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Standard Guide for the Inspection of Water Systems for Legionella and the Investigation of Possible Outbreaks of Legionellosis (Legionnaires' Disease or Pontiac Fever)[1]

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1. Scope

1.1 This guide covers appropriate responses for employers, building owners and operators, facility managers, health and safety professionals, public health authorities, and others: (*1*) to a concern that a water system may be contaminated with the bacterium known as legionella (see 6.1); and (*2*) to the identification of one or more cases of Legionnaires' disease or Pontiac fever (see 6.3 – 6.5). Comprehensive and explicit recommendations to limit legionella multiplication in water systems, disinfect potential sources of human exposure to legionella, and prevent health-care associated infections are beyond this guide's scope.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* See 7.3 and 8.5 for specific hazard statements.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C1080 Specification for Asbestos-Cement Products Other Than Fill For Cooling Towers
D512 Test Methods for Chloride Ion In Water
D596 Guide for Reporting Results of Analysis of Water
D887 Practices for Sampling Water-Formed Deposits
D1067 Test Methods for Acidity or Alkalinity of Water
D1129 Terminology Relating to Water
D1293 Test Methods for pH of Water
D1356 Terminology Relating to Sampling and Analysis of Atmospheres
D2331 Practices for Preparation and Preliminary Testing of Water-Formed Deposits
D3370 Practices for Sampling Water from Closed Conduits
D3856 Guide for Management Systems in Laboratories Engaged in Analysis of Water
D4840 Guide for Sample Chain-of-Custody Procedures
E645 Practice for Evaluation of Microbicides Used in Cooling Water Systems
F444 Consumer Safety Specification for Scald-Preventing Devices and Systems in Bathing Areas
F445 Consumer Safety Specification for Thermal-Shock-Preventing Devices and Systems in Showering Areas

2.2 *APHA Documents:*[3]

Public Health Law Manual, Third Edition
Standard Methods for the Examination of Water and Wastewater, Twenty-first Edition
Control of Communicable Diseases Manual, Eighteenth Edition

2.3 *ASHRAE Documents:*[4]

Codes and Standards. 2004 ASHRAE Handbook—Heating, Ventilating, and Air-Conditioning Systems and Equipment
Cooling Towers. 2004 ASHRAE Handbook—Heating, Ventilating, and Air-Conditioning Systems and Equipment
Water Treatment. 2004 ASHRAE Handbook—Heating, Ventilating, and Air-Conditioning Systems and Equipment
12–2000 Minimizing the Risk of Legionellosis Associated with Building Water Systems
62.1-2007 ASHRAE Standard. Ventilation for Acceptable Indoor Air Quality

[1] This guide is under the jurisdiction of ASTM Committee D22 on Air Quality and is the direct responsibility of Subcommittee D22.08 on Sampling and Analysis of Mold.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Public Health Association (APHA), 800 I St., NW, Washington, DC 20001, http://www.apha.org.

[4] Available from American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329, http://www.ashrae.org.

2.4 *ASM Documents:*
Manual of Clinical Microbiology, Ninth Edition[5]
Manual of Environmental Microbiology, Third Edition[6]
Manual of Molecular and Clinical Laboratory Immunology, Seventh Edition[7]

2.5 *AWT Document:*[8]
Legionella 2003: An Update and Statement by the Association of Water Technologies (AWT)

2.6 *CDC Documents:*[9]
2000 Guidelines for Preventing Opportunistic Infections Among Hematopoietic Stem Cell Transplant Recipients
2003 Guidelines for Environmental Infection Control in Health-Care Facilities
2003 Guidelines for Preventing Health-Care-Associated Pneumonia
2005 Procedures for the Recovery of Legionella from the Environment
2005 Case Definition for Legionellosis (*Legionella pneumophila*)

2.7 *Code of Federal Regulations:*[10]
42CFR84 Title 42, Volume 1, 84. Approval of Respiratory Protective Devices

2.8 *CTI Document:*[11]
Legionellosis Guideline: Best Practices for Control of Legionella

2.9 *OSHA Document:*[12]
2003 Occupational Safety and Health Administration (OSHA) Technical Manual, Section III: Chapter 7, Legionnaires' Disease

2.10 *WHO Document:*[13]
Legionella and the Prevention of Legionellosis

3. Terminology

3.1 *Definitions from Compilation of ASTM Standard Definitions:*

3.1.1 *aerosol, n*—a dispersion of solid or liquid particles in a gaseous medium.

