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1.0 Introduction

1.1 Overview

These guidelines were first developed in 2016/17 by a multi-disciplinary group composed of epidemiologists, physicians, environmental health officers (EHOs), infection control practitioners (ICPs), microbiologists, engineers and industrial hygienists. They were updated following two cooling tower outbreaks in Fraser Health in 2018 and 2020 to address gaps in environmental investigation and management. A review of the published literature and a jurisdictional scan for other guidelines were conducted. Expert opinion and group consensus were used when evidence and practice standards were not available.

The goal is to provide evidence-based guidelines for the epidemiological, environmental and microbiological investigation and management of single cases and outbreaks of legionellosis in British Columbia (BC). While these guidelines are intended for use by public health professionals, they may also be useful to others.

1.2 Pathogen and Disease

1.2.1 Clinical Illness

Infection with *Legionella* bacteria causes a disease known as legionellosis, which presents as Legionnaires' disease (LD), Pontiac fever or as an asymptomatic infection. It is unclear if legionellosis is a spectrum of illness or if it only presents in these 3 forms (1).

Legionnaires' disease manifests as pneumonia which cannot be clinically differentiated from other causes of pneumonia, characterized by fever, dry cough, dyspnea, chest pain, headache, malaise and myalgia (1, 2). The respiratory infection is often severe and can progress to respiratory and multi-organ failure. Gastro-intestinal symptoms are common with diarrhea occurring in 20-40% of patients (1). Rarely, extrapulmonary infection can occur, including cellulitis, septic arthritis and endocarditis (1). Infection is treated with macrolide or fluoroquinolone antibiotics (1). Mortality is 11-25% (3-5).

Individuals at increased risk of Legionnaire's disease include older adults, males, smokers, and those with underlying conditions including immunosuppression, chronic lung disease, diabetes and cancer (1, 4).

Pontiac Fever is characterized by fever, fatigue, myalgia, headache and malaise with or without cough (5-7). Patients recover within 2-5 days without treatment. Because of its mild nature, Pontiac fever is usually identified in outbreak settings.

1.2.2 Incubation Period

Legionnaires' Disease has an average incubation period of 5-6 days (5) with a range of 1-19 days (3, 8). Pontiac Fever has an incubation period of 5-72h (5).

1.2.3 Organism

Gram negative bacilli bacteria from the genus *Legionella* consist of over 50 species, further divided into approximately 70 serogroups with associated sub-types. *Legionella pneumophila* serogroup 1 causes about 70% of human disease. Other species associated with human disease include *L. longbeachae, L. micdadei, L. bozemanii, L. feeleii, L. gomanii and L. anisa.* Appendix 1 includes the distribution of *Legionella* strains by water sources.

1.3 Epidemiology

1.3.1 Reservoir

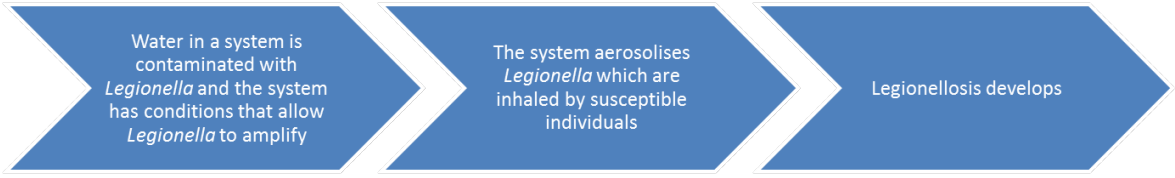
Legionella bacteria occur naturally and are ubiquitous in freshwater, including groundwater, and soil. They become a human health risk when allowed to multiply rapidly due to warm water temperatures between 25 and 50^{o} Celsius and are a particular hazard in manufactured environments (e.g. hot tubs, evaporative cooling systems etc.) where aerosolization may occur. Other factors, such as biofilm formation (micro-organism and polysaccharide matrix) and associated protozoa, water stagnation (e.g. periods of low useage, dead legs) and the presence of essential nutrient sources (sludge, scale, rust & algae), may also contribute to bacterial growth. Bacterial nutrient supply may be influenced by plumbing materials (e.g. rubber gaskets provide a nutrient rich substrate for bacterial growth and pipe corrosion may supply iron)(9).

1.3.2 Modes of Transmission

Infection with *L. pneumophila* occurs through inhalation of aerosolized particles generated from manufactured freshwater systems; infection with *L. longbeachae* occurs

through contact (direct contact or via aerosolized material) with contaminated soil or compost. There is generally no person to person spread of *Legionella*, however, a highly likely single case of person-to-person spread has recently been described (10). Transmission is illustrated in Figure 1 (11).

Figure 1: Transmission of *Legionella* via aerosolised water



1.3.3 Environmental Exposures

Community

Sources of infection include devices and systems that aerosolise water (e.g. cooling towers, evaporative condensers, hot tubs, shower heads, fountains, humidifiers, , emergency eye wash stations) and compost and potting soil (Appendix 2). Certain occupations may present a particular risk to legionellosis. For example, *L. longbeachae* infections have been associated with occupations associated with soil processing and packaging, composting and recycling of vegetable matter (12).

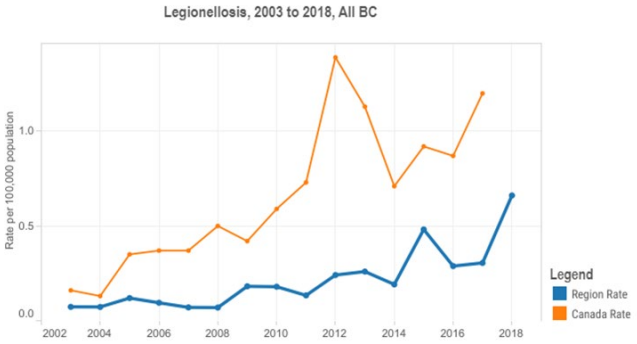
Nosocomial

Transmission in institutions, such as hospitals and long-term care facilities, can result from a combination of inadequate design and/or maintenance of building infrastructure and risk factors present in the residents or patients (13). Larger water distribution systems, long pipe runs, poor water temperature control, and low water flow rates can facilitate growth of *Legionella* bacteria. Underlying medical conditions of residents, in combination with use of respiratory therapy devices (e.g. nebulizers and ventilators), nasogastric tubes, aspiration or recent surgery, can increase their risk of infection. Construction adjacent to facilities, which can lead to soil disruption and dust creation is an additional risk factor particularly when it occurs close to air intakes for ventilation systems.

1.3.4 BC Epidemiology

Rates of legionellosis in BC have increased from 0.1 per 100,000 in 2006 to 0.7 cases per 100,000 in2018 (14). Rates in BC are lower than Canadian rates (Figure 2). Rates are likely higher than reported as a result of under-diagnosis. This is in part because clinical presentation of LD is not distinct from pneumonias caused by more common bacteria and, in most jurisdictions, diagnostic screening is not routinely conducted for *Legionella* in community-acquired pneumonia.

Figure 2: Legionellosis rates in Canada and BC by year, 2003-2018 (14, 15)

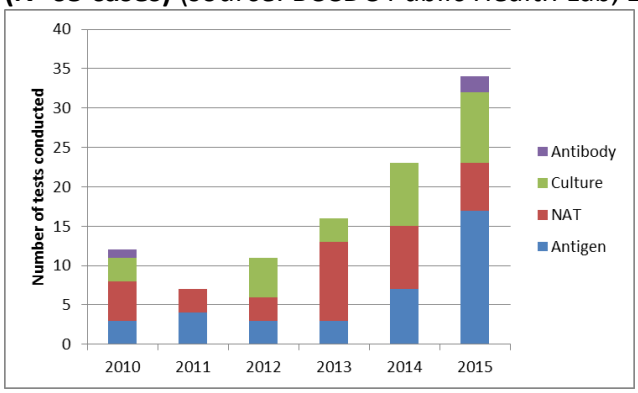


In BC, legionellosis has a seasonal pattern with half of the cases occurring between July and October. The annual number of cases ranges from 8-33. Most cases are over 40 years of age. The number of cases is higher in males than in females. Fraser Health Authority reports half of the cases in BC. This may be due to their larger population and higher use of urine antigen test (Figure 3).

An outbreak in FHA accounts for the peak in BC in 2018. An outbreak in Quebec accounts for the peak in Canada in 2012.

Increasing rates of legionellosis over time in BC and Canada may be due to an increasing use of the urinary antigen detection test for diagnosis rather than a true increase in rates (Figure 3). The proportion of BC legionellosis cases having received a urine antigen test has increased from 38% in 2010 to 81% of cases in 2015. The use of culture has remained low and stable.

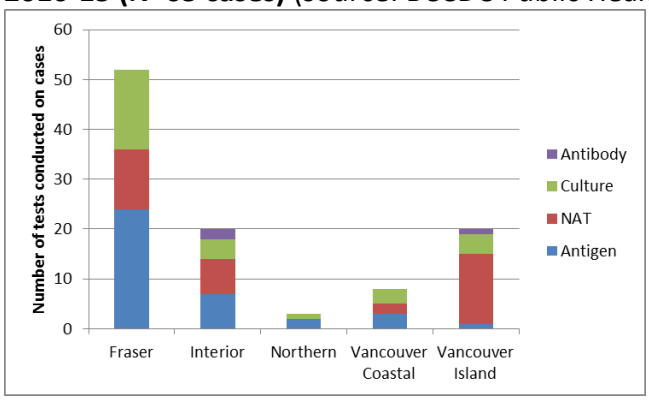
Figure 3. *Legionella* diagnosis tests used by year for reported cases, BC, 2010-2015 (N=65 cases) (source: BCCDC Public Health Lab, 2016)



NAT=nucleic acid test

The number and proportion of cases receiving different tests varies by Health Authority (Figure 4). Fraser Health is more likely to use the urine antigen test whereas Island Health is more likely to use a nucleic acid test (NAT) (Table 2).

