Current Environmental Health Reports (2018) 5:263–271
https://doi.org/10.1007/s40572-018-0201-4

WATER AND HEALTH (T WADE, SECTION EDITOR)

Outbreaks of Legionnaires' Disease and Pontiac Fever 2006–2017

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Published online: 9 May 2018
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Abstract

Purpose of Review The global importance of Legionnaires' disease (LD) and Pontiac fever (PF) has grown in recent years. While sporadic cases of LD and PF do not always provide contextual information for evaluating causes and drivers of *Legionella* risks, analysis of outbreaks provides an opportunity to assess these factors.

Recent Findings A review was performed and provides a summary of LD and PF outbreaks between 2006 and 2017. Of the 136 outbreaks, 115 were LD outbreaks, 4 were PF outbreaks, and 17 were mixed outbreaks of LD and PF. Cooling towers were implicated or suspected in the a large portion of LD or PF outbreaks (30% total outbreaks, 50% confirmed outbreak-associated cases, and 60% outbreak-associated deaths) over this period of time, while building water systems and pools/spas were also important contributors.

Summary Potable water/building water system outbreaks seldom identify specific building water system or fixture deficiencies. The outbreak data summarized here provides information for prioritizing and targeting risk analysis and mitigation strategies.

Keywords Legionnaires' disease · Legionellosis · Pontiac fever · Outbreak · Cooling tower · Water · Buildings

Introduction

Legionnaires' disease (LD) and the milder form of illness, Pontiac fever (PF), are respiratory illnesses caused by infection with the bacteria *Legionella spp*. Infection results when the bacteria are inhaled or aspirated. *L. pneumophila* is the most common cause of LD and PF [1]. Legionnaires' disease is a reportable illness in Europe, the USA, Canada, New Zealand, Japan, Singapore, and Australia [2]; however, specific source attributions or systematized, cross-regional data collection regarding water system deficiencies resulting in outbreaks is sparse. Infections are typically of concern for the elderly and those with underlying health conditions [3].

Although there are over 50 species of *Legionella* [1] and a growing list of at least 16 serogroups of *L. pneumophila* [4], the majority of human infections are determined by the predominant urinary antigen testing to be caused by *L. pneumophila* serogroup 1 [2]. However, the dominance of serogroup 1 may be biased due to the fact that the urinary antigen test is designed to identify this serogroup [5••]. Therefore, the importance of infections with other serogroups may be underestimated. *L. pneumophila* serogroup 1 can be further distinguished based on subtypes, determined using monoclonal antibody (MAb) subtyping into monoclonal subgroups such as Allentown/France, Bellingham, Benidorm, Camperdown, Heysham, Knoxville, OLDA, Oxford, and Philadelphia [6, 7]. Additionally, sequence-based typing (SBT) using comparison with seven gene loci proposed by the European Society for Clinical Microbiology Study Group on *Legionella* Infections (ESGLI; formerly the European Working Group on *Legionella* Infections, EWGLI) can be used to determine how closely two isolates are related [5••, 8, 9].

Management of *Legionella* in water systems is complex as it occurs commonly in most aquatic environments and survives readily within biofilms [10]. However, its presence is not necessarily synonymous with risk, resulting in varied

This article is part of the Topical Collection on *Water and Health*

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s40572-018-0201-4) contains supplementary material, which is available to authorized users.

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philosophies regarding monitoring [11, 12]. Some evidence from longitudinal studies has indicated that outbreaks are most likely to occur in health care settings when more than 30% of distal sites in the water system were colonized [13, 14].

Despite the existence of numerous guidance documents for preventing *Legionella* proliferation and mitigating risks in engineered water systems [15], the reported number of legionellosis cases (where legionellosis includes LD and PF and the estimate incorporates sporadic cases) has increased from 0.42 to 1.62 per 100,000 persons in the USA from 2000 to 2014 [16], and recent large outbreaks have drawn attention to the need for analysis of outbreak information for prioritizing resources [17]. Sources of outbreaks have included cooling towers [18•], building water systems, decorative water features, and other common water uses [19] and often have resulted from deficiencies in water quality management, including operating conditions and maintenance [20, 21].

Eighty percent of LD cases are sporadic in nature [3], and while the source of sporadic LD and PF cases is seldom explored, outbreaks represent a valuable opportunity to analyze causes of adverse events when outbreak investigations are carried out [22]. As a result, we performed a systematic review of LD and PF outbreaks for studies published from 2006 through 2017. The goals of this review are to (1) summarize quantitative data for LD and PF outbreaks with ≥ 5 confirmed cases, (2) determine which sources contribute most significantly to the recent outbreak-associated LD and PF disease burden with the goal of prioritizing prevention resources towards the riskiest sources, (3) and identify information gaps for future study and risk mitigation strategy development.

Methods

A literature review was conducted for outbreaks of LD and PF. The Web of Science and PubMed were searched using the keywords (legionella OR legionnaires OR legionellosis OR pontiac fever) AND outbreak AND (2006/01/01: 2017/12/31) for peer-reviewed and government documents. References were imported into an Endnote® library with duplicate removal. Studies that were multiple publications of a primary study were included where unique aspects of the outbreak were covered, and details from multiple reports were combined in a single table entry for each outbreak where applicable Inclusion criteria included:

- Peer-reviewed or government documents published between January 1, 2006, and December 31, 2017. The outbreak(s) described by each published study was included if it occurred in the 10 years prior to the publication inclusion dates (between January 1, 1996, and December 31, 2017). This caveat is included as some government reports provide summaries of outbreaks occurring over a large historical time period for which the original peer-reviewed papers describing the outbreak were published before the inclusion dates.
- For publications that reported multiple outbreaks, each outbreak was included as a separate data point. Data from summary reports were cross-checked with the peer-reviewed reports and combined where identified to represent the same outbreak.
- Outbreaks were defined as five or more diagnosed (confirmed) cases of LD or PF linked epidemiologically to the outbreak [18•].
- Study described provides primary information about an outbreak investigation.
- Study is reported in English.

Results and Discussion

Literature Review Results The literature review returned 485 records. One hundred sixteen records met the inclusion criteria and were the focus of the current review. These records covered 136 unique LD and/or PF outbreaks with 3642 total confirmed cases of LD, 725 cases of PF, and 251 total deaths (Table 1; Supplemental Table S1). Information for interpreting US Centers for Disease Control and Prevention (CDC) criteria for strength of evidence and deficiency attributions are described in Supplemental Tables S2 and S3, respectively.