3.1.2 *air conditioning, n*—the simultaneous control of all, or at least the first three, of those factors affecting both the physical and chemical conditions of the atmosphere within any structure. These factors include temperature, humidity, motion, distribution, dust, bacteria, odor, and toxic gases.

3.1.3 *biocide, n*—any chemical intended for use to kill organisms.

3.1.4 *biofilm, n*—an accumulation of cells immobilized on a substratum and frequently embedded in an organic polymer matrix of microbial origin.

3.1.5 *cooling tower, n*—a structure used to dissipate heat in open recirculating cooling systems.

3.1.6 *exposure, n*—contact with a chemical, biological, physical, or other agent over a specified time period.

3.1.7 *inspection, n*—the process of measuring, examining, testing, gaging, or otherwise evaluating materials, products, services, systems, or environments.

3.1.8 *monitoring, n*—the continual sampling, measuring, recording, or signaling, or both, of the characteristics of water or waterborne material.

3.1.9 *pH, n*—the negative logarithm of hydrogen-ion activity in aqueous solution or the logarithm of the reciprocal of the hydrogen-ion activity.

3.1.10 *sample, n*—a portion of a population intended to be representative of the whole.

3.1.11 *sampling, n*—a process consisting of the withdrawal or isolation of a fractional part of the whole.

3.1.12 *scale, n*—a deposit formed from solution directly upon a surface.

3.1.13 *sludge, n*—a water-formed sedimentary deposit.

3.1.14 *testing, n*—the determination by technical means of properties; performance; or elements of materials, products, services, systems, or environments which involve application of established scientific principles and procedures.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *acute phase, n—of legionellosis*, the initial phase of infection; the first weeks following symptom onset.

3.2.2 *antibody, n—to legionella*, a substance in blood synthesized in response to a legionella antigen that enters the body.

3.2.3 *antibody rise, n—in legionella antibody*, an increase in the highest serum dilution at which legionella antibody is detected in a blood sample collected weeks or months after legionellosis onset as compared with the highest dilution for a sample collected before or shortly after illness onset.

3.2.4 *antigen, n—to legionella*, a legionella molecule that stimulates an antibody response by a host immune system.

3.2.5 *aseptically, adv*—using precautions to prevent contamination of samples by microorganisms.

3.2.6 *back-flow preventer, n*—a control valve to prevent reverse flow of water.

3.2.7 *bacterium, n—pl. -ria*, a typically small unicellular microorganism.

[5] Edelstein, P.H., "*Legionella*," in *Manual of Clinical Microbiology*, Murray, P.R., Ed., American Society for Microbiology, Washington, DC 20005, USA, 2007, pp. 835–849.
[6] Fields, B.S., "Legionellae and Legionnaires' disease" in *Manual of Environmental Microbiology*,Hurst, C.J., Ed., American Society for Microbiology, Washington, DC 20005, USA, 2007, pp. 1005–1015.
[7] Edelstein, P.H., "Detection of Antibodies to Legionella," in *Manual of Molecular and Clinical Laboratory Immunology*, Detrick, B., Hamilton, R.G., Folds, J.D., Eds., American Society for Microbiology, Washington, DC 20005, USA, 2006, pp. 468–476.
[8] Available from Association of Water Technologies (AWT), 9707 Key West Avenue, Suite 100, Rockville, MD 20850, http://www.awt.org.
[9] Available from U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention (CDC), 1600 Clifton Rd., Atlanta, GA 30329-4027, http://www.cdc.gov.
[10] Available from U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol St., NW, Washington, DC 20401-0001, http://www.access.gpo.gov.
[11] Available from Cooling Tower Institute, PO Box 681807, Houston, Texas 77268, http://www.cti.org.
[12] Available from Occupational Safety and Health Administration (OSHA), 200 Constitution Ave., Washington, DC 20210, http://www.osha.gov.
[13] Available from World Health Organization, Avenue Appia 20, 1211 Geneva 27, Switzerland, http://www.who.int/en.