Figure 4. *Legionella* diagnosis tests used by Health Authority for reported cases, BC, 2010-15 (N=65 cases) (source: BCCDC Public Health Lab and Panorama, 2016)



L. pneumophila is responsible for the majority of reported cases in BC (Table 1).

Table 1: BC Legionella cases by species, 2010-2015

Species	Number (%)
Pneumophila	53 (80%)
Longbeachae	7 (11%)
Micdadei	3 (5%)
Wadsworthii	1 (2%)
Unknown	2 (3%)
Total	66 (100%)

Four outbreaks caused by *L. pneumophila* were identified in BC between 2005 and 2020; one in the spring of 2005 (5 cases) associated with a VCH cooling tower, one in the fall of 2014 (3 cases) where the source was not confirmed, but possibly associated with a dishwasher in a FHA food service establishment, one in the summer of 2018 (14 cases) associated with a FHA cooling tower and another in the fall of 2020 (6 cases) also associated with another FHA cooling tower.

The source of illness for the majority of sporadic cases in BC was not identified. In terms of risk factors, 19.1% (9/47) of BC cases occurring between 2010 and 2015 were attributed to travel. Underlying medical conditions were identified in 38% of cases and 83% of cases currently and/or previously smoked cigarettes. The majority of cases (29/40, 73%) were admitted to the Intensive Care Unit. This may in part be due to a diagnostic bias.

1.4 Diagnosis

A wide range of laboratory tests are available for diagnosis of *Legionella* infections (see Table 2). Testing is also available for environmental samples to support public health investigations (see Section 3.2.4).

Table 2. *Legionella* tests used in clinical diagnosis

Test type	Samples*	Advantages	Disadvantages
Culture	Sputum, Bronchial Washings, Tracheal Aspirates, Lung Tissues, Fluid (pleural, pericardial, etc.)	-Produces an isolate which can be subtyped for comparison between strains -Detects all *Legionella* species	-Long turnaround time (7-10d) -May be negative once antibiotics started
Nucleic acid test (NAT) as part of respiratory panel[1]	Same as above	-Fast and sensitive -Detects all *L. pneumophila* serogroups	-Unable to differentiate live from dead cells -Unable to detect non-*L. pneumophila* species -Unable to subtype and compare between strains
Urine Antigen	Urine (for acute stage of the disease), 5-10 mL	-Fast and simple -Remains positive for several months	-Only detects *L. pneumophila* sg 1
Antibody (serology)[2]	Blood (acute and convalescent taken 2-4 wks apart)	-Can be used for patients on antibiotics -Detects all *L. pneumophila* serogroups	-Unable to detect non-*L. pneumophila* species -Unable to subtype and compare between strains

**When collecting clinical samples for Legionella, use sterile, non-bacteriostatic water rather than saline as saline may be inhibitory*

Appropriate diagnostic tests should be ordered for patients with clinical presentations consistent with Legionnaires' disease (see Table 3). For hospitalized patients, the British

[1] As of November 2016, the BCCDC PHL performs a pan-respiratory pathogen NAT testing panel that includes *L. pneumophila* for certain patient populations. Please indicate *Legionella* NAT on requisition to ensure respiratory panel is conducted as the first line test.

[2] This test is conducted by the Ontario Public Health Laboratory on behalf of the BCCDC PHL.

Columbia Centre for Disease Control (BCCDC) Public Health Laboratory (PHL) recommends the submission of urine for antigen testing and a lower respiratory sample (e.g., broncheo-alveolar lavage) for culture and nucleic acid testing (NAT). This results in rapid and sensitive results. For community patients, the PHL recommends a NAT or urine antigen. For patients deemed to be part of an outbreak, the PHL recommends ordering a culture and NAT to obtain specimens for subtyping.

Table 3. Diagnostic tests recommended by BCCDC PHL by type of patient/case

Type of patient/case	First line tests	Second line tests
Hospitalized and/or critically ill patient	Culture, NAT[1] and urine antigen	Antibody if illness resolved[3]
Single community patient	NAT[1] or urine antigen	Antibody if illness resolved[3]
Patient in an outbreak 1. Clinical case 2. Lab-confirmed case	1. Culture and NAT[1] 2. Not applicable (already diagnosed)	1. Antibody if illness resolved[3] 2. Culture if not already done to enable subtyping

Culture is required to perform *Legionella* subtyping to assist in the identification and solving of outbreaks. To facilitate this, if a patient tests positive for urine antigen, the PHL report includes a comment to obtain respiratory samples for culture. All NAT positive samples are set up for culture at the BCCDC PHL or frontline laboratory. All positive cultures are submitted to the National Microbiology Laboratory for serotyping and multilocus sequence typing (MLST) which allows comparison between clinical isolates and, if applicable, with environmental isolates.

Health professionals can refer to the BCCDC PHL Guide to Programs and Services for specimen and collection system details (http://www.bccdc.ca/resource-gallery/Documents/Statistics%20and%20Research/Statistics%20and%20Reports/Labs/GuidetoProgramsServices.pdf or http://www.elabhandbook.info/PHSA/Default.aspx). Please consult with the Program Head, BCCDC PHL Bacteriology and Mycology Laboratory at 604-707-2618 or the BCCDC PHL Medical Microbiologist on-call at 604-661-7033 for further information on clinical or environmental testing.

[3] As single antibody titre may be useful for patient diagnosis and care. To meet the case definition (Section 2.1), a person requires acute and convalescent serology.

2.0 Case management

2.1 BC Case Definition

A confirmed case of legionellosis is defined as a clinical illness* with laboratory confirmation of infection:

- isolation of *Legionella* sp. from respiratory secretions, lung tissue, pleural fluid, or other normally sterile fluids **OR**
- a significant (e.g. fourfold or greater) rise in *Legionella* sp. IgG titre between acute and convalescent sera **OR**
- seroconversion from non-reactive to IgG or IgM reactive or from IgM reactive to IgG reactive
- demonstration of *L. pneumophila* antigen in urine **OR**
- demonstration of *Legionella* spp. DNA by NAT from respiratory secretions, lung tissue, pleural fluid, or other normally sterile fluids.

*Clinical illness is defined as two distinct illnesses: Legionnaires' disease, characterized by fever, myalgia, cough and pneumonia, and Pontiac fever, a milder illness without pneumonia (16).

2.2 Case Investigation

All confirmed cases of legionellosis should be interviewed by Regional Health Authority public health staff using the BCCDC Case Report Form (http://www.bccdc.ca/resource-gallery/Documents/Guidelines%20and%20Forms/Forms/EH/Legionellosis%20Case%20Report%20Form/Legionella_Case_Form.pdf). The interview is an opportunity 1) to gather information on potential exposures to identify common sources and 2) to provide education on further prevention. An attempt to interview should be made within 3 business days of case notification.

Wherever possible, assess whether cases are community-acquired, occupationally acquired, healthcare facility/long-term care-related, or travel-related to determine further notifications and actions. Cases which cannot be classified may be classified later if other cases with similar characteristics occur. Most *sporadic* cases (single cases

occurring without a known link to other cases) do not require further investigation beyond the initial interview.[4]

- **Healthcare /long-term care facility [5]-related cases**: These include residents and staff of such facilities. Inform Infection Control Practitioner (ICP) or Director of Care. Review patient movement and exposure details and facility-based risk factors, with further investigation at the Medical Health Officer's (MHO) discretion. The MHO may consider case finding amongst other residents/patients with recent respiratory illnesses.

- **Travel-related cases:** If a case traveled outside BC during the incubation period, obtain travel details including names of hotels, room number, sites visited, possible high risk exposures (e.g. air conditioning, spas, fountains) travel dates and modes of travel including tour operators. If travel outside BC occurred, inform BCCDC for further notifications (e.g. to notify other jurisdictions).

- **Community-acquired, occupational and other cases**: Community and occupationally-acquired cases are defined as those exposed to a high risk source in the community or at their workplace. Further investigation is not usually necessary, unless the case is clearly or possibly linked to a water system that requires intervention to protect public health. If a case is believed to be occupationally-acquired, inform WorkSafe BC (WSBC) for their investigation.

See Appendix 3 for a flowchart on the investigation of a single case of legionellosis.

[4] Sporadic cases do not usually require further investigation into the source of infection because it is usually very difficult to link single cases to a potential source due to insufficient epidemiological evidence. Microbiological investigation of several potential sources is expensive. In addition, microbiological investigation has limitations as colonization of *Legionella* within a source is common but sporadic; several strains may co-colonize the same system, with the predominant strains periodically changing. Considered together with the difficulty of eradicating *Legionella* entirely from the system makes sporadic case environmental investigation of questionable value.

[5] Includes licensed and non-licensed facilities.

2.3 Reporting Requirements

Legionellosis is a reportable disease under the BC Public Health Act, Reporting Information Affecting Public Health Regulation. Physicians and laboratories must report cases to the MHO. The MHO must report cases to the Provincial Health Officer (PHO) (via its delegate, the BCCDC). Cases should be entered into the electronic public health information system, along with the BC Communicable Disease Policy Advisory approved minimum dataset.

If a case could be occupationally-related, please inform WorkSafeBC to support their investigations.

3.0 Outbreak Management

The objective of the outbreak investigation is to identify and control the source of the outbreak. Epidemiological, environmental and microbiological investigations are necessary.

Due to the underdiagnosis of legionellosis, lack of adequate specimens for genotyping (see Section 1.4) and difficulty in defining community outbreaks, few legionellosis outbreaks are identified and only 4% of legionellosis cases have been associated with outbreaks (17).

If a legionellosis outbreak is identified, the investigation is often challenging due to lack of sufficient epidemiological, environmental or microbiological data. The environmental source is identified in less than 50% of outbreaks (18). The following are required for a successful investigation:

- Substantial detailed epidemiological information on cases' movements and exposures.
- Thorough understanding of existing environmental sources, their location and their risk of *Legionella* contamination.
- Adequate samples from possible environmental sources.
- Genotyping of clinical and environmental specimens.

During an investigation a communication plan is required to ensure partners and the public is informed.