Legionnaires' Disease Surveillance and Outbreak Detection Outbreak surveillance and case ascertainment differ by region [2], and variations in measured outbreaks may not necessarily indicate lesser occurrence in some areas. Although outbreaks were not reported from some regions, this is not likely to be due to an absence of *Legionella*, and diagnostic and analytical capabilities may vary globally. Additionally, there is currently no agreed-upon case definition of PF [2, 23–25], making it challenging to interpret PF cases specified as "confirmed" versus "probable"; for the purposes of the current work, these categories were combined. *Legionella* occurrence in water and wastewater is thought to be ubiquitous and is not limited to those countries with surveillance programs [26•, 27].

Reporting for *Legionella* began in the USA in 2001. From 2001 to 2006, *Legionella* was identified as the causative agent of 38 of 833 US drinking water outbreaks from all source water types (389 cases), and from 1971 to 2006, it was identified as the cause of all reported drinking water-associated acute respiratory illness (ARI) [28]. In 2005–2006, ARI surpassed acute gastrointestinal illness (AGI) as the leading cause of waterborne illness from drinking water in the USA [29]. Major European LD outbreaks and clusters up to 2004 and 2005 are reported in Bartram et al. 30 and Joseph and Ricketts [31], respectively. From 1995 to 2005, 656 outbreaks

Table 1 Summary of Legionnaires' disease and Pontiac fever outbreaks 2006–2017. "Potable water systems" refers to building water systems and components connected to building potable water supply unless otherwise noted as defined by US Centers for Disease Control and Prevention (CDC) definitions provided in McClung et al. [82]

Source	Total confirmed LD cases	Total suspected/ probable LD cases	Total PF cases*	Deaths	Average case fatality rate (%) (range in outbreaks with ≥ 1 fatality)
Potable water/building water systems	564	50	7	43	6.2 (7.7, 30)
Non-potable water systems, excluding cooling towers	94	31	139	9	8.1 (5.6, 33.3)
Pools or spas	319	283	433	16	3.6 (8.7, 14.3)
Cooling towers, air conditioning units, or evaporative condensers	2083	236	146	151	8.4 (1, 22)
Unknown sources	219	28	0	12	6.2 (3.5, 33.3)
Multiple sources	363	43	0	20	16.4 (1.4, 40)
Total	3642	671	725	251	7.2 (1, 40)

*PF cases include cases identified as "confirmed" and "suspected" as there is no standardized case definition criteria for PF [2, 23–25]

(over 32,000 cases) of legionellosis from 35 European countries were reported to The European Working Group for Legionella Infections (EWGLI) [31]. These outbreaks were associated with nosocomial infection (100), community-acquired pneumonia (160), travel (390), and other causes (6), with the most frequently identified major sources reported as building water systems (207), cooling towers (57), and spa pools (33) [31]. From 2005 to 2006, 214 outbreaks were reported (11,980 cases) across 35 countries with a case fatality rate (CFR) of 6.6% [32].

Outbreak Investigation Outbreak detection is dependent on the clinical surveillance methods used. The most common methods for defining a clinical case of LD in the reported outbreaks were (1) epidemiologic (temporal, spatial) association with the outbreak source; (2) culture from clinical respiratory isolates; (3) positive urinary antigen; (4) clinical symptoms; (5) radiographically confirmed pneumonia; (6) serological evidence of infection via indirect fluorescent antibody (IFA) assay, enzyme-linked immunosorbent assay (ELISA), and/or a fourfold increase in antibody titer to *Legionella* (seroconversion). Polymerase chain reaction (PCR) was also used to confirm *Legionella* in clinical samples in some cases [33–41]. Matching of patient clinical samples and environmental samples from the source using serotyping and/or molecular subtyping was successfully obtained in 48 (35%) of outbreaks and performed but unsuccessful in 7 (4%) of outbreaks. Matching of clinical and environmental samples is established using sequence-based typing (SBT) and monoclonal antibody (MAb) profiles [5••]. In addition to the bias of the urinary antigen test towards serogroup 1 as a contributing factor to underreporting of LD outbreaks, sensitivity and specificity of other methods used for diagnosis and lack of recognition of the disease in hospitalized patients with other serious conditions are contributing factors [8]. The sensitivity of the indirect serotype 1–6 immunofluorescence antibody test (IFAT), the rapid microagglutination test (RMAT) IgM serotype 1 antibody assay, and ELISA for IgM and IgG serotype 1–7 antibodies has been reported as 61, 44, and 64%, respectively, for normal titer levels and 86, 48, and 75% for high standing titers that would be representative of an epidemic situation [42]. Additionally, Binax and Biotest kits were found to have sensitivities ranging from 51.4 to 81.8% and from 28.6 to 42.4%, respectively [43].

***Legionella* Species and Subtypes Implicated** *Legionella* spp. isolates can be characterized according to their species which are comprised of serogroups, subtypes, and sequence-based types. With regard to species and serogroups observed, the majority of outbreaks in the current literature review were observed to be due to *L. pneumophila* serogroup 1, with the exception of one outbreak where *L. maceachernii* was isolated from patients exposed to a pool/spa [29], two outbreaks due to *L. longbeachae* in potting soil [35, 44], and one outbreak due to *L. pneumophila* serogroup 1 with unproven linkage to *L. longbeachae* from a cooling tower at a rural dairy processing plant [45]. *L. longbeachae* has been demonstrated to occur in soil and has previously been associated with soil-associated disease clusters [46, 47], but rarely, if ever, with waterborne transmission. However, concerns regarding clinical reliance on the *Legionella* urinary antigen test (which captures only *L. pneumophila* serogroup 1) have created a "blind spot" for non-*Legionella pneumophila* serogroup 1 strains [5••], which as a result may be underreported. Additionally, one outbreak reported *L. pneumophila* serogroup 1 and *L. pneumophila* serogroup 3 attributed to a cold mist ultrasonic humidifier in neonates [48].

Multiple subtypes were found in patient clinical samples including Philadelphia [49–51], Benidorm [22, 37, 49, 52, 53], Knoxville [51, 53–58], Allentown/France [59–62], and Bellingham [52, 55], or a mixture of strains [49]. More than 20 different sequence types were identified across outbreaks. The most common sequence types were ST23 (4 outbreaks) and ST222 (3 outbreaks). Sequence types are known to demonstrate considerable spatial and temporal variability [63].

Sources of Outbreaks One hundred nineteen outbreaks (98 LD outbreaks, 4 PF outbreaks, and 17 mixed LD and PF outbreaks) reported an attributed source or suspected source, and in some cases, multiple sources were suspected. It is noted that the CDC defines drinking water or potable water as water for human consumption (e.g., drinking, bathing, showering, hand washing, teeth brushing, food preparation, dishwashing, maintaining oral hygiene) and includes water collected, treated, stored, or distributed in public and individual water systems, as well as bottled water" [64]. For waterborne outbreaks reported in the Morbidity and Mortality Weekly Report (MMWR), some outbreaks are classified as attributable to a "potable water" or "drinking water" source [16]. Although outbreaks associated with *Legionella* spp. are generally categorized using codes for "contamination of water at points not under the jurisdiction of a water utility or at the point of use" [65], the term "potable water system" is used in accordance with reported terminology in summary tables when a specific deficiency or setting was not reported. The term "potable/building water systems" is used to refer to the combined category. Attributed or suspected attributed sources for combined LD and PF outbreaks were as follows: 42 outbreaks (30%) potable water/building water systems; 10 (7%) non-potable water sources excluding cooling towers; 41 (30%) cooling towers, air conditioners, or evaporative condensers; 19 (14%) pools or spas; 7 (5%) multiple sources; and 17 (13%) had an unknown source.