3.2.8 *CDC, n*—Centers for Disease Control and Prevention, U.S. Public Health Service, Atlanta, Georgia.

3.2.9 *clean, adj*—visibly free of sludge, sediment, scale, biofilm, algae, fungi, rust, corrosion, and extraneous matter.

3.2.10 *clean, v*—to remove sludge, sediment, scale, biofilm, algae, fungi, rust, corrosion, and extraneous matter by physical or chemical means.

3.2.11 *colony, n—of legionella*, a macroscopic group of legionella cells arising from bacterial multiplication on the surface of semisolid culture medium.

3.2.12 *colony-forming unit, n—of legionella*, a colony arising from the multiplication of one or a cluster of viable legionella.

3.2.13 *confirmed case, n—of Legionnaires' disease*, a case of physician-diagnosed pneumonia verified by at least one confirmatory test as meeting the laboratory criteria jointly developed by the CDC and the Council of State and Territorial Epidemiologists.

3.2.14 *contamination, n—with legionella*, the presence of legionella on or in inanimate articles or substances.

3.2.15 *convalescent phase, n—of legionellosis*, the recovery phase of infection, typically four to eight weeks following symptom onset.

3.2.16 *DFA, adj*—direct fluorescent-antibody.

3.2.17 *dead leg, n*—a length of pipe closed at one end or ending at a fitting through which water flows only when the fitting is open.

3.2.18 *direct fluorescent-antibody test, n—for legionella*, a staining procedure that detects legionella surface antigens through the use of specific antibodies labeled with fluorescent compounds; bacteria to which antibody has attached fluoresce when viewed under appropriate irradiation.

3.2.19 *disinfect, v*—to eliminate virtually all pathogenic microorganisms, but not necessarily all microbiological forms, outside the body by direct exposure to chemical or physical agents.

3.2.20 *drift, n—from water-cooled heat-transfer equipment*, water droplets carried from a cooling tower or other water-cooled heat-transfer system by air movement through the unit; drift can be confused with condensed water vapor appearing as steam leaving a unit.

3.2.21 *drift eliminator, n*—a plastic, metal, or wood baffle designed to entrain water droplets and to reduce aerosol escape.

3.2.22 *evaporative condenser, n*—a heat exchanger in which refrigerant is cooled by a combination of air movement and water spraying.

3.2.22.1 *Discussion*—Evaporative air coolers (swamp coolers), which do not produce large numbers of water droplets, have not been associated with legionella transmission to date.

3.2.23 *exhaust outlet, n—in a ventilation system*, an outlet from which an air-handling system discharges air outdoors.

3.2.24 *false-negative, adj*—incorrectly indicating the absence of a finding, condition, or disease.

3.2.25 *false-positive, adj*—incorrectly indicating the presence of a finding, condition, or disease.

3.2.26 *free residual chlorine, n*—the total concentration of hypochlorous acid and hypochlorites available to act as disinfectant.

3.2.27 *genus, n*—a taxonomic classification of organisms; the division between the family or tribe and the species; a group of species alike in broad organizational features but different in detail.

3.2.28 *gram-negative, adj*—losing the primary violet or blue stain during decolorization in Gram's staining method.

3.2.29 *HVAC, adj*—heating, ventilating, and air-conditioning.

3.2.30 *humidifier, n*—a device for adding moisture to air by boiling, spraying, or atomizing water.

3.2.31 *IHC, n*—immunohistochemistry.

3.2.32 *immunocompromised, adj*—a person's state when the body's natural defenses to infection are below normal.

3.2.33 *immunohistochemistry, n*—a staining procedure that detects antigens in tissue sections through the use of specific labeled antibodies.