3.1 Epidemiological Investigation

Investigation of a legionellosis outbreak should follow the same steps as any outbreak (see outbreak investigation flow chart in Appendix 4). The steps are iterative; for example during the attempt to describe the outbreak or hypothesize a source it may become necessary to collect additional data, new clinical or environmental samples, or adapt the outbreak definition.

1) Determine that an outbreak exists

Two outbreak definitions were developed by consensus by the BC *Legionella* Guidelines Working Group in 2016:

> ***Cluster requiring further investigation***: Two or more cases infected by the same *Legionella* species residing, working or spending a significant amount of time within a defined temporal and geographic area[6] [7]
>
> ***Outbreak***: Two or more cases infected by the same *Legionella* species with epidemiological[8] or microbiological evidence of a common source

2) Confirm the diagnosis

3) Develop an outbreak case definition

Establish an outbreak-specific case definition[9], which may include clinical, epidemiological and microbiological elements.

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[6] A review of legionellosis outbreaks from 1994-2013 found that cooling tower-related outbreak cases occur within 11km (usually within 3km) of the source and outbreaks last 2 weeks to 5 months (usually 1-2 months). Legionellosis outbreaks cases associated with other sources all have been at or very near the source and outbreaks last 1 week to 4 months (usually <1 month) (19).

[7] The *Legionella* cluster space and time parameters in use in BC can be obtained from the BCCDC at 604-707-2558.

[8] Epidemiological links include visiting or residing in the same facility or the same accommodation or using or being close to the same device or system (e.g. hot tub, cooling tower).

[9] Examples of case definitions can be found here https://legionnaires.ecdc.europa.eu/?pid=207

4) Establish an outbreak team (11)

The team should be scalable based on the size and complexity of the outbreak. At a minimum, it should consist of the local MHO and Environmental Health Officer (EHO), as well as an epidemiologist and microbiologist with experience in *Legionella*. If the outbreak is occupationally-related, the team should include a WSBC physician and Occupational Hygiene Officer. See Table 4 for roles of the various team members.

Table 4. *Legionella* outbreak team members

Profession	Role
Medical Health Officer	Leads regional investigation including declaring the start and end of an outbreak and taking action to control the outbreak
Environmental Health Officer	Interviews cases and leads environmental investigation including inspection and environmental sample collection
Epidemiologist	Conducts data management and epidemiological analyses
Public health lab microbiologist	Conducts and interprets clinical and environmental sample testing
Infection Control Practitioner (ICP) or Officer	Identifies hospitalised cases, collects data on cases, provides liaison between public health authorities and facility staff, assists with facility investigation
Mechanical/Plumbing Engineer	Designs and assesses ventilation and plumbing systems in buildings
Plumbing/Mechanical Inspectors	Examining mechanical equipment/plumbing systems and maintenance records and procedures.
Public health (water) engineer	Assesses water systems in buildings and the community
Occupational health physician	Assesses likelihood of occupational exposure
Industrial hygienist	May conduct on-site workplace water system assessments, advise on sample collection and recommend control measures to prevent health risks
Facilities manager	Provides liaison between the outbreak team and the facility, including technical facility staff (e.g. water treatment specialist, engineer, industrial hygienist)
Medical Geographer	Provides assistance in mapping cases, use of GIS, access to spatial and climate data

Other specialists may be helpful such as hydrologists (assist in assessing ground water quality) and meteorologists (assist in accessing and analyzing meteorological data). Community Care Facility Licensing Officers should be included if the outbreak setting is in a licensed community care facility. The local building department may have engineers and inspectors that can provide expertise on building systems and equipment. As needed, staff involved in communications should be included to ensure partners and the public are informed.

In an outbreak affecting a single Health Authority, the local MHO leads the investigation; if multiple Health Authorities are affected, BCCDC leads the investigation.

5) Case finding

Active case finding should be considered to inform the source investigation and increase the ability to solve the outbreak. If more than one case resides in a health care facility, active case finding is recommended for other residents/patients and staff of the facility (11).

6) Data collection

Collect environmental, epidemiological and microbiological data.

Epidemiological data is collected through case interviews. The Case Report Form may be sufficient to identify a common exposure. If not, a focused or open-ended questionnaire can be developed to ask questions related to a suspected source or to generate a hypothesis, respectively.[10] Some considerations include daily diaries of places visited, receipts (purchasing records), routes and journeys taken and a description of frequent potential exposure locations (19-21).

Environmental data such as the location and type of at-risk water systems are collected through site inspections and through manufacturer information, often found online (see Section 3.2). **Microbiological data** on cases and the environment are collected through sample collection and testing (see Section 3.2). Consult the BCCDC Public Health Laboratory for advice on appropriate sampling and interpretation of results. Molecular typing (e.g. MLST) of isolates from cases and environmental sources can confirm the link between cases and sources.

[10] A template for a trawling questionnaire is available at: https://legionnaires.ecdc.europa.eu/?pid=215

In cooling tower-associated outbreaks, meteorological data can inform the dispersal of aerosols contaminated with *Legionella*. Temperature, humidity, atmospheric stability, wind speed and direction may influence dispersal (22, 23). Meteorological data is available at: http://climate.weather.gc.ca/

7) Describe the outbreak by person, place and time

Descriptive epidemiology may be sufficient to establish a hypothesis as to the source of the outbreak. An epidemiological curve can help assess whether the outbreak was due to a single release over a short time period or an ongoing source. Consider mapping locations visited during the incubation period using a map or geographic information system (GIS) to visualize overlap between cases and potential environmental sources, such as cooling towers (21). It may be necessary to map travel routes and cooling towers in the vicinity of cases. Assistance can be requested from BCCDC for mapping and/or using GIS.

8) Develop a hypothesis as to the environmental source of the outbreak

The environmental source of the outbreak may be a specific device or location or a general area and will guide the inspection and specimen collection within that area.

9) Test the hypothesis

Ideally, the descriptive epidemiology combined with site inspections and microbiological data will confirm the source. This is particularly true if the same *Legionella* genotype is found in cases and plausible environmental sources.

Analytical studies may be needed but are expensive and time-consuming. They should only be used when descriptive epidemiology combined with environmental and microbiological data are insufficient to confirm the hypothesis and there is a specific hypothesis to test using statistical methods. Case-control studies have most often been used when cooling towers were the source (24-26).[11] When accurate location information is available, GIS can be used in advanced analytical studies such as buffer analysis and dispersion modeling. BCCDC has developed a summary of available tools which is available upon request. GIS expertise is also available upon request at the BCCDC.

[11] Examples of study types used in legionellosis outbreaks: https://legionnaires.ecdc.europa.eu/?pid=426 and https://legionnaires.ecdc.europa.eu/?pid=418

3.2 Environmental Investigation Including Microbiological Sampling

The environmental investigation should be performed in an iterative manner as depicted in Appendix 4, starting with identification of the potential epicentre through epidemiological assessment, followed by identification of high risk sources within the site, inspection of these sources and subsequent sampling. Findings from the environmental investigation may require enhancement of the epidemiological investigation.

Some buildings operated and/or leased by federal government agencies may follow Public Services and Procurement Canada standards that outline *Legionella* control, monitoring and record keeping requirements (35). In some areas there may also be by-laws with related requirements.

3.2.1 Investigative Approach

Initiation of an environmental investigation should occur within 24 hours of identification of a suspected source or potential at-risk site, depending on the case context. The environmental investigation includes:

- Site assessment and system inspection
- Environmental sampling
- Microbiological testing

The environmental investigation will usually be coordinated by an EHO in consultation with the facility manager, the ICP, engineers and industrial hygienists, depending on the scope of the investigation (see Table 3 for guidance on outbreak team composition). If the setting is occupational, WSBC should be involved. A site assessment and sampling plan should be developed collaboratively with the outbreak team to ensure an understanding of the sampling context and accurate interpretation of the results. Appendix 5 provides system characteristics that should be considered during an inspection and Table 5 provides a list of possible sampling sites.

Safety [8]

Investigators should liaise with the facility manager to identify potential hazards which may be encountered during an investigation. These hazards will dictate the steps necessary to mitigate the risk of exposure to aerosolized contaminated water which would necessitate system shut down and/or the use of respiratory protective equipment. Investigators must comply with Occupational Health and Safety Regulations, including Exposure Control Plans and Respiratory Protection Programs (e.g. use of N95 or higher

rated respirator). Personnel at increased risk of *Legionella* infection due to underlying conditions or immunosuppression should not be involved in onsite environmental investigation.

3.2.2 Site Assessment and System Inspection

The initial investigation should begin with the site(s) implicated by the epidemiological investigation (e.g. building, water system/feature). If a single site has not been identified, define an initial area (e.g. neighbourhood) for investigation based on the environmental context. If no source is identified following sampling, the area under investigation should be expanded.[12] Consultation with meteorologists or other specialists may inform this process.

If available, review existing documents to provide background information (e.g. swimming pool or hot tub treatment records, cooling tower maintenance logs, site water management plans, logs of routine sampling and inspection protocols etc.). If system is subject to local by-law or federal standards, documentation required by those policies may be available e.g. maintenance logs, other record keeping. This review, coupled with a direct walk-through of the site, can increase familiarity with the complexities of the water system, which is essential to the collection of representative samples based on potential operational risks. Some buildings operated and/or leased by federal government agencies may follow Public Works and Government Services Canada standards that outline *Legionella* control, monitoring and record keeping requirements (35). In some areas (e.g. the City of Vancouver) there may also be by-laws with related requirements.

Within the site(s) or area, identify all systems using water and consider the following (27, 28):

- Sites at risk of aerosol release, such as shower heads, hot tubs, water features and fountains
- temperature range between 25 to 50^{o}C
- intermittent or inadequate disinfection
- sites with stagnant or non-flowing water
- piping system dead legs or reservoirs for amplification
- infrequently used outlets/fixtures, such as sink faucets

[12] Aerosolized transmission from cooling towers has been reported up to 12 km from the source (20).