Case fatality rates were up to 30% for potable/building water system outbreaks, up to 33.3% for non-potable system outbreaks, 14.3% for pools and spas, 22% for cooling towers, 33.3% for unknown sources, and 40% for outbreaks with multiple sources. Attack rates varied substantially and were up to 6% for potable/building water systems, 90% for non-potable systems, 33.7% for pools or spas, and up to 76.7% for cooling towers. The greatest number of confirmed LD cases was associated with cooling towers (2083 confirmed cases, 151 deaths), potable water/building systems (564 confirmed cases), outbreaks with multiple sources (363 confirmed cases), pools or spas (319 confirmed cases), and unknown sources (219 cases). The greatest number of PF cases were associated with pools or spas (433 cases); cooling towers, air conditioning units, or evaporative condensers (146 cases); and non-potable water systems (139 cases). Cooling tower outbreaks were therefore associated with the largest disease burden, identified as a direct contributor or associated factor in 50% of confirmed LD and PF outbreak-associated cases and 60% of outbreak-associated deaths.

Of the outbreaks that were potentially attributed to elements of indoor building water systems, showers were implicated in two outbreaks [16, 65], bathroom taps in one outbreak [65], and hot water systems in three outbreaks [65–70]. In a 2010 outbreak of LD in a nursing home in Slovenia with a chlorinated, "circular" system and unidentified outbreak source, "water flow disturbances" and "closed pipes that were walled up and had no water flow" were suggested as probable risk factors for *Legionella* growth due to renovation on some of the bathrooms in the facility [71, 72]. An epidemiological link was made by genotyping a patient isolate and matching it to cold and hot water samples from sink faucets, shower heads, air conditioners, and other locations throughout the nursing home. Water stagnation and elevated water temperatures are known to exacerbate *Legionella* growth [73]; furthermore, proper management of hot water systems is important for mitigating *Legionella* concentrations observed at the point of use [74].

It was noted for the two outbreaks in Flint, Michigan, increased water main breaks, instability of chlorine residual in the distribution system, elevated water temperatures during summer months, and elevated iron concentrations consistent with a corrosive water chemistry were contributing factors [17, 75]. Although the report did not meet inclusion criteria for this review, a study by Cohn et al. [76] suggested low disinfectant residuals as a potentially contributing factor in a LD cluster. Centrally located (not individual-building) community water system storage tanks in a water supplier system with low chlorine residual and stagnant water served a geriatric center and nearby high-rise housing complex for seniors [76]; however, limited information was provided regarding the water system.

Several outbreaks were attributed to elements of water systems not designed for potable use. Of the non-potable outbreaks, decorative water features were the most common cause, with ten outbreaks attributed to, or suspected partially to be attributed to, features such as ornamental fountains [16, 22, 29, 39, 64, 77–83]. Within medical settings, one outbreak in neonates was due to a cold mist ultrasonic humidifier [48, 84]. While not included in the review, a similar study reported a contaminated ice bath in a bronchoscopy suite where uncapped syringes were immersed in the ice bath during procedures and was considered a "pseudo-outbreak" [85]. Two outbreaks were due to potting soil [35, 44]. Outbreaks were also reported to be associated with supermarket mist machines [86], an asphalt paving machine [36], dust-controlling spray at a construction site [57], a sprinkler [83], and sullage tanks in a dockyard [87].

Outbreaks associated with long-range dispersal from cooling towers, air scrubbers, air conditioning units, or evaporative condensers were reported with cases up to large distances from the suspected source, with a maximum of 12 km reported for a cooling tower-associated outbreak in Christchurch, New

Zealand [88]. In some scenarios, due to the nature of the outbreak and environmental investigation findings, it was difficult to attribute the outbreak to a single source. For recurring outbreaks in 2001, 2005, and 2008 in areas surrounding a wood-based chemical factory in Fredrikstad/Sarpsborg, Norway, air scrubbers were originally implicated, with additional investigations suggesting that biological wastewater treatment plant aeration ponds from the same plant played a role in both direct dissemination of aerosols and introduction of contaminated effluent to the Glomma river which may have also played a role in dissemination [89–93]. Another investigation of an outbreak in Warstein, Germany, identified the epidemic strain isolate (serogroup 1 Knoxville, ST345) in environmental samples from cooling towers, a sewage treatment plant, and river water [58, 94–96].

Previously identified risk factors for cooling tower outbreaks include population age, smoking status, male sex, and underlying diseases as well as poor cooling tower maintenance and meteorological factors [18•]. In addition, cooling towers can be poorly co-located with population dense areas or the presence of immune-compromised individuals. For example, in an outbreak attributed to cooling towers in Barrow-in-Furness, UK [97], the cooling tower mist dispersed into a narrow walkway through which most of the town's population passed to reach a shopping area [8]. Poor maintenance practices were also mentioned in some studies [49, 50, 93, 97–99] as well as cooling tower start-up [100]. Additionally, unusual weather conditions during the outbreak period were indicated as influential by multiple studies [50–52, 58, 101–103]. Meteorological conditions identified included thermal inversions [51, 101], unusually warm temperatures and favorable wind conditions [52, 58], and high humidity [50, 102, 103].

