develop a water management program, beginning with the identification of water systems at risk for *Legionella* amplification and transmission, to providing real-life examples of how potential risk could be reduced. The adoption of these standards through widespread use of water management programs could reduce the burden of LD in the U.S.

Acknowledgements: We thank epidemiologists Kate Henschel and Drew Pratt from the Missouri Department of Health and Senior Services and thank all staff for participation in the environmental assessment. We thank microbiologist Natalia Kozak-Muiznieks and the CDC laboratory for processing water samples and characterizing *Legionella* isolates. The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of CDC.

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