- sites with pH in range of 5.5 to 9.2
- sites with sediment, scale, deposits or biofilms
- systems that have been disrupted by construction or maintenance or have had flow stopped (shut down or 'lay-up') and have been re-started again
- systems which have recently been, or are soon to be commissioned

If up-to-date maintenance logs and other records are not available, assessing the above parameters may support the development of the sampling plan. Each at-risk system identified through the site assessment should be thoroughly inspected, with documentation of findings. Investigators should consider system details that may increase risk of *Legionella* colonization, as listed in Appendix 5.

Investigations of internal piped water systems should include rooms (e.g. hospital or hotel) used by cases and may need to expand to the entire system (11). Special consideration should be given to high risk sources of *Legionella* outlined in Appendix 1. If the cluster under investigation is associated with *L. longbeacheae*, sites where individuals may come into direct contact with soil or compost should be identified (11).

Investigators should also consider whether there have been any recent changes to routine maintenance practices (e.g. activities causing pipe re-pressurisation, disinfection practices or products), personnel or renovation/construction activities that may have led to system disruption or affected the environment immediately around the system/building. Temporary displays (e.g. hot tubs, fountains) or use of small aerosol-producing devices should also be considered. Focus should be on conditions that fall within the incubation period prior to the onset of the first cases associated with the outbreak. Public health staff may refer to Appendix 8 for more detailed guidance on preparing for the site assessment, system inspection and developing the sampling plan.

3.2.3 Environmental Sampling

Sampling Plan

Sampling sites within the implicated water device or system should be chosen based on suitability for *Legionella* colonization and growth, as determined through the system assessment (see Table 5 and Appendix 5). The sampling approach and number of samples required will depend on the nature of the site, past testing results, maintenance quality control and the characteristics of the outbreak, including the species of *Legionella* implicated (e.g. *L. longbeacheae* vs *L. pneumophila*). Please consult the BCCDC PHL

Environmental Microbiology Laboratory at 604-707-2620 prior to sampling for guidance on which sites to sample and how many samples to collect.

Sampling helps confirm the link between an environmental source and cases. Samples should be collected by a qualified professional (e.g. EHO or industrial hygienist or water technician) from the sampling plan created through the site assessment step. These initial samples should be collected prior to any precautionary disinfection or system flushing of potential sources, unless disinfection cannot be delayed. Investigators should collect samples in consultation with personnel with expertise in the site water system(s) (e.g. maintenance technicians) to ensure the appropriate samples are obtained and collection is representative of both circulating water and possible dead legs.

Sampling equipment (29)

- Personal protective equipment (impervious gloves, fitted air purifying respirator and disposable coveralls, as determined by risk assessment)
- Sterile DNA/RNA free water bottles containing sodium thiosulfate (2L per site sampled. Use 2x1L bottles or 10x200mL bottles[13])
- Environmental swabs (as needed) to collect biofilm samples[13]
- BCCDC PHL Water Bacteriology Requisition Forms[13]
- Ziploc bags to keep bottles and requisition forms together
- Chlorine/halogen/residual oxidant test kit, turbidity meter
- Flashlight
- pH test kit to help identify sampling sites
- Calibrated thermometer
- Camera to document site/systems/sampling sites etc.
- Sterile plastic bags for collecting solid material
- Field data sheets to record site investigation details

[13] Available at http://www.elabhandbook.info/PHSA or call 604 707 2620.

Table 5. Potential sampling sites and environmental samples to collect from at-risk systems (29-32)

System	Potential sampling sites	Samples to collect
Cooling towers, evaporative condensers[14] [15]	• Make-up water or lines passing over areas where they may become heated to 25-50^{0}C • Collection basin • Sump (where water is pumped back from collection basin) • Return service near heat source • Distribution header/ sprayers/ or deck	• Water (2L) • Biofilm swab
Potable water systems	• Incoming service connection • Water softener • Tanks and cisterns • Water heater, at inflow, outflow and flush spigot • Expansion vessel • Shower heads, faucets (pre-flush), aerators • Ice machine (ice sample) • Drinking water fountains	• Water (2L) • Biofilm/surface swab

Small aerosol-producing devices	• Decorative water features– reservoir, trough and foam
	• Humidifiers, evaporative coolers
	• Ice machines (in heat exchange area)
	• Irrigation equipment
	• Power washers
	• Medical equipment (e.g. medication jet nebulizer used in respiratory therapy)
	• Hot tubs, whirlpools, spas
	  ○ Pool water, filter housing and balance tank
	  ○ Filter material and biofilm from inside air jets, hoses, taps, shower heads and pipes
	  ○ Biofilm above water line
		• Water (2L)
		• Biofilm/surface swab

[14] See Appendix 6 for diagrams of a cooling tower and an evaporative condenser.
[15] Apply caution when inspecting and sampling. Do not remove the hatch/door or enter without a good understanding of how to do so safely. Consult the site manager for safe entry.

Water sample collection and submission

Water samples should be collected and submitted using the following protocol:

- Prior to collection, please consult the BCCDC PHL Environmental Microbiology Laboratory at 604-707-2620
- Collect in sterile DNA/RNA free water bottles containing Sodium Thiosulfate. Specially provided 1L bottles or routine 200mL drinking water sample bottles can be used for this purpose
- Collect at least 2 litres (1L for culture and 1L for PCR) of implicated water using sterile techniques (consult the eLab Handbook at http://www.elabhandbook.info/PHSA)
- Label each water bottle with clear sample identifiers
- Measure chlorine level for each water sample and record on requisition
- Complete a BCCDC PHL Water Bacteriology requisition form (http://www.elabhandbook.info/PHSA) and write "*Legionella* testing" under the section "Test Information".
- Place requisition in a ziploc bag and ship with water samples
- Keep samples at ambient temperature during storage and transportation. Samples should not be frozen and extreme cold and extreme warm temperature should be avoided
- Ship sample within 24 hours of collection
- Submit samples to:

  BCCDC Public Health Laboratory
  Environmental Microbiology
  655 West 12th Avenue
  Vancouver, BC
  V5Z 4R4

Biofilm/solid sample collection

If samples other than water are being considered for testing (ie. biofilms, swabs, soil, compost, ice or other), contact the BCCDC PHL Environmental Microbiology Laboratory at 604-707-2620 for sampling equipment needed and additional instructions.

3.2.4 Microbiological Testing

The BCCDC PHL can only conduct testing of environmental samples associated with an outbreak investigation. Private labs should be used for testing of environmental samples used in monitoring.[16] Recommended protocols for routine sampling are distinct from outbreak sampling protocols.

The BCCDC PHL Environmental Microbiology Laboratory conducts a NAT (PCR) screen which identifies all *Legionella sp*. If the NAT screen is positive, the sample is cultured and *Legionella* are enumerated. Then *L. pneumophila* is confirmed using matrix-assisted laser desorption/ionization-time of flight (MALDI-TOF) mass spectrometry or NAT methods. If a bacterial isolate is recovered, the final isolate is sent to the National Microbiology Laboratory for typing using MLST.

It is ideal to recover an isolate from environmental samples to compare genetically to isolates recovered from clinical cases but this may not always be possible due to method limitations including:

- *Legionella* may enter viable but non-culturable (VBNC) forms when stressed, such as at low temperatures, and may be difficult to recover by culture
- Other organisms found in water may compete with and kill-off *Legionella* in culture
- NAT tests may be inhibited by compounds (e.g. chlorine) found in water
    - Adequate flushing, circulation and/or a waiting period after shock treatment/chlorination of suspected water sources prior to sample collection will minimize the impacts of chlorine on NAT tests.
- NAT tests cannot differentiate between live and dead cells, which is an important consideration in disinfected water supplies

[16] Ensure private labs used to analyze samples for monitoring purposes are ISO 17025 certified (or equivalent) and/or participate in external proficiency testing such as the US CDC Environmental Legionella Isolation Techniques Evaluation (ELITE) Program. Labs that meet ISO 11731 (Enumeration of Legionella) can also be considered.

4.0 Outbreak Control

The purpose of this section is to describe the actions required to control a *Legionella* outbreak once a source has been identified.

Occasionally, an outbreak source is not identified with certainty. However, in the course of an investigation, potential *Legionella* sources may be identified. These may include systems or devices with inadequate treatment or maintenance and/or with positive testing results which identify a different *Legionella* strain. Additional steps to remediate such potential sources may be required. These will be based on the opinion of the MHO and applicable legislation and regulations, depending on the extent of the hazard and the population exposed.

According to the hierarchy of controls, the most effective controls are implemented preferentially, wherever possible (31). Namely, elimination of the outbreak source should be considered followed by substitution of the contaminated device or medium, engineering controls, administrative controls and personal protective equipment.

4.1 Mandate

The MHO has the legislative authority to require actions be taken to control an outbreak.

The owner of the device, system or facility identified as the outbreak source is responsible for:

- Developing a remediation plan and/or other requirements as determined by the MHO; and
- Implementing and paying for the control measures

If needed, the owner can obtain assistance from public health authorities or contracted technical experts to develop the remediation plan and/or implement control measures. The plan should take into account the relevant regulations associated with the outbreak source.

Based on a risk assessment, professionals working on or near a *Legionella* source should take the precautions necessary to limit their own risk, such as wearing personal protective

equipment (PPE). Occupational health should be consulted and the *Occupational Health and Safety Regulation* must be followed.

4.2 Control Methods

The main control steps involve water treatment and disinfection. This includes physical cleaning, an initial shock treatment to remove contamination followed by adequate ongoing treatment (see Table 6). Depending on system type, disinfection can be done by thermal or chemical means or both. Combined disinfection (e.g. combined thermal and chlorine disinfection) is most effective. Wherever possible, physical cleaning needs to occur prior to chemical disinfection since chemicals do not penetrate biofilms or solids. Although thermal disinfection eradicates bacteria found in solids, physical removal of the solids should be done to improve heat penetration and prevent re-contamination.

Next, address all the features of the system that may have contributed to the outbreak. These include, but are not limited to, identifying and eliminating dead legs in the piping, maintaining the appropriate water flow, temperatures and disinfectant residuals and other water quality parameters (pH, corrosion & scale control, water cycling) to avoid *Legionella* growth, verifying the effective use of in-line filters, identifying infrequently used circulation pumps which may contribute to water stagnation, checking for and repairing mechanical and other equipment defects, and minimizing misting and aerosol production.