Importance of Meteorological Factors and Relationship to Sporadic Cases The linkage between meteorological variables and sporadic LD and PF cases has been previously demonstrated. These factors are described here as they may also play a role in outbreaks. Several studies have identified thermal inversions as an important factor in the spread of the bacteria over distances as far as 8 km [104–106]. A case-crossover analysis of LD cases in the greater Philadelphia metropolitan area showed an increase in cases with increased precipitation and humidity (but not temperature), with most cases occurring during the summer months [107]. In a similar analysis on national surveillance data from 2003 to 2007 in the Netherlands, multivariate models showed that mean weekly precipitation intensity, mean weekly temperature, and mean relative humidity (RH) accounted for 43.3% of variability in the incidence of LD [108]. Linear models demonstrated that low sunshine, high cloud cover, mean temperatures close to 17.5 °C, high RH, and intense precipitation were associated with higher incidence of LD, but that the warmest days did not overlap with the highest LD incidence throughout the year. Ng et al. [109] reported that changes in local hydrology such as low watershed levels (OR = 3.6, 95% CI 2.4–5.3) contributed more strongly to LD risk in Toronto, Canada, compared to decreased lake temperature (33% increase, 95% CI 8–64%) or weather factors like humidity (34% increase, 95% CI 14–57%) using a case-crossover design. A study of five US Mid-Atlantic states revealed a 1-cm increase in rainfall was associated with a 2.6% increase in LD incidence; when rainfall increased 5.3 cm from the 1990–2002 summer period to the 2003 summer period, this was associated with a 14.6% increase in LD risk [110]. Ricketts et al. [111] reported an association between RH and LD cases in England and Wales from July to September (2003–2006) but not during winter, with stronger association when maximum temperature was ≥ 20 °C. No association was found for wind speed. A summer and autumn seasonal peak of LD is reported in several studies [3, 111, 112]. In a Scotland study, the summer/autumn peak was observed for travel-related cases, but an autumn and early winter peak was noted for non-travel cases from 1978 to 1982 and 1983 to 1986, respectively [113]. Nosocomial cases were clustered during the winter months. Decreases in weather events have been offered as an explanation for a decrease in LD in the Netherlands [114].

Research Gaps Outbreaks occurred frequently in susceptible populations such as the elderly in long-term care senior living, retirement, or nursing home facilities (22 outbreaks, 16%), with one outbreak among immune-suppressed patients [78] and another among neonates [115]. Thirty-one (23%) outbreaks occurred in hospital or health care settings. With regard to building types, 20 (15%) outbreaks occurred at hotels and one outbreak occurred in a green building [116] When evaluating factors associated with legionellosis outbreaks, increased attention to local and building-specific factors can be useful for informing mitigation strategies such as flushing of particular types of fixtures in health care facilities, for example.

To inform *Legionella* spp. risk mitigation strategies, it would be beneficial to prioritize exposure scenarios and populations at risk based on the findings of the current outbreak review with a focus on cooling towers and susceptible populations. Quantitative microbial risk assessment (QMRA) is one approach that can be used to model risks associated with *Legionella* spp. exposures [117], and models have been developed for a variety of indoor and outdoor exposures, including cooling towers [118, 119]. However, current dose-response models used to determine *Legionella* spp. risks have only considered the use of dose-response models for "clinical severity" and "sublinical" infection risks rather than explicitly considering variations across multiple types of susceptible populations [120, 121]. Quantitative relationships between different susceptible population categories and likelihood of infection have not yet been developed for this purpose. The use of outbreak information can help to inform the derivation of such values, as well as provide attack rates (No. ill/No.

exposed) useful for evaluating the plausibility of risk models. As a result, the analysis of attack rates summarized in this review and augmentation of this information with a summary of corresponding environmental concentrations of *Legionella* spp. is recommended for further study.

Conclusions

- A review of 136 Legionnaires' Disease and Pontiac Fever outbreaks between 2006 and 2017 provides useful information for prioritizing and targeting mitigation strategies.
- Cooling towers, air conditions, and evaporative condensers were implicated in a large portion (60%) of outbreak-associated deaths due to Legionnaires' disease or Pontiac fever between 2006 and 2017.