3.2.34 *in vitro, adj*—(Latin: in glass), refers to laboratory tests performed in a test tube or other container as opposed to a living system; the opposite of *in vivo*.

3.2.35 *in vivo, adj*—(Latin: in living), refers to laboratory tests performed in living organisms; the opposite of *in vitro*.

3.2.36 *incubation period, n— of legionellosis*, the time interval between initial contact with legionella and appearance of the first legionellosis sign or symptom.

3.2.37 *infection, n—with legionella*, the entry and development, or multiplication, of legionella in humans.

3.2.38 *inspector, n*—a person examining an environment for possible contamination with legionella.

3.2.39 *investigator, n*—a person conducting an epidemiological investigation of a potential legionellosis outbreak.

3.2.40 *isolate, n*—a microorganism grown from a clinical or environmental sample.

3.2.41 *isolate, v—in vitro* growth of microorganisms on culture medium.

3.2.42 *Legionella, n*—a bacterial genus containing over 50 species and at least 71 serogroups; abbreviated to the first initial when used repeatedly with a species name, for example, *L. pneumophila*.

3.2.43 *legionella, n—pl. -ae*, a bacterium in the genus *Legionella*.

3.2.44 *legionellosis, n*—a respiratory illness caused by or associated with legionella; two forms of legionellosis due to inhalation of airborne legionella are recognized, that is, Legionnaires' disease and Pontiac fever.

3.2.45 *Legionnaires' disease, n*—an illness characterized by pneumonia and caused by or associated with legionella infection, most often *L. pneumophila*.

3.2.46 *maintain, v*—to perform regular and routine activities aimed at preserving equipment, operational standards, and cleanliness; includes inspection, repair, preventive servicing, and cleaning.

3.2.47 *maintenance program, n*—the assembly of relevant data and the setting out of a formal strategy and recording system for effective management of a series of maintenance procedures.

3.2.48 *make-up water, n*—fresh water added to a circulating water system to compensate for losses due to evaporation, purging, drift, or leakage.

3.2.49 *microorganism, n*—a microscopic organism.

3.2.50 *N95 filtering facepiece respirator, n*—a device that has met the requirements of 42 Code of Federal Regulations, Part 84, to protect the wearer against inhalation of a harmful atmosphere and provides a minimum of 95 % filter efficiency against certain solid and non-oil-based particles.

3.2.51 *opportunistic infection, n*—an infection caused by normally nonpathogenic organisms in a host whose resistance has been decreased.

3.2.52 *outbreak, n—of legionellosis*, the occurrence of two or more confirmed legionellosis cases in a limited time period (for example, weeks to months) and geographic region (for example, a building, limited area within a building, or up to several kilometres around a potential source); the occurrence of cases in excess of the number expected in a given time period and locale.

3.2.53 *outdoor air intake, n—for ventilation systems*, an opening through which outdoor air is introduced into a building's air-handling system.

3.2.54 *PCR, adj*—polymerase chain reaction.

3.2.55 *polymerase chain reaction test, n*—a technique for the selection and amplification of specific genetic sequences.

3.2.56 *Pontiac fever, n*—a self-limited, short-duration, nonfatal disease characterized by fever and cough caused by or associated with legionella.

3.2.57 *protozoan, n—pl. -a*, single-celled microorganism representing the lowest form of animal life.

3.2.58 *sensitivity, n—of a test for legionellosis or legionella*, a method's ability to accurately detect the presence of the disease being tested (that is, legionellosis) or a causative agent (that is, a legionella).

3.2.59 *serogroup, n—of legionella*, a subgroup within a legionella species.

3.2.60 *serology, n*—the study of blood serum for evidence of infection, performed by evaluation of antigen-antibody reactions *in vitro*.

3.2.61 *serum, n—pl. -a*, the clear, thin, sticky fluid portion of blood remaining after coagulation.

3.2.62 *source, n—of legionella*, the water system, supply, or equipment from which legionella pass to a host.

3.2.63 *species, n*—a taxonomic classification of organisms; the division between genus and variety or individual; a group of organisms bearing a close resemblance in essential organizational features.