Finally, conduct a review of operation and maintenance procedures to ensure they are appropriate and adjust them when necessary (e.g. frequency and scope of inspections and cleaning, adequacy of chemical treatment systems). Control methods and testing protocols recommended by Public Works and Government Services Canada (35) may also be considered.

Table 6. Disinfection for *Legionella* (see Appendix 7 for more details)

Types	Steps	Considerations
Thermal disinfection	Flush the entire system at >70°C for at least 30min[17] (29)	• Only applicable to hot water systems. • Ensure that the device or system can withstand high temperatures. • High water temperatures can cause scalding. Minimize potential for aerosolization and other contact. • Best done when few people are onsite or few people need the water. • Some hot water systems may have insufficient supply or pressure to support thermal disinfection. • Dead legs or blind ends cannot be effectively flushed and will cause recontamination of water system; attempt to remove or close off.
Chemical disinfection (31, 33, 34)[18]	• Remove sediment, sludge, scale and biofilms with physical cleaning before chemical disinfection • Flush the system with a chemical disinfectant • Chlorination is most often used. It is available in gas, liquid and pill forms. • In potable water systems, use at 50ppm for a minimum contact time of 1h with a residual of 30ppm. Flush the system with clean water to reach 0.5-1.0ppm (29, 30). • In cooling towers, during shock treatment, maintain circulation throughout the system at pH<7 and a residual of >5ppm for ≥6h or 15ppm for ≥2h (35)	• Cleaning in & around equipment requires appropriate safety measures re: moving parts, chemicals, etc. • Industry terms for disinfection may include 'on-line' (with the equipment running) and 'off-line' (with the equipment shut off) • Ensure the device or system can withstand the chemical. • Address the risk that chemicals and their by-products may contaminate the system. • Ensure chemicals are compatible with each other (i.e. do not neutralise) • Chlorination targets a range of pathogens, can be used in hospital systems, but can be corrosive to pipes

[17] The time it takes depends on the water temperature when it reaches the outlets (31).
[18] Other treatments (e.g. monochloramine, chlorine dioxide, silver stabilised hydrogen peroxide, copper silver ionisation) exist but are either experimental or used mainly in industrial settings (31, 34).

The following section summarizes specific steps to consider for different sources.[19] Advice from individuals that are familiar with the water system should also be included whenever possible. This may include staff responsible for operations and maintenance, plumbers, engineers or building inspectors.

4.2.1 Control Methods for Select Water System Types

Small aerosol-producing devices (e.g. hot tubs, showers, fountains, humidifiers, sprinklers, emergency eye showers) (36, 37)[20]

1. Discontinue use and close access
2. Shut off the implicated system
3. Drain all water; dispose to waste or as directed by local by-laws
4. Scrub surfaces with a chemical disinfectant, where applicable
5. Rinse with clean water
6. Disinfect with thermal or chemical disinfection or both, where applicable (Table 6)
7. Remove and replace any defective components or components that cannot be disinfected
8. Flush with clean water

Potable water system (e.g. hospital or other facility water system) (20, 29, 32, 38, 39)[21]

1. Consider shutting off affected part of the system, if possible
2. Disinfect with thermal or chemical disinfection or both (Table 6)
3. Drain and clean water tanks (including descaling if necessary) after thermal disinfection
4. Remove and replace any damaged or at-risk components or components that cannot be disinfected
5. If the system has recurring issues with *Legionella* growth, consider installation of a secondary disinfection system (e.g. copper ion, UV, Ozone)

[19] It is assumed at this point that environmental samples have already been collected. If they have not, attempt to collect them prior to the system shut down or shortly thereafter.

[20] Specific guidance for hot tubs can be found here: http://www.cdc.gov/legionella/downloads/hot-tub-disinfection.pdf

[21] The recommendations for remediation of hospital water systems vary by jurisdiction. See (20) for a review of these recommendations.

Cooling systems (including cooling tower, evaporative condenser, HVAC and other components) (35, 38, 40, 41)

Different agencies recommend slightly different sequences or series of steps. The following proposed steps were modeled on Public Works and Government Services Canada recommendations (35). As there are thousands of patented Cooling Tower and Evaporative Condenser designs on the market, the steps must be tailored to each machine brand/model.

Consult an engineer or other qualified person that is familiar with the system. Guidance documents or standards from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), Public Services and Procurement Canada (PSPC) or the American Industrial Hygiene Association (AIHA) specific to cooling systems can be used.

1. Prepare system for disinfection (Some systems are designed to continue to operate while others must be shut down
2. Conduct physical cleaning
3. Conduct chemical disinfection by shock chlorination (Table 6)
    a. Maintain free chlorine residual of ≥5ppm for ≥6h or ≥15ppm for ≥2h and pH <7.5 (tested every 30 min)
4. Resume water treatment program with scale and rust inhibitors and biocides

4.2.2 Reflex Remediation of Suspected Source

Delay in sampling and testing for *Legionella* can be a barrier to timely risk mitigation (42, 43). As a result, reflex remediation may be considered. In BC, this is defined as the application of control measures to a suspect source prior to the availability of testing results, based on evidence from the other components of the outbreak investigation. Reflex remediation may include testing, cleaning, in-line disinfection, system shutdown or other actions.

The decision to conduct reflex remediation is informed by considerations such as:

- Potential for ongoing exposure (particularly to at-risk populations)
    - Is there risk of further exposure to at-risk populations (including older adults and individuals with risk factors for clinical infection)?
- Certainty of causation
    - What is the certainty that the suspected source is the cause of the outbreak, based on the epidemiological and environmental evidence?

- Criticality of device/system
    - Is the function of the device/system critical (e.g. decorative vs. required for temperature control of life-saving equipment)?
- Maintenance and performance history of device/system
    - Do the records and/or inspection identify current concerns?
- Anticipated timeframe for testing results
    - Will sampling and/or testing results be significantly delayed?

Reflex remediation is increasingly used, including in BC. Examples from select jurisdictions are summarized in Table 7. All pertain to cooling towers but may be relevant to other water system types. Some jurisdictions apply reflex remediation within a certain radius of an exposure source, outbreak zone or centroid of cases but the distance used varies and is dependent upon the local context and history of outbreaks.

Table 7. Policies or practice from select jurisdictions related to reflex remediation of *Legionella* outbreak sources

Jurisdiction	Key elements
Fraser Health Authority (2018 and 2020 cooling tower outbreaks)	• Identify and notify cooling tower operators in a 2km radius from case centroid to test and clean towers • All towers that test positive are resampled by FHA and tested by PHL
New York City Department of Health and Mental Hygiene (44)	• Sample all cooling towers in outbreak zone • All towers that test positive are cleaned and disinfected
Victoria State Government (Australia) SOP: Environmental investigation and response to a legionellosis case, cluster or outbreak (45)	• Identify all cooling towers within 500 meters of exposure site(s) • Test and disinfect all towers identified
Public Services and Procurement Canada, MD 15161 – 2013: Control of Legionella in mechanical systems (35)	• Increase routine testing frequency of systems under existing monitoring plan when multiple cases of Legionnaire's disease are reported in area • Follow corrective actions based on result and water system type[22] (see Table 8)

[22] Interpretation of results by water system type is found in Figures 1-4. Full document can be found here: https://www.tpsgc-pwgsc.gc.ca/biens-property/documents/legionella-eng.pdf (35).

4.3 Testing and Restarting a Remediated Outbreak Source

The water at the source or suspected source of a *Legionella* outbreak should be retested before the device or system is restarted or placed on line (in full operation) as it is possible that disinfection may have been inadequate or physical cleaning may have dislodged additional bacteria. The Medical Health Officer can require proof that the remediation treatment was effective. In household and/or small water systems, testing may not be needed but a risk assessment should be conducted to assess ongoing risk, including assessment of adequate treatment.
As previously described, the collection of water samples connected to a *Legionella* outbreak in BC is coordinated by the health authorities and testing is completed by the provincial Public Health Laboratory.

In a drinking water system or small aerosol-producing device, *Legionella* should be non-detectable (Lp_{tot} concentration <1 cfu/mL). If *Legionella* is greater or equal to 1 cfu/mL, reassess and repeat the disinfection steps. If *Legionella* is less than 1 cfu/mL, consider ongoing testing as per the water management plan.

In a cooling system, even after disinfection, there may still be some *Legionella* present. If the concentration is low, the risk of an outbreak is low. If the Lp_{tot} concentration is <10 cfu/mL then the system can be considered for re-opening. Repeat the disinfection step if the Lp_{tot} concentration is $\geq$10 cfu/mL but <1000 cfu/mL (35). Above this range, factor in environmental and epidemiological information along with microbiological results to assess the next course of action. See Table 8[23] for recommended actions based on *Legionella* culture results in various water system types.

[23] Note that Table 8 is based on Public Services and Procurement Canada MD 15161 (35) and was originally written for commercial and office buildings.

Table 8. Actions to be taken based on post-disinfection *Legionella* testing results in an outbreak setting by water system type. (Adapted from reference 35)

SYSTEM TYPE	*Legionella* culture result (cfu/mL)[24]	RECOMMENDED ACTIONS		
		Re-open system	Clean and disinfect on-line (continue to operate)	Immediately eliminate water dispersion by aerosol
Small aerosol-producing devices	Lp_{tot} <1	✓		
	1 ≤ Lp_{tot} ≤100		✓	
	Lp_{tot} >100		✓	✓
Potable water systems (excluding healthcare facilities)*	Lp_{tot} <10	✓		
	10 ≤ Lp_{tot} ≤100		*Flush storage tank then disinfect*	
	Lp_{tot} >100		*Flush storage tank then disinfect*	✓
Cooling systems	Lp_{tot} <10	✓		
	10 ≤ Lp_{tot} ≤1000		✓	
	Lp_{tot} >1000		✓	✓

*For potable water systems in healthcare facilities, the BC *Legionella* Guidelines Working Group recommends that *Legionella* bacteria should not be detected (Lptot <1 cfu/mL).