- Building water systems were also major contributors to outbreak-related cases (13%) and deaths (17%).
- Potable/building water system-associated outbreaks typically are not attributed to a specific failure; however, such information would be useful for risk-ranking purposes.

Acknowledgements This research was developed under Assistance Agreement No. R836880 awarded by the U.S. Environmental Protection Agency. It has not been formally reviewed by EPA. The views expressed in this document are solely those of the authors and do not necessarily reflect those of the Agency. EPA does not endorse any products or commercial services mentioned in this publication. Additional support was provided by the Virginia Tech Institute for Critical Technology and Applied Science.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Papers of particular interest, published recently, have been highlighted as:
- • Of importance
- •• Of major importance

1. Diederen BMW. *Legionella* spp. and Legionnaires' disease. J Infect. 2008;56(1):1–12.
2. Phin N, Parry-Ford F, Harrison T, Stagg HR, Zhang N, Kumar K, et al. Epidemiology and clinical management of Legionnaires' disease. Lancet Infect Dis. 2014;14(10):1011–21.
3. Marston BJ, Lipman HB, Breiman RF. Surveillance for Legionnaires' disease: Risk factors for morbidity and mortality. Arch Intern Med. 1994;154(21):2417–22.
4. Benson RF, Fields BS. Classification of the genus *Legionella*. Semin Respiratory Infect. 1998;13(2):90–9.
5.•• Mercante JW, Winchell JM. Current and emerging *Legionella* diagnostics for laboratory and outbreak investigations. Clin Microbiol Rev. 2015;28(1):95–133. **This study provides a thorough review of *Legionella* diagnostics that impact outbreak reporting**.
6. Helbig J, Bernander S, Pastoris M, Etienne J, Gaia V, Lauwers S, et al. Pan-European study on culture-proven Legionnaires' disease: distribution of *Legionella pneumophila* serogroups and monoclonal subgroups. Eur J Clin Microbiol Infect Dis. 2002;21(10):710–6.
7. Joly JR, McKinney RM, Tobin JO, Bibb WF, Watkins ID, Ramsay D. Development of a standardized subgrouping scheme for *Legionella pneumophila* serogroup 1 using monoclonal antibodies. J Clin Microbiol. 1986;23(4):768–71.
8. Joseph C, Ricketts C. Chapter 3: The Epidemiology of Legionnaires' disease. In: Heuner K, Swanson M, editors. *Legionella*: Molecular microbiology. Norfolk. ISBN 978-1-904455-26-4 pp35-52: Caister Academic Press; 2008.
9. Scaturro M, Losardo M, De Ponte G, Ricci M. Comparison of three molecular methods used for subtyping of *Legionella pneumophila* strains isolated during an epidemic of legionellosis in Rome. J Clin Microbiol. 2005;43(10):5348–50.
10. Lau H, Ashbolt N. The role of biofilms and protozoa in *Legionella pathogenesis*: Implications for drinking water. J Appl Microbiol. 2009;107(2):368–78.
11. Whiley H. *Legionella* risk management and control in potable water systems: Argument for the abolishment of routine testing. Int J Environ Res Public Health. 2016;14(1):12.
12. Doleans A, Aurell H, Reyrolle M, Lina G, Freney J, Vandenesch F, et al. Clinical and environmental distributions of *Legionella* strains in France are different. J Clin Microbiol. 2004;42(1):458–60.
13. Ozerol IH, Bayraktar M, Cizmeci Z, Durmaz R, Akbas E, Yildirim Z, et al. Legionnaire's disease: a nosocomial outbreak in Turkey. J Hosp Infect. 2006;62(1):50–7.
14. Best M, Stout J, Muder R, Yu V, Goetz A, Taylor F. Legionellaceae in the hospital water-supply: Epidemiological link with disease and evaluation of a method for control of nosocomial Legionnaires' disease and Pittsburgh pneumonia. Lancet. 1983;322(8345):307–10.
15. Parr A, Whitney EA, Berkelman RL. Legionellosis on the rise: A review of guidelines for prevention in the United States. J Public Health Manag Pract. 2015;21(5):E17–26.
16. Garrison LE, Kunz JM, Cooley LA, Moore MR, Lucas C, Schrag S, et al. Vital signs: Deficiencies in environmental control identified in outbreaks of Legionnaires' disease—North America, 2000–2014. Am J Transplant. 2016;16(10):3049–58.
17. Rhoads WJ, Garner E, Ji P, Zhu N, Parks J, Schwake DO, et al. Distribution system operational deficiencies coincide with reported Legionnaires' Disease clusters in Flint, Michigan. Environ Sci Technol. 2017;51(20):11986–95.
18.• Walser SM, Gerstner DG, Brenner B, Höller C, Liebl B, Herr CE. Assessing the environmental health relevance of cooling towers–a systematic review of legionellosis outbreaks. Int J Hyg Environ Health. 2014;217(2):145–54. **This study provides an excellent companion to this review regarding cooling tower-associated outbreaks of Legionnaires' Disease**.
19. Hines SA, Chappie DJ, Lordo RA, Miller BD, Janke RJ, Lindquist HA, et al. Assessment of relative potential for *Legionella* species or surrogates inhalation exposure from common water uses. Water Res. 2014;56:203–13.
20. Rangel KM, Delclos G, Emery R, Symanski E. Assessing maintenance of evaporative cooling systems in legionellosis outbreaks. J Occup Environ Hyg. 2011;8(4):249–65.