3.2.64 *specificity, n—of a test for legionellosis or legionella*, a method's ability to identify accurately an illness as legionellosis or a bacterium as a legionella; a method's ability to select and distinguish legionella from all other bacteria in the same environment.

3.2.65 *sporadic case, n—of legionellosis*, an occurrence of legionellosis apparently independent of other cases.

3.2.66 *subtype, n—of legionella*, a subgroup within a legionella serogroup.

3.2.67 *surveillance, n—of legionellosis*, the continuing scrutiny of aspects of the occurrence and spread of legionellosis that are pertinent to effective control.

3.2.68 *susceptibility, n—to legionellosis*, the state of not possessing sufficient resistance against legionella to prevent infection or disease, if or when, exposed to the bacterium.

3.2.69 *titer, n—in legionellosis serology*, the highest serum dilution at which a test detects legionella antibody.

3.2.70 *viable, adj*—capable of living or replicating under a given set of growth conditions; usually determined by isolation of legionella on culture medium, that is, *in vitro*, or in laboratory animals, that is, *in vivo*.

3.3 Refer to Terminology D1129 and Terminology D1356 for definitions of other terms used in this guide.

4. Summary of Guide

4.1 Section 6 of this guide provides background information on (*1*) legionella bacteria; (*2*) microbiological analysis of environmental samples for legionella; and (*3*) recognition and diagnosis of legionellosis. Section 7 describes environmental inspections of water systems for legionella and suggests general control measures to limit legionella multiplication. Section 8 explains how to collect environmental samples to detect the presence of legionella. Section 9 outlines an epidemiological investigation of a possible legionellosis outbreak. Section 10 recommends control measures for (*1*) water-cooled heat-transfer systems; (*2*) potable hot and cold water supplies; (*3*) heating, ventilating, and air-conditioning (HVAC) systems; (*4*) spas, whirlpool baths, and jacuzzis; and (*5*) decorative fountains. This guide uses the term *inspector* when referring to a person examining the environment for possible legionella contamination (see Section 7) and the term *investigator* when referring to a person conducting an epidemiological study of a possible legionellosis outbreak (see Section 9). Inspection and investigation teams may include public health authorities, corporate or institutional health-care providers, building owners and operators, facility managers, employee representatives, and public or private health and safety professionals.

5. Significance and Use

5.1 Water systems may be inspected (see Section 7) and tested (see Section 8) for legionella under three circumstances (*1*) in the absence of reported legionellosis (see 5.2); (*2*) when

a single legionellosis case has been reported (see 5.3); and (*3*) when two or more legionellosis cases are reported in a limited time period and geographic region (see 5.4). Following are factors building owners and operators need to understand when considering testing water systems for legionella in the absence of illness (see 5.2) and for single legionellosis cases (see 5.3). Refer also to the CDC 2003 Guidelines for Preventing Health-Care Associated Pneumonia, and the CDC 2000 Guidelines for Preventing Opportunistic Infections Among Hematopoietic Stem Cell Transplant Recipients, and the WHO Legionella and the Prevention of Legionellosis. Detection of legionella in a water system is not sufficient to identify the system as a health hazard. However, failure to detect legionella does not indicate, conclusively, that the bacterium is not present (see 6.2.4) or that the water system may not pose a potential health hazard. Methods to detect legionella vary in sensitivity and specificity (see 6.2), and laboratories vary in their skill and experience in the isolation and identification of legionella. Isolation of apparently identical legionellae from clinical and environmental samples (see 6.2.1, 6.6.2.4, and Section 8) may suggest that a water system was the source of the legionella responsible for a patient's infection (see 5.3.2). However, cases of Legionnaires' disease due to different legionella serogroups or species need not necessarily have different sources of exposure because a system may be contaminated by more than one legionella. Timely inspection, testing, and treatment of possible legionella sources may reduce legal liabilities for facility owners and operators. Refer also to the APHA Public Health Law Manual.