Once a system has tested satisfactorily, there may be a need to continue testing for a period of time. The frequency and duration of retesting should be determined by the outbreak team, developed with consideration to the source of the outbreak, the risk to the public, and be included in the remediation plan. Several US and Canadian guidelines recommend sampling every 2 weeks for 3 months or every month for 3 months but the evidence for these frequencies is not conclusive (29, 32, 36, 39).

[24] The values in this table could also be based on results obtained through qPCR, if available.

Outside of outbreak scenarios, the Public Services and Procurement Canada (PSPC) standard recommends increased testing frequency when *Legionella* bacteria are detected within 90 days after a system has been disinfected (35). Routine testing frequencies resume once test results are within acceptable ranges. Testing frequencies and acceptable ranges vary by system type as specified in the PSPC standard[25].

5.0 Prevention of *Legionella*

Once an outbreak has been controlled, efforts should be aimed at the prevention of future outbreaks. Best practice is for routine monitoring and other preventive measures to be in place for systems and devices at risk of *Legionella* contamination and aerosolisation, regardless of the presence or absence of an outbreak history related to the system.

The purpose of this section is to provide public health professionals with the information necessary to ensure system and device owners are implementing best practices to routinely prevent the contamination, growth and dissemination of *Legionella*. These recommendations and procedures may differ from outbreak investigation and control measures.

The owner of a facility is responsible for preventive maintenance of at-risk devices and systems (BC Occupational Health and Safety Regulation and Canada Occupational Health and Safety Regulations). In the case of a drinking water system in a healthcare facility or large building and of a cooling system, this should be documented in the form of a water safety plan/program, a facilities management plan or a preventive maintenance program (46).[26] Industry standards should be followed in all cases (31, 35, 47, 48).

Regional health authorities, municipalities and building maintenance companies may consider including seasonal messaging around preventive maintenance of at-risk devices

[25] Testing protocols by system type can be found in Figures 1-4 here: https://www.tpsgc-pwgsc.gc.ca/biens-property/documents/legionella-eng.pdf (35). Refer to 'Emergency Mode' criteria for increased testing frequencies.
[26] Guidance for the development of a Water Management Program can be found here: http://www.cdc.gov/legionella/downloads/toolkit.pdf (46).

and systems in their communication plans. Current best practice in BC is considered to be the federal Public Works and Government Services Canada standards or MD 15161 – 2013 Control of Legionella in Mechanical Systems for non-healthcare facilities and the CSA Z317.1 Special Requirements for Plumbing Installations in Healthcare Facilities for healthcare facilities (35, 57).

5.1 Risk Minimisation

Legionella risk minimisation can be accomplished by (11):

- Appropriate design and installation (applicable to new systems and repairs)
  - Minimise stagnation and dead legs which lead to biofilm formation, sediments and deposits
  - Select materials that do not act as substrates or provide nutrients for biofilm formation
  - Ensure access to water sources for maintenance activities
  - Ensure location of cooling towers provides adequate distance from building air intakes and sources of bio-matter (e.g. trees, kitchen exhausts)
  - Ensure location of humidifiers in ducts allow for absorption of water mist
  - Ensure drain pans can drain properly
- Proper operation of equipment
  - Prevent low flow rates and stagnation of water
  - Be aware of, and address risks associated with, flushing (aerosolisation), restarting (dislodging of biofilms), and construction (contamination of exposed water systems)
  - Conduct regular inspections and regular cleaning
- Temperature control
  - Where possible, keep the temperature outside the range for *Legionella* growth (25-50^{o}C)
    - Maintain cold water at <20^{o}C
    - Maintain circulating hot water at >50^{o}C (>60^{o}C in hot water tank) (49)
  - This may not be possible in cooling towers and potable water systems
    - Maintain water temperature at the limits of the *Legionella* growth range
    - Conduct periodic flushing at 50-60^{o}C

- Regular disinfection to control biofilm formation and protozoal and *Legionella* growth
    - Regular use of disinfectants (e.g. chlorine), biocides (e.g. bromine) including oxidizers and pH adjusters

5.2 Monitoring Control Measures

The operation of at-risk water systems should include a monitoring plan and any site-specific safety protocols and PPE needed to maintain this plan. Components of a monitoring plan may include:

- Ensuring preventive measures are being conducted,
- Conducting visual inspections,
- Testing routine parameters (e.g. water temperature, pH, chemical residuals) and
- Microbiological testing through private labs[27]

Consideration can be given to including microbiological testing of *Legionella* bacteria in water systems as part of the overall monitoring plan (30-32, 39, 47). Periodic *Legionella* testing can help validate the effectiveness of preventive controls and lead to system adjustments. Microbiological testing for routine monitoring purposes can be completed through private laboratories. Buildings operated and/or leased by the federal government may follow their own standards for *Legionella* control and some municipalities may have specific by-laws with similar requirements.[28]

The decision to test should be based on an overall risk assessment. Higher risk systems that may warrant this include, but are not limited, to the following:

- Water systems where appropriate controls are difficult to maintain (e.g., cooling towers)
- Systems serving, or potentially exposing high-risk populations (e.g., transplant units in hospital settings)
- Water systems previously colonized or suspected to be colonized with *Legionella*

[27] Ensure private labs are ISO 17025 certified (or equivalent) and/or participate in external proficiency testing such as the US CDC Environmental Legionella Isolation Techniques Evaluation (ELITE) Program. Labs that meet ISO 11731 (Enumeration of Legionella) can also be considered.

[28] The BC *Legionella* Guidelines Working Group (2020) advises that current best practice for routine monitoring of *Legionella* in non-healthcare facilities in BC is the Public Works and Government Services Canada standard (35).

- Systems where routine parameter testing has detected a problem

As outlined in Appendix 2, a wide variety of water systems may act as reservoirs for *Legionella*. Monitoring protocols will differ between types of systems, and may also differ between specific systems of the same type. As previously stated, non-healthcare facilities can refer to MD 15161 – 2013 Control of *Legionella* in Mechanical Systems (35) for best practices or Table 8. If a threshold for action is met, preventive steps should be taken immediately to mitigate the risk.

A review of US guidelines for the primary prevention of legionellosis identified a variety of monitoring recommendations (17). Several national, state and local guidelines recommend monitoring water for *Legionella* in certain healthcare facilities/units. The types/location of water samples, the frequency of testing and the threshold for action all vary. An Institut National de Santé Publique du Quebec literature review and expert consultation concluded that routine healthcare facility testing of *Legionella* may not be feasible or useful for primary prevention (52). Although the risk of legionellosis is higher when the concentration of *Legionella* in the water system is higher, the infectious dose for *Legionella* is not known and therefore the threshold for action cannot be set with certainty (52). This same document recommends preventive measures, particularly water temperature control, to control *Legionella* in healthcare facility water systems (see Section 5.1).

Healthcare settings
There is no safe threshold levels of *Legionella* established for healthcare settings. The BC Provincial Infection Control Network (PICNet) (2021) and the BC *Legionella* Guidelines Working Group (2020) recommend that any detectable levels in healthcare settings be actionable by further investigation, review of prevention and control measures, and appropriate corrective actions taken to ensure levels are below detectable levels.

The CSA Z317.1-16 for plumbing installations in health care facilities recommends testing as a means to verify disinfection/treatment and water treatment protocol, tracing the source of outbreak or on a proactive basis to support inspections and maintenance of water systems (57).

Cooling tower registry
A few health authorities have implemented requirements for the registration of cooling towers, other building water systems as well as regular testing for, and reporting of, *Legionella*. Registration facilitates identifying and locating cooling towers during an outbreak and regular testing and reporting (where mandated) allows for oversight of practices and results. A registry can also facilitate communication with cooling tower owners/operators.

In 2019, the City of Vancouver implemented a by-law requiring an operating permit and regular testing for *Legionella* in cooling towers and certain building water systems (http://vancouver.ca/operating-permit). In 2014, the province of Quebec legislated that all cooling towers must be registered and tested for *Legionella* on a regular basis (20). If the result shows >1,000,000CFU/L (>1000CFU/ml) of *L. pneumophila*, the owner has to inform the authorities and take corrective measures. New York State also legislated similar requirements in 2016 (53). In Europe, several countries require cooling towers to be registered with local authorities and monitored for *Legionella* regularly (49).

5.3 Novel Water Uses and Technologies

Alternative water sources
There is increasing interest and use of alternative water sources such as rainwater and greywater (e.g. water from showers, bath, laundry) in non-potable applications such as household (http://publications.gc.ca/collections/collection_2014/schl-cmhc/NH15-474-2013-eng.pdf), community (e.g. living walls) and industrial uses. No *Legionella* outbreaks associated with these alternative water sources have been reported to date but as with other water sources, these still have the potential to contain *Legionella* (http://www.wateronline.com/doc/how-prevalent-is-legionella-in-recycled-water-0001)
The risk of *Legionella* growth increases when water is stagnant, warm and contains nutrients (see section 1.3.1). The risk of *Legionella* transmission is present if the water may be aerosolised. These factors should be assessed when reviewing or approving water reuse projects.

New technologies
Devices that use water and create mist or aerosols are at risk of transmitting *Legionella*. Any new technologies/devices should follow the manufacturer's instructions to disinfect and prevent contamination.

In 2016, heater-cooler units used in cardiac surgery were linked to legionellosis in Washington State (http://www.seattletimes.com/seattle-news/health/operating-room-machines-test-positive-for-legionella-at-uwmc/). In 2011, an outbreak of legionellosis occurred in a paper shredding plant (www.promed.org, posting 20110826.2604). The source was believed to be the shredder which used water for cooling and lubrication purposes. There have been several case reports of neonatal legionellosis associated with water births (www.promed.org, posting 20170608.5093537). Devices/processes should be used according to the Manufacturer's Instructions for Use. If they create mists and aerosols, they should be used with caution with high risk individuals and be considered a potential source during an outbreak investigation.

New processes such as composting on a large scale may also increase legionellosis risks (54). In 2015, a case of *L. longbeachae* occurred in a compost worker in BC.