21. Ruiz J, Kaiser AS, Lucas M. Experimental determination of drift and PM10 cooling tower emissions: Influence of components and operating conditions. Environ Pollut. 2017;230:422–31.
22. O'Loughlin RE, Kightlinger L, Werpy MC, Brown E, Stevens V, Hepper C, et al. Restaurant outbreak of Legionnaires' disease associated with a decorative fountain: An environmental and case-control study. BMC Infect Dis. 2007;7:93.
23. Burnsed LJ, Hicks LA, Smithee LMK, Fields BS, Bradley KK, Pascoe N, et al. Legionellosis Outbreak Investigation Team. A large, travel-associated outbreak of legionellosis among hotel guests: Utility of the urine antigen assay in confirming Pontiac fever. Clin Infect Dis. 2007;44(2):222–8.
24. Tossa P, Deloge-Abarkan M, Zmirou-Navier D, Hartemann P, Mathieu L. Pontiac fever: An operational definition for epidemiological studies. BMC Public Health. 2006;6(1):112.
25. Edelstein PH. Urine antigen tests positive for Pontiac fever: Implications for diagnosis and pathogenesis. Clin Infect Dis. 2007;44(2):229–31.
26.• Buse HY, Schoen ME, Ashbolt NJ. Legionellae in engineered systems and use of quantitative microbial risk assessment to predict exposure. Water Res. 2012;46(4):921–33. **This study provides a review of *Legionella* occurrence in engineered water systems**.
27. Prussin AJ, Schwake DO, Marr LC. Ten questions concerning the aerosolization and transmission of *Legionella* in the built environment. Build Environ. 2017;123:684–95.
28. Craun GF, Brunkard JM, Yoder JS, Roberts VA, Carpenter J, Wade T, et al. Causes of outbreaks associated with drinking water in the United States from 1971 to 2006. Clin Microbiol Rev. 2010;23(3):507–28.
29. Yoder J, Roberts V, Craun GF, Hill V, Hicks L, Alexander NT, et al. Surveillance for waterborne disease and outbreaks associated with drinking water and water not intended for drinking–United States, 2005-2006. MMWR CDC Surveill Summ. 2008;57(9):39–62.
30. Bartram J, Chartier Y, Lee J, Pond K, Surman-Lee S. *Legionella* and the prevention of legionellosis. World Health Organization, 2007.
31. Joseph C, Ricketts C. The Epidemiology of Legionnaires' disease. In: Heuner K, Swanson M, editors. *Legionella*: Molecular Microbiology. Norfolk: Caister Academic Press; 2008.
32. Ricketts KD, Joseph CA. European Working Group for *Legionella* Infections. Legionnaires' disease in Europe: 2005-2006. Euro Surveill. 2007;12(12):E7–8.
33. McDonough EA, Metzgar D, Hansen CJ, Myers CA, Russell KL. A cluster of *Legionella*-associated pneumonia cases in a population of military recruits. J Clin Microbiol. 2007;45(6):2075–7.
34. van den Hoek A, Ijzerman E, van Steenbergen J. Outbreak of Legionnaires' disease in Amsterdam, June-July 2006: Source confirmed. Euro Surveill. 2006;11(29):3002.
35. Cramp GJ, Harte D, Douglas NM, Graham F, Schousboe M, Sykes K. An outbreak of Pontiac fever due to *Legionella longbeachae* serogroup 2 found in potting mix in a horticultural nursery in New Zealand. Epidemiol Infect. 2010;138(1):15–20.
36. Coscolla M, Fenollar J, Escribano I, Gonzalez-Candelas F. Legionellosis outbreak associated with asphalt paving machine, Spain, 2009. Emerg Infect Dis. 2010;16(9):1381–7.
37. Coetzee N, Duggal H, Hawker J, Ibbotson S, Harrison T, Phin N, et al. An outbreak of Legionnaires' disease associated with a display spa pool in retail premises, Stoke-on-Trent, United Kingdom, July 2012. Euro Surveill. 2012;17(37):1–4.
38. Ahmed M, Laza-Stanca V, Mustfa N. *Legionella pneumophila* outbreak related to a display spa pool at a retail unit. Thorax. 2013;68:A189–90.
39. Smith SS, Ritger K, Samala U, Black SR, Okodua M, Miller L, et al. Legionellosis outbreak associated with a hotel fountain. Open Forum Infect Dis. 2015;2(4):ofv164.
40. Lapierre P, Nazarian E, Zhu Y, Wroblewski D, Saylors A, Passaretti T, et al. Legionnaires' disease outbreak caused by endemic strain of *Legionella pneumophila*, New York, New York, USA, 2015. Emerg Infect Dis. 2017;23(11):1784–91.
41. Weiss D, Boyd C, Rakeman JL, Greene SK, Fitzhenry R, McProud T, et al. A large community outbreak of Legionnaires' disease associated with a cooling tower in New York City, 2015. Public Health Rep. 2017;132(2):241–50.
42. Yzerman EP, den Boer JW, Lettinga KD, Schel AJ, Schellekens J, Peeters M. Sensitivity of three serum antibody tests in a large outbreak of Legionnaires' disease in the Netherlands. J Med Microbiol. 2006;55(5):561–6.
43. Olsen C, Elverdal P, Jørgensen C, Uldum S. Comparison of the sensitivity of the *Legionella* urinary antigen EIA kits from Binax and Biotest with urine from patients with infections caused by less common serogroups and subgroups of *Legionella*. Eur J Clin Microbiol Infect Dis. 2009;28(7):817–20.
44. Potts A, Donaghy M, Marley M, Othieno R, Stevenson J, Hyland J, et al. Cluster of Legionnaires' disease cases caused by *Legionella longbeachae* serogroup 1, Scotland, August to September 2013. Euro Surveill. 2013;18(50):20656.
45. Thornley C, Harte D, Weir R, Allen L, Knightbridge K, Wood P. *Legionella longbeachae* detected in an industrial cooling tower linked to a legionellosis outbreak, New Zealand, 2015; possible waterborne transmission? Epidemiol Infect. 2017;145(11):2382–9.
46. Pravinkumar S, Edwards G, Lindsay D, Redmond S, Stirling J, House R, et al. A cluster of Legionnaires' disease caused by *Legionella longbeachae* linked to potting compost in Scotland, 2008-2009. Euro Surveill. 2010;15(8):19496.
47. Whiley H, Bentham R. *Legionella longbeachae* and Legionellosis. Emerg Infect Dis. 2011;17(4):579–83.
48. Yiallouros PK, Papadouri T, Karaoli C, Papamichael E, Zeniou M, Pieridou-Bagatzouni D, et al. First outbreak of nosocomial *Legionella* infection in term neonates caused by a cold mist ultrasonic humidifier. Clin Infect Dis. 2013;57(1):48–56.
49. Sabria M, Alvarez J, Dominguez A, Pedrol A, Sauca G, Salleras L, et al. A community outbreak of Legionnaires' disease: Evidence of a cooling tower as the source. Clin Microbiol Infect. 2006;12:642–7.
50. Sala Ferre MR, Arias C, Oliva JM, Pedrol A, Garcia M, Pellicer T, et al. A community outbreak of Legionnaires' disease associated with a cooling tower in Vic and Gurb, Catalonia (Spain) in 2005. Eur J Clin Microbiol Infect Dis. 2009;28(2):153–9.
51. Scaturro M, Fontana S, Crippa S, Caporali M, Seyler T, Veschetti E, et al. An unusually long-lasting outbreak of community-acquired Legionnaires' disease, 2005–2008, Italy. Epidemiol Infect. 2015;143(11):2416–25.
52. Hugosson A, Hjorth M, Bernander S, Claesson BE, Johansson A, Larsson H, et al. A community outbreak of Legionnaires' disease from an industrial cooling tower: Assessment of clinical features and diagnostic procedures. Scand J Infect Dis. 2007;39(3):217–24.
53. Keramarou M, Evans M. A community outbreak of Legionnaires' disease in South Wales, August–September 2010. Euro Surveill. 2010;15(42):19691.
54. Beyrer K, Lai S, Dreesman J, Lee JV, Joseph C, Harrison T, et al. Legionnaires' disease outbreak associated with a cruise liner, August 2003: epidemiological and microbiological findings. Epidemiol and Infect. 2007;135(5):802–10.
55. von Baum H, Härter G, Essig A, Lück C, Gonser T, Embacher A, et al. Preliminary report: Outbreak of Legionnaires' disease in the cities of Ulm and Neu-Ulm in Germany, December 2009 - January 2010. Euro Surveill. 2010;15(4):19472.
56. Ambrose J, Hampton L, Fleming-Dutra K, Marten C, McClusky C, Perry C, et al. Large outbreak of Legionnaires' disease and Pontiac fever at a military base. Epidemiol Infect. 2014;142(11):2336–46.
57. Knox N, Weedmark K, Conly J, Ensminger A, Hosein F, Drews S. Unusual Legionnaires' outbreak in cool, dry Western Canada: An investigation using genomic epidemiology. Epidemiol Infect. 2017;145(2):254–65.