5.2 *Environmental Testing for Legionella in the Absence of Illness:*

5.2.1 Concerned employers, building owners and operators, facility managers, and others seek to prevent real and potential health hazards, if possible. Water system operators may identify undesirable situations by monitoring routinely for legionella and may be able to implement control measures before the bacterium reaches an amount sufficient to cause human illness (see 6.2.4.2). The CDC 2000 Guidelines for Preventing Opportunistic Infections Among Hematopoietic Stem Cell Transplant Recipients advises that because transplant recipients are at much higher risk for disease and death from legionellosis compared with other hospitalized persons, periodic culturing for legionella in water samples from a center's potable water supply could be regarded as part of an overall strategy for the prevention of Legionnaires' disease in transplant centers and other facilities housing persons at high risk of infection if exposed (see 6.4.2). There is some evidence that environmental legionella surveillance should be considered a proactive strategy for the prevention of hospital-acquired Legionnaires' disease (**1**). However, the optimal methodology (that is, frequency or number of sites) for environmental surveillance cultures in transplant centers has not been determined, and the cost-effectiveness of such a strategy has not been evaluated for either transplant centers or other health-care settings nor for institutional, commercial, or residential buildings.

5.2.2 Some experts advise against testing water systems for legionella in the absence of illness, particularly in buildings other than hospitals or health-care facilities, given that absolute exclusion of this bacterium from water systems may not be necessary to prevent legionellosis nor may it be achievable without considerable expense. Microbiological water monitoring increases operational costs, and interpretation of test results may be difficult (see 6.2.4). Identification of legionella in environmental samples also may cause unwarranted alarm and unnecessary remediation. The WHO publication states that legionella testing cannot be considered a control measure, but does provide some evidence that the water safety plan is effective and that control measures are operating properly. Sampling for legionella cannot provide results sufficiently quickly to be useful in operational monitoring, which instead should be by measures that provide real-time results, for example, monitoring of the biocide concentration, temperature, and pH of the water.

5.3 *Environmental Testing for Legionella for a Single (Sporadic) Legionellosis Case:*

5.3.1 Testing potential legionella sources as soon as possible after confirmation of legionellosis may increase the likelihood of identifying the responsible source. Environmental conditions and equipment operation may change frequently, which may affect the likelihood of legionella detection. Inspectors may fail to identify the responsible source if they postpone sampling until an illness is confirmed as legionellosis (see 6.6 and 6.7) or until a search for other cases identifies common exposures (see Section 9).

5.3.2 Persons with legionellosis often have been exposed to more than one possible source during the disease's incubation period (see 6.4.3, 6.5.3) and may not recognize or recall all possible exposures. Isolation of apparently identical legionellae from clinical and environmental samples (see 6.2.1, 6.6.2.4, and Section 8) is suggestive, but does not identify a source absolutely as the site of a patient's exposure because the distribution of legionella species, serogroups, and subtypes (see 6.1.1 and 6.1.2) in the environment is not known, that is, the same legionella could colonize more than one water system. Identification of the environmental source responsible for legionella transmission may be difficult if no clinical isolate is available for comparison with environmental isolates (see 6.2.1, 6.6.2.4). Legionella has been found in a substantial proportion of water systems tested in prevalence surveys and outbreak investigations. Without a clinical isolate, identification of the probable source of legionella transmission must be based on environmental and epidemiological information (see Sections 7 – 9).

5.4 *Environmental Testing for Legionella for Multiple Legionellosis Cases*—Identification of multiple legionellosis cases in a circumscribed area and limited time period or that share a potential source warrants (*1*) environmental inspection of suspect sources to identify the water system responsible for legionella transmission to prevent further illness (see Sections 7 – 9); and (*2*) epidemiological investigation to identify common risk factors for cases (see 6.4.2, 6.5.2). Information from an epidemiological investigation (see Section 9) often facilitates identification of specific environments the legionellosis patients shared and on which inspectors should focus attention (see Sections 7 and 8). Environmental testing supplements, but does not replace, inspection and prompt

correction of identified problems (see Section 10) at all possible legionella sources regardless of whether or not legionella is detected or the potential source is implicated in patient exposure.