5.4 Education for Public Health Professionals

Awareness and understanding of *Legionella* disease, epidemiology and risk factors is necessary to enable rapid identification, investigation and control of outbreaks as well as to implement and monitor preventive actions. Professionals in public health, laboratories, infection control, industrial hygiene and building engineering should have this knowledge and organizations can support this through ongoing training and education.

6.0 Appendices

Appendix 1: Risk Factors for *Legionella* Infection by Source (Source: WHO) (11)

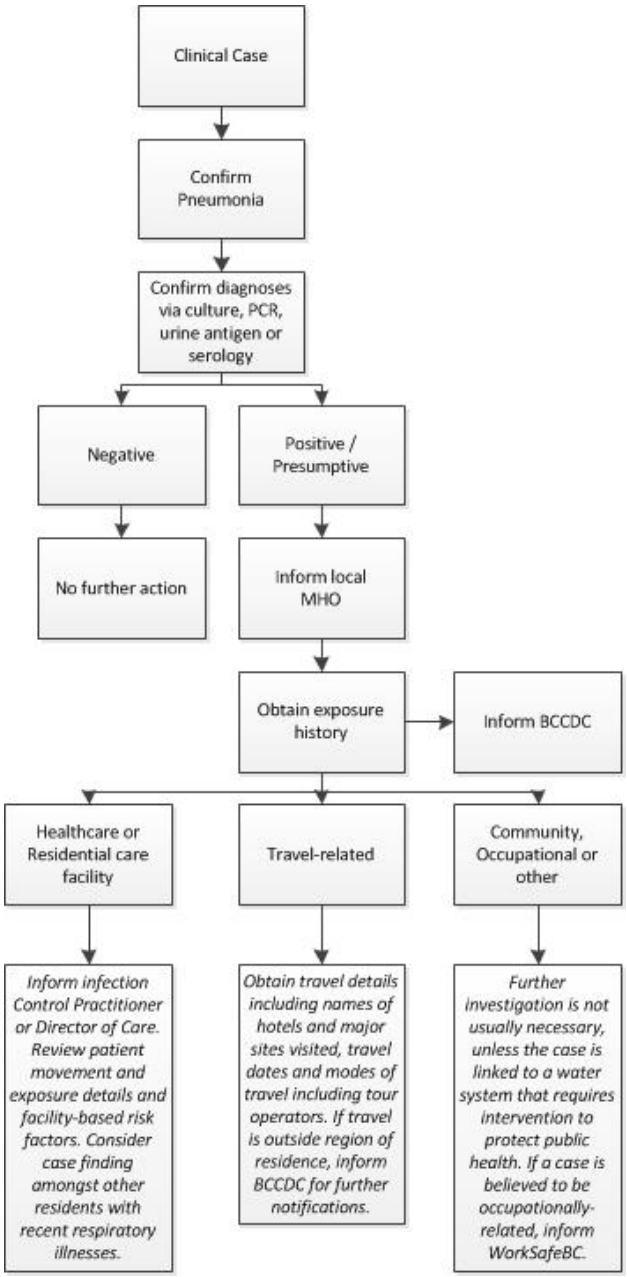
	Cooling water systems	**Hot and cold-water systems**	**Hot tubs Natural spa pools Thermal springs**	**Humidifiers Respiratory equipment**	**Potting mixes Compost**
Commonly implicated *Legionella* species	Predominantly *L. pneumophila* sg* 1	*L. pneumophila* sg 1, 2 ,4, 6, 12, *L. micdadei, L. bozemanii, L. feeleii* and others	*L. pneumophila* sg 1, *L. micdadei, L. gormanii, L. anisa*	*L. pneumophila* sg 1,3 and others	Exclusively *L. longbeachae*
Modes of transmission	Inhalation of aerosol	Inhalation of aerosol, aspiration	Inhalation of aerosol, possible aspiration	Inhalation of aerosol	Direct contact or inhalation of aerosols
Disease outbreaks	Rapid onset over wide area, resolve within incu-bation period	Low numbers of cases over prolonged periods	Rapid onset confined to users and those in close proximity	Low numbers over prolonged periods. Rapid onset confined to users and those in close proximity	Low numbers of cases over prolonged periods
Risk factors (environmental)	Proximity of population, seasonal/climatic conditions, intermittent use, poor maintenance, poor design	Complex water systems, long pipe runs, poor temperature control, low flow rates/ stagnation	Poor maintenance, stagnant areas in system	Use of non-sterile water, poor mainten-ance / cleaning, operation at temperatures conducive to *Legionella* growth	Seasonal (spring and autumn), use of potting mixes/compost gardening

*sg = serogroup

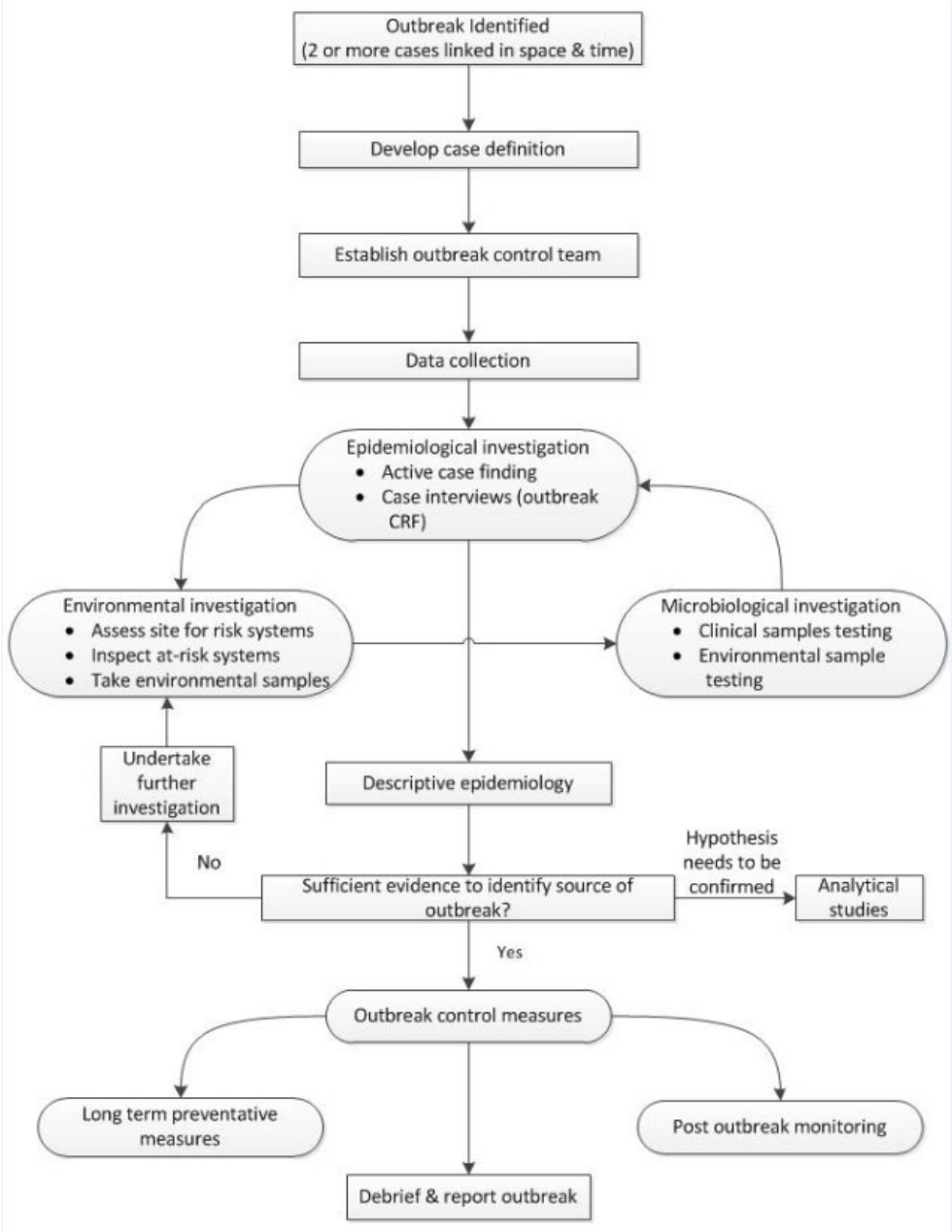
Appendix 2: Potential *Legionella* Sources in Installations (Adapted from Irish Health Protection Surveillance Centre) (19)

High Risk Sources	Other Risk Sources
Cooling towers/evaporative condensers/air conditioning systems and hybrid systems – associated with major community outbreaks	High pressure hosing/cleansing
Potable hot water systems (particularly in hospitals, hotels, leisure facilities and care homes to a lesser extent) – often related to shower-heads	Car/train wash
Whirlpools/spa baths (both 'display' and leisure)/birthing pools, Fountains	Industrial water systems (for example concrete batching plants, aqueous tunnel washers)
	Plant and machinery cooling systems (which are open)
	Commercial irrigation system (e.g. used in sports venues)
	Sewage plants
	Ship water pump repair
	Growing media / composted green waste (specific species: *L. longbeachae*)
	Garden sprinkling water systems (both from indoor and outdoor taps)
	'Respiratory therapy devices' which generate aerosols; 'Aerosolising' devices
	Contaminated hospital equipment
	Hot spring bath water
	Public bath water
	Ice machines
	Dental equipment
	Food display humidifiers
	Air humidifiers

Appendix 3. *Legionella* Single Case Investigation Flowchart (see Section 2.2) (55)



Appendix 4. *Legionella* Outbreak Investigation Flow Chart (see Section 3.1 for details)



Appendix 5. System characteristics to consider during inspection (27, 31, 35, 47, 56)