58. Maisa A, Brockmann A, Renken F, Luck C, Pleischl S, Exner M, et al. Epidemiological investigation and case-control study: A Legionnaires' disease outbreak associated with cooling towers in Warstein, Germany, August-September 2013. Euro Surveill. 2015;20(46):12–20.
59. Castilla J, Barricarte A, Aldaz J, Cenoz MG, Ferrer T, Pelaz C, et al. A large Legionnaires' disease outbreak in Pamplona, Spain: Early detection, rapid control and no case fatality. Epidemiol Infect. 2008;136(6):823–32.
60. Rota M, Scaturro M, Fontana S, Foroni M, Boschetto G, Trentin L, et al. Cluster of travel-associated Legionnaires’ disease in Lazise, Italy, July to August 2011. Euro Surveill. 2011;16(40):19982.
61. Burckhardt F, Brion A, Lahm J, Koch HU, Prior K, Petzold M, et al. Confirming Legionnaires' Disease outbreak by genome-based method, Germany, 2012. Emerg Infect Dis. 2016;22(7):1303–4.
62. Dias A, Cysneiros A, Lopes F, von Amann B, Costa C, Dionísio P, et al. The typical presentation of an atypical pathogen during an outbreak of Legionnaires’ disease in Vila Franca de Xira, Portugal, 2014. Rev Port Pneumol (Engl Ed). 2017;23(3):117–23.
63. Sánchez-Busó L, Coscollà M, Palero F, Camaró ML, Gimeno A, Moreno P, et al. Geographical and temporal structures of *Legionella pneumophila* sequence types in Comunitat Valenciana (Spain), 1998 to 2013. Appl Environ Microbiol. 2015;81(20):7106–13.
64. Beer KD, Gargano JW, Roberts VA, Hill VR, Garrison LE, Kutty PK, et al. Surveillance for waterborne disease outbreaks associated with drinking water—United States, 2011–2012. MMWR Morb Mortal Wkly Rep. 2015;64(31):842–8.
65. Hlavsa MC, Roberts VA, Anderson AR, Hill VR, Kahler AM, Orr M, et al. Surveillance for waterborne disease outbreaks and other health events associated with recreational water—United States, 2007–2008. MMWR CDC Surveill Summ. 2011;60(12):1–32.
66. Chuchalin A. *Legionella* epidemy in Ekaterinburg region in Russia: Experience and lessons. International Conference on Clinical Microbiology and Microbial Genomics, September 16-17, 2013 Hampton Inn Tropicana, Las Vegas.
67. Joseph C, Ricketts K. Legionnaires’ disease in Europe 2007–2008. Euro Surveill. 2010;15(8):19493.
68. Onishchenko GG, Lazikova GF, Chistiakova GG, Demina YV, Nikonov BI, Romanenko VV, et al. Epidemiologic characteristic of Legionnaires' disease outbreak in town Verkhnyaya Pyshma. Zh Mikrobiol Epidemiol Immunobiol. 2008;2:82–5.
69. Tartatovskiy I, Demina Y, Voronina O, Alyapkina Y, Karpova T. From large community outbreak in Verhnaya Pyshma to effective prevention of legionellosis in Russia. *Legionella* 2009 conference, 13-17 October 2009, Institut Pasteur, Paris, France, p13-17 (English summary p58).
70. Fitzhenry R, Weiss D, Cimini D, Balter S, Boyd C, Alleyne L, et al. Legionnaires' disease outbreaks and cooling towers, New York City, New York, USA. Emerg Infect Dis. 2017;23(11):1769–76.
71. Trop Skaza A, Beskovnik L, Storman A, Ursic S, Groboljsek B, Kese D. Outbreak of Legionnaires’ disease in a nursing home, Slovenia, August 2010: Preliminary report. Euro Surveill. 2010;15(39):19672.
72. Trop Skaza A, Beskovnik L, Storman A, Kese D, Ursic S. Epidemiological investigation of a legionellosis outbreak in a Slovenian nursing home, August 2010. Scand J Infect Dis. 2012;44(4):263–9.
73. Wang H, Masters S, Edwards MA, Falkinham JO III, Pruden A. Effect of disinfectant, water age, and pipe materials on bacterial and eukaryotic community structure in drinking water biofilm. Environ Sci Technol. 2014;48(3):1426–35.
74. Rhoads WJ, Ji P, Pruden A, Edwards MA. Water heater temperature set point and water use patterns influence *Legionella pneumophila* and associated microorganisms at the tap. Microbiome. 2015;3(1):67.
75. Zahran S, McElmurry SP, Kilgore PE, Mushinski D, Press J, Love NG, et al. Assessment of the Legionnaires’ disease outbreak in Flint, Michigan. Proc Natl Acad Sci. 2018;115(8):E1730–9.
76. Cohn PD, Gleason JA, Rudowski E, Tsai SM, Genese CA, Fagliano JA. Community outbreak of legionellosis and an environmental investigation into a community water system. Epidemiol Infect. 2015;143(6):1322–31.
77. CDC. Surveillance for waterborne disease outbreaks associated with drinking water and other nonrecreational water-United States, 2009-2010. MMWR Morb Mortal Wkly Rep. 2013;62(35):714–20.
78. Haupt TE, Heffernan RT, Kazmierczak JJ, Nehls-Lowe H, Rheineck B, Powell C, et al. An outbreak of Legionnaires’ disease associated with a decorative water wall fountain in a hospital. Infect Control Hosp Epidemiol. 2012;33(2):185–91.
79. Demirjian A, Lucas CE, Garrison LE. The importance of clinical surveillance in detecting legionnaires' disease outbreaks: A large outbreak in a hospital with a *Legionella* disinfection system-Pennsylvania, 2011-2012 (vol 60, pg 1596, 2015). Clin Infect Dis. 2017;64(11):1635–5.
80. Demirjian A, Lucas CE, Garrison LE, Kozak-Muiznieks NA, States S, Brown EW, et al. The importance of clinical surveillance in detecting Legionnaires' disease outbreaks: A large outbreak in a hospital with a *Legionella* disinfection system—Pennsylvania, 2011–2012. Clin Infect Dis. 2015;60(11):1596–602.
81. Beer KD, Gargano JW, Roberts VA, Reses HE, Hill VR, Garrison LE, et al. Outbreaks associated with environmental and undetermined water exposures—United States, 2011–2012. MMWR Morb Mortal Wkly Rep. 2015;64(31):849–51.
82. McClung RP, Roth DM, Vigar M, Roberts VA, Kahler AM, Cooley LA, et al. Waterborne disease outbreaks associated with environmental and undetermined exposures to water—United States, 2013–2014. MMWR Morb Mortal Wkly Rep. 2017;66(44):1222–5.
83. Pelaz C, Cano R, Chico M, Asensio G, Bellido B, Iascu A. A large community outbreak of Legionnaires' disease in Manzanares, Ciudad Real, Spain, 4th ESGLI Conference, Amsterdam, 2016.
84. Collective Unit for Surveillance and Control of Communicable Diseases. Legionnaires’ disease in a neonatal unit of a private hospital, Cyprus. Euro Surveill. 2009;14(2):19090.
85. Schuetz AN, Hughes RL, Howard RM, Williams TC, Nolte FS, Jackson D, et al. Pseudo-outbreak of *Legionella pneumophila* serogroup 8 infection associated with a contaminated ice machine in a bronchoscopy suite. Infect Control Hosp Epidemiol. 2009;30(5):461–6.
86. Barrabeig I, Rovira A, Garcia M, Oliva JM, Vilamala A, Ferrer MD, et al. Outbreak of Legionnaires' disease associated with a supermarket mist machine. Epidemiol Infect. 2010;138(12):1823–8.
87. Hyland JM, Hamlet N, Saunders C, Coppola J, Watt J. Outbreak of Legionnaires' disease in West Fife: Review of environmental guidelines needed. Public Health. 2008;122(1):79–83.
88. White P, Graham F, Harte D, Baker M, Ambrose C, Humphrey A. Epidemiological investigation of a Legionnaires' disease outbreak in Christchurch, New Zealand: The value of spatial methods for practical public health. Epidemiol Infect. 2013;141(4):789–99.
89. Borgen K, Aaberge L, Werner-Johansen O, Gjosund K, Storsrud B, Haugsten S, et al. Cluster of Legionnaires’ disease linked to an industrial plant in southeast Norway, June - July 2008. Euro Surveill. 2008;13(38):18985.
90. Olsen JS, Aarskaug T, Thrane I, Pourcel C, Ask E, Johansen G, et al. Alternative routes for dissemination of *Legionella pneumophila* causing three outbreaks in Norway. Environ Sci Technol. 2010;44(22):8712–7.
91. Blatny JM, Reif BAP, Skogan G, Andreassen O, Høiby EA, Ask E, et al. Tracking airborne *Legionella* and *Legionella pneumophila* at a biological treatment plant. Environ Sci Technol. 2008;42(19):7360–7.