6. Background

6.1 *Legionella*—Refer to the APHA Standard Methods for the Examination of Water and Wastewater, the ASM Manual of Clinical Microbiology, the ASM Manual of Environmental Microbiology, the WHO Legionella and the Prevention of Legionellosis, and Refs (**2 and 3**) for background information on legionella.

6.1.1 *The Genus Legionella*—The legionella family is a diverse group of mesophilic, motile, obligately aerobic, nutritionally fastidious, poorly staining, gram-negative, rod-shaped bacteria. Microbiologists currently recognize over 50 species in this genus of which approximately one half have been associated with human illness. The genus name *Legionella* is abbreviated when used repeatedly with species names, for example, *Legionella pneumophila* is written as *L. pneumophila*. Microbiologists can distinguish serogroups, identified by number, within some legionella species, for example, *L. pneumophila* Serogroup 1. Some serogroups can be separated further into subtypes.

6.1.2 *Pathogenic Legionella—L. pneumophila* (in particular Serogroup 1) accounts for more than 90 % of legionellosis cases that have been studied in the United States. Other species associated with clinical infections include *L. micdadei, L. dumoffii, L. bozemanii*, and *L. longbeachae*. It is likely that most *Legionella* species can cause human disease under appropriate conditions; however, such infections are reported infrequently because they are rare and diagnostic reagents are lacking. Some legionellae cannot be grown on routine legionella medium and have been termed *Legionella*-like amebal pathogens, of which at least one is considered a human pathogen.

6.1.3 *Legionella in the Environment*—Legionella is found worldwide in a variety of natural and man-made aquatic environments, usually ones with moderately elevated temperatures (see 6.1.4, 6.3.4, 7.3.6). Legionella lives in biofilms near the surfaces of lakes, rivers, and streams and in conjunction with specific free-living protozoa.

6.1.4 *Legionella in Man-Made Water Systems*—Factors known to enhance legionella colonization of man-made water systems (see 6.1.3 and 6.3.4) include warm temperature (25 to 45°C), suitable pH (2.5 to 9.5), and water stagnation followed by agitation, as well as the presence of other organisms, sediment, and scale (see 6.1.3, 6.1.5). It is uncommon to find legionella proliferation at water temperatures below 20°C and the bacterium does not survive in waters warmer than 60°C. Chlorination of potable water supplies may not eradicate legionella (see 6.1.5). Low concentrations of legionella (even below concentrations detectable by conventional test methods, see 6.2) can colonize water systems and can multiply under suitable conditions. Monochloramine rather than chlorine disinfection of municipal water supplies may reduce legionella transmission (**4**, **5**).

6.1.5 *Association of Legionella with Other Organisms*—In humans, legionella infects alveolar macrophages, a type of white blood cell in the lungs. In the environment, the bacterium infects free-living aquatic amebae and other protozoa (see 6.1.3 and 6.1.4). Legionella inside protozoa may be protected from biocides, desiccation, and other environmental stresses.

6.2 *Microbiological Analysis of Environmental Samples for Legionella*—Legionella can be detected in environmental samples by three methods (*1*) growth of viable bacteria on culture medium (see 6.2.1); (*2*) detection of legionella cells with a direct fluorescent-antibody (DFA) stain (see 6.2.2); and (*3*) detection of legionella genetic material with a polymerase chain reaction (PCR) test (see 6.2.3). DFA and PCR results are available sooner than culture, but isolation is the standard or primary laboratory method to detect legionella (see 6.2.1) because it provides information on bacterial viability (necessary for infection) and allows more thorough bacterial characterization (necessary for outbreak investigation and source identification) (see 6.2.1.2). Legionella cells in water samples and washings of other materials (see Section 8) typically are concentrated by filtration or centrifugation before testing. Detection limits for these methods depend on the source material, volume of sample analyzed, and analytical method. Refer to Guides D596 and D3856, Practice D2331, the APHA Standard Methods for the Examination of Water and Wastewater, the CDC 2005 Procedures for the Recovery of Legionella from the Environment, and the WHO Legionella and the Prevention of Legionellosis for information on the detection and identification of legionella from environmental samples.