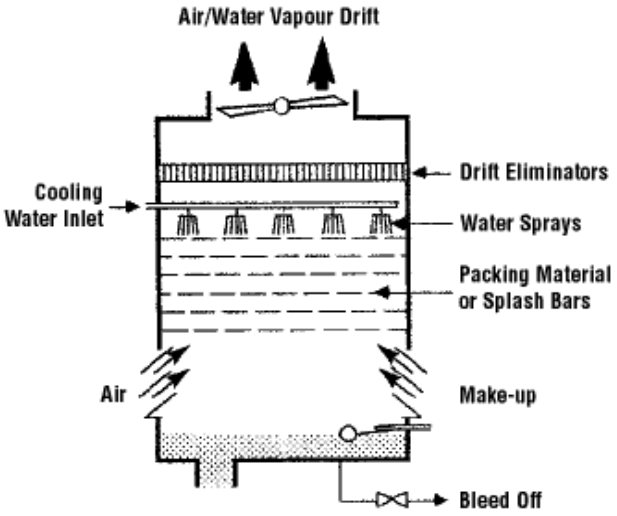
System	Characteristic	Interpretation
Cooling towers, evaporative condensers	Proximity to air intake/outlet	To assess proximity to cases and locations to sources of contamination/debris (e.g. dust, pollen, trees, exhaust, smoke)
	Location of device	
	Type of cooling tower (model, serial number etc.)	e.g. Natural Draft Spray, Induced Draft, Counter Flow Induced Draft, or Cross Flow Induced Draft Tower and evaporative condensers in conjunction with HVAC systems
	Use of drift eliminator, location of demister, presence of dead legs	To assess whether mechanical devices reduce amount of water droplets and mist and/or have stagnation risks
	Visible condition	To determine physical damage, presence of leaks in cooling tower, into air exchange or building HVAC and the presence of visible bacterial growth or biofilm and debris
	Use of algaecide or biocide (and method of application)	To determine use of these treatment chemicals (e.g. halogen, residual oxidants) in recommended concentrations and log of routine testing regimen
	Date of installation	To assess age of system, construction material, risk of sediment, rust and other deposits, biofilms, stagnancy/dead legs, past control measures, potential risk factors, whether recent cleaning or intermittent operation
	Water management plan, operation record	
	Routine maintenance, service records, repair history, preventive work records	
	Service company contact information	To obtain further information on past control measures and potential risk factors
	Connections to potable water system/non-potable water sources (industrial)	To assess quality of feed water, risk to others and water treatment in use
	Water temperature	Growth range between 25 to 50^{o}C
	Backflow prevention (BFP)	High risk areas should have BFPs that are maintained and inspected.

System	Characteristic	Interpretation
Domestic water systems	Area served	To assess proximity to case locations and vulnerable populations
	Date of installation	To assess risk of sediment, deposits, biofilms, stagnancy and whether recent cleaning or intermittent use
	Supplier	
	Chlorine residual	To characterize water in the system and loss of residual at different points in system; within appropriate range?
	Temperature at proximal and distal locations	To determine if adequate for prevention of *Legionella* growth
	Water recirculation	To determine if dead zones or stagnant areas; if recirculation is continuous or scheduled
	Backflow prevention (BFP)	High risk areas should have BFPs to ensure not contaminating facility that are maintained and inspected
	Water heaters or break tanks	Assess settings to determine if temperature suitable for *Legionella* growth
	Tank design	Side heaters (as opposed to bottom heaters) increase *Legionella* growth risk
	Dead legs in plumbing designs	Assess increase risk of low-flow or stagnant water in pipes
	Shower heads and point of use (near, mid, distal)- design and locations	Determine proximity to cases, if used regularly, ability to create aerosols, potential reservoir for biological growth, presence of aerators
	Maintenance records	Cleaning schedule and adequacy
	Supplemental disinfection system for control of *Legionella* or other microorganisms	To assess that adequate Quality Assurance/Quality Control measures used to ensure necessary disinfection
Humidifiers, fountains, misters, irrigation systems (e.g. water picks),	Indoor vs. outdoor	Useful for determination of pathway for exposure, temperature variations
	Visible condition	Visible bacterial or fungal growth on surface walls and unclear water indicate presence of biofilms

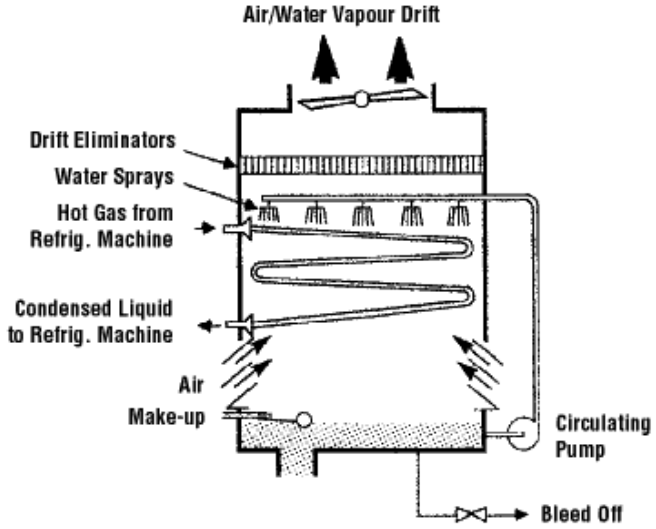
System	Characteristic	Interpretation
emergency equipment (e.g. eye wash/showers), fire suppression systems and other water features	Use of algaecide or biocide	Assess if in use and in sufficient concentrations to prohibit growth
	Water supply	To assess feed water purity (eg., residual chlorine/halogenation)
	Filtration	Type and maintenance of filter, assess as source of biofilm growth
Spas, whirlpools, hot tubs	Indoor vs. outdoor	Useful for determination of exposure routes, temperature etc.
	Visible condition	To assess visible debris, dead legs, aerosol generation
	Chlorine/bromine concentration	Determine if within required range
	pH	Growth range between pH 5.5 to 9.2
	Cyanuric acid level	Determine if within required range
	Type of filters	Assess maintenance practices
	Date last backwashed	Assess maintenance practices
	Date last drained and scrubbed	Assess maintenance practices
	Temperature	Growth range between 25 to 50^{o}C
	Visible biofilm layer (check skimmer baskets too)	Biofilms can be sites for legionella colonization
	Fill water supply	Should be from approved source with backflow preventer; Assess levels of chlorination and sediment/opacity
	Review and obtain copy of maintenance records	To assess residual sampling (chemicals & biological culture tests including surrogate bacterial indicators –Total Coliforms, fecal coliforms), cleaning, water changes, etc.
	Adequate ventilation	Air flow supply rates from the local air handling system

Appendix 6: Diagram of a cooling tower (a) and evaporative condenser (b) (Source: Canadian Centre for Occupational Health and Safety)

A. Cooling tower



B. Evaporative condenser



Appendix 7: Water Treatment and Disinfection Options against *Legionella* (11, 47, 48)

Treatment	Method of Action	Pros	Cons
Thermal	- Kills via heat - Damages cell wall/envelope - Denatures vital proteins	- Effective against range of organisms - Not corrosive to piping - Readily available for emergency use - Found in current infrastructure for hot water systems - Typically doesn't require vendors - Inexpensive	- Difficult to achieve and maintain adequate temperature throughout the system - No residual action - May not be very effective against biofilm - Likely re-colonization if no further action - Scalding risk - Potential damage to temperature sensitive equipment - Time consuming if large system
Chlorination[29]	- Oxidation - Sodium hypochlorite or chlorine gas	- Targets range of pathogens - Recommended for use in hospital water treatment (CDC, 2003) - Adequate residual concentration - Various forms: gas, solution, tablets, powder, etc. - Wide range of pH - Inexpensive	- Powerful oxidant, corrosive to pipes - Efficacy impacted by temperature, pH - Gas is toxic even at low levels; stringent isolation controls are required in BC - Biofilm penetration limited - Aesthetic properties (odor) - May produce regulated disinfection by-products (e.g., trihalomethanes, haloacetic acid) - Introducing chlorine into a plumbing system can cause backflow issues.

[29] Other chemical disinfectants also exist. Consult references (11, 47, 48)

Appendix 8: Resources for Site Assessment and Sampling Plan (27, 29)

- Review 3.2 Environmental Investigation Including Microbiological Sampling
- Contact/notify BCCDC PHL Environmental Microbiology Laboratory at 604-707-2620
- Print Water Bacteriology Requisition Forms (http://www.elabhandbook.info/PHSA)
- Consult resources below (not all details may be applicable)

Resource	Description	URL
US CDC – Legionella Environmental Assessment Form (27)	• Preparations before arriving on site • How to measure water parameters • Template for environmental assessment • Informs development of sampling plan	https://www.cdc.gov/legionella/downloads/legionella-environmental-assessment.pdf
US CDC – Interpreting the Environmental Assessment for Legionellosis Outbreaks	• Supplements document linked above • (Video, *10:12 minutes*)	https://www.youtube.com/watch?v=fRnAsRYjzis
US CDC – How to Make a Sampling Plan for Legionellosis Outbreak Investigations	• Case study demonstrating how to select sampling sites after Environmental Assessment has been completed • (Video, 5:14 minutes)	https://www.youtube.com/watch?v=xeFa2P2rddE
US CDC – Other videos related to Legionella	• Legionella Ecology (*14:49 minutes*) • How to Sample Potable Water (*7:11 minutes*) • How to Sample Cooling Towers (*5:15 minutes*) • How to Sample Spas and Fountains (*7:32 minutes*)	https://www.cdc.gov/legionella/videos.html

Sampling equipment to bring on-site

- Personal protective equipment if needed
- Sterile DNA/RNA free water bottles containing sodium thiosulfate
- BCCDC PHL Water Bacteriology Requisition Forms
- Chlorine/halogen/residual oxidant test kit, turbidity meter
- Flashlight, camera
- pH test kit
- Calibrated thermometer
- Ziploc bags for sample bottles
- Field data sheets to record site investigation details

Instructions for *Legionella* sampling (3.2.3)*:*

- Bring enough bottles (2x1L bottles or 10x200ml drinking water bottles)
- Measure chlorine level for each sample and record on requisition (under *Recreational And Other Water* section)
- Complete Water Bacteriology requisition form and write "Legionella testing" under "Test Information"
- If samples other than water are being collected (ie. biofilms, swabs, soil, compost or other), contact BCCDC PHL at 604-707-2620 for additional instructions.

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