92. Wedege E, Bolstad K, Borgen K, Fritzsonn E, Caugant DA. Molecular characterization of clinical and environmental isolates of *Legionella pneumophila* in Norway, 2001-2008. Scand J Infect Dis. 2013;45(1):59–64.
93. Nygård K, Werner-Johansen Ø, Rønsen S, Caugant DA, Simonsen Ø, Kanestrøm A, et al. An outbreak of Legionnaires' disease caused by long-distance spread from an industrial air scrubber in Sarpsborg, Norway. Clin Infect Dis. 2008;46(1):61–9.
94. Gagen C, Humpert L, Menke-Mollers I, Luck C. P13. Detection of *Legionella pneumophila* and *Streptococcus pneumoniae* urinary antigens during the largest German outbreak of Legionnaires' disease in Warstein, 4th ESGLI Conference, Amsterdam, 2016.
95. Petzold M, Ehricht R, Slickers P, Pleischl S, Brockmann A, Exner M, et al. Rapid genotyping of *Legionella pneumophila* serogroup 1 strains by a novel DNA microarray-based assay during the outbreak investigation in Warstein, Germany 2013. Int J Hyg Environ Health. 2017;220(4):673–8.
96. Petzold M, Prior K, Moran-Gilad J, Harmsen D, Lück C. Epidemiological information is key when interpreting whole genome sequence data – lessons learned from a large *Legionella pneumophila* outbreak in Warstein, Germany, 2013. Euro Surveill. 2017;22(45):17–00137.
97. Bennett E, Ashton M, Calvert N, Chaloner J, Cheesbrough J, Egan J, et al. Barrow-in-Furness: a large community legionellosis outbreak in the UK. Epidemiol Infect. 2014;142(8):1763–77.
98. Kirrage D, Reynolds G, Smith GE, Olowokure B. The Hereford Legionnaires' Outbreak Control Team. Investigation of an outbreak of Legionnaires' disease: Hereford, UK 2003. Respir Med. 2007;101(8):1639–44.
99. Sonder G, van den Hoek J, Bovée L, Aanhane F, Worp J, Du Ry van Beest Holle M, et al. Changes in prevention and outbreak management of Legionnaires' disease in the Netherlands between two large outbreaks in 1999 and 2006. Euro Surveill. 2008;13(38):18983.
100. Nguyen TMN, Ilef D, Jarraud S, Rouil L, Campese C, Che D, et al. A community-wide outbreak of legionnaires disease linked to industrial cooling towers—how far can contaminated aerosols spread? J Infect Dis. 2006;193(1):102–11.
101. George F, Shivaji T, Pinto CS, Serra LAO, Valente J, Albuquerque MJ, et al. A large outbreak of Legionnaires' disease in an industrial town in Portugal. Rev Port Saúde Pública. 2016;34(3):199–208.
102. Ulleryd P, Hugosson A, Allestam G, Bernander S, Claesson BE, Eilertz I, et al. Legionnaires' disease from a cooling tower in a community outbreak in Lidköping, Sweden-epidemiological, environmental and microbiological investigation supported by meteorological modelling. BMC Infect Dis. 2012;12(1):313.
103. Shivaji T, Pinto CS, San-Bento A, Serra LAO, Valente J, Machado J, et al. A large community outbreak of Legionnaires' disease in Vila Franca de Xira, Portugal, October to November 2014. Euro Surveill. 2014;19(50):13–6.
104. Addiss DG, Davis J, Laventure M, Wand P, Hutchinson M, McKinney R. Community-acquired Legionnaires' disease associated with a cooling tower: Evidence for longer-distance transport of *Legionella pneumophila*. Amer J Epidemiol. 1989;130(3):557–68.
105. García-Fulgueiras A, Navarro C, Fenoll D, García J, González-Diego P, Jiménez-Buñuales T, et al. Legionnaires' disease outbreak in Murcia, Spain. Emerg Infect Dis. 2003;9(8):915–21.
106. Engelhart S, Pleischl S, Luck C, Marklein G, Fischnaller E, Martin S, et al. Hospital-acquired legionellosis originating from a cooling tower during a period of thermal inversion. Int J Hyg Environ Health. 2008;211(3-4):235–40.
107. Fisman DN, Lim S, Wellenius GA, Johnson C, Britz P, Gaskins M, et al. It's not the heat, it's the humidity: Wet weather increases legionellosis risk in the greater Philadelphia netropolitan area. J Infect Dis. 2005;192:2066–73.
108. Karagiannis I, Brandsema P, Van der Sande M. Warm, wet weather associated with increased Legionnaires' disease incidence in The Netherlands. Epidemiol Infect. 2009;137(2):181–7.
109. Ng V, Tang P, Jamieson F, Drews SJ, Brown S, Low DE, et al. Going with the flow: legionellosis risk in Toronto, Canada is strongly associated with local watershed hydrology. Ecohealth. 2008;5(4):482–90.
110. Hicks LA, Rose CE, Fields BS, Drees ML, Engel JP, Jenkins PR, et al. Increased rainfall is associated with increased risk for legionellosis. Epidemiol Infectx. 2007;135(5):811–7.
111. Ricketts KD, Charlett A, Gelb D, Lane C, Lee JV, Joseph CA. Weather patterns and Legionnaires' disease: A meteorological study. Epidemiol Infect. 2009;137(7):1003–12.
112. Fisman DN. Seasonality of infectious diseases. Annu Rev Public Health. 2007;28:127–43.
113. Bhopal R, Fallon R. Seasonal variation of Legionnaires' disease in Scotland. J Infect. 1991;22(2):153–60.
114. Euser S, Bruin J, Mooi-Kokenberg E, Peeters M, Verbakel H, Yzerman E, et al. Diagnostic testing for Legionnaires' disease in the Netherlands between 2007 and 2009: A possible cause for the decline in reported Legionnaires' disease patients. Eur J Clin Microbiol Infect Dis. 2012;31(8):1969–74.
115. Collective Unit for Surveillance and Control of Communicable Diseases. Legionnaires' disease in a neonatal unit of a private hospital, Cyprus. Euro Surveill. 2009;14(2):19090.
116. Nicolay N, Boland M, Ward M, Hickey L, Collins C, Lynch M, et al. Investigation of Pontiac-like illness in office workers during an outbreak of Legionnaires' disease, 2008. Epidemiol Infect. 2010;138(11):1667–73.
117. Haas CN, Rose JB, Gerba CP. Quantitative Microbial Risk Assessment. John Wiley & Sons, Inc., 2014.
118. Hamilton KA, Ahmed W, Toze S, Haas CN. Human health risks for *Legionella* and *Mycobacterium avium* complex (MAC) from potable and non-potable uses of roof-harvested rainwater. Water Res. 2017;119:288–303.
119. Hamilton KA, Hamilton MT, Johnson W, Jjemba P, Bukhari Z, LeChevallier M, et al. Health risks from exposure to *Legionella* in reclaimed water aerosols: Toilet flushing, spray irrigation, and cooling towers. Water Res. 2018;134(1):261–79.
120. Armstrong TW, Haas CN. Legionnaires' disease: Evaluation of a quantitative microbial risk assessment model. J Water Health. 2008;6(2):149–66.
121. Armstrong TW, Haas CN. A quantitative microbial risk assessment model for Legionnaires' disease: Animal model selection and dose-response modeling. Risk Anal. 2007;27(6):1581–96.