6.2.1 *Legionella Isolation:*

6.2.1.1 *Primary Isolation*—Water samples and washings of other materials (see Section 8) may be treated with heat or buffered acid solution to reduce the numbers of nonlegionella organisms prior to inoculation of culture medium; specificity: 100 %; sensitivity: varies with water source and sample handling. Preliminary culture results typically are not available for three to five days after sample receipt because the method depends on bacterial multiplication into visible colonies. Some legionellae may not form visible colonies for 10 to 14 days. Confirmation of culture results may require an additional three to five days following primary isolation. Hold primary plates for at least 14 days before reporting them as negative, that is, no legionella isolated.

6.2.1.2 *Isolate Identification*—The specific species, serogroup, and subtype to which an environmental legionella isolate belongs may be identified with a DFA test (see 6.2.2 and 6.6.2.2) or by biochemical or nucleic acid analyses. Laboratories should preserve any environmental legionella isolates from outbreak investigations to allow further examination by public health authorities and for more specific identification by methods that may not be available commercially (see 5.3.2 and 6.6.2.4).

6.2.2 *Direct Fluorescent-Antibody (DFA) Test*—Microbiologists can detect bacteria in environmental samples with DFA stains similar to those used to identify culture isolates (see 6.2.1.2 and 6.6.2.4) and to detect legionella directly in clinical specimens (see 6.6.2.2). However, DFA stains react with both living and dead legionella cells and may stain other bacteria. Contaminants in specimen containers and

laboratory reagents also may give false-positive test results. This method allows rapid sample screening because results are available in one day, but optimal sensitivity and specificity require exacting staining procedures and experience.

6.2.3 *Polymerase Chain Reaction (PCR) Test*—The PCR technique selects pre-determined sequences of genetic material and then amplifies and labels them with detectable markers. The PCR technique, although specific, amplifies genetic material from living and dead legionellae, as well as contaminants in specimen containers and laboratory reagents. Not all environmental samples can be analyzed by PCR because some samples may contain compounds or materials that interfere with or inhibit a PCR test. This method has been described in the literature and allows rapid sample screening because results are available in one day. Although, commercial PCR kits are available for clinical specimens, none are available for environmental samples.

6.2.4 *Interpretation of Water Sampling Results*—Determine, before testing environmental samples for legionella, (*1*) the reasons for sampling (see Section 5); (*2*) how to interpret laboratory results (see 6.2.4.1 and 6.2.4.2); and (*3*) what action to take based on the information obtained (see Section 10). Use only culture methods (see 6.2.1) to document legionella presence conclusively in environmental samples because the DFA test occasionally gives false-positive results (see 6.2.2), the PCR procedure has not been validated (see 6.2.3), and both of these analyses identify both viable and nonviable legionella cells.

6.2.4.1 *Legionella Not Detected*—Rule out the possibility of false-negative test results when legionella is not detected in environmental samples before concluding that the bacterium is not present. Possible reasons for not detecting a legionella that is present are (*1*) limited sample number or volume; (*2*) testing unconcentrated samples; (*3*) culturing samples without heat or acid treatment (see 6.2.1.1), which may allow overgrowth by other organisms; (*4*) failing to run proper control samples to detect field or laboratory errors; (*5*) collection of unrepresentative samples; and (*6*) improper collection or handling of samples (see 8.3 and 8.4). Detection methods that rely on culturing legionella (see 6.2.1) may fail to isolate it if the bacterium loses viability during sample storage or transport to a laboratory or during the culturing process, for example, as a result of heat or acid treatment (see 6.2.1.1). Laboratories also may fail to isolate legionella by the culture method if the bacterium has lost viability due to biocide treatment or natural die-off or if it is unable to grow on available culture media or under given laboratory conditions.

6.2.4.2 *Legionella Detected*—Detection of viable legionella in environmental samples by the culture method (see 6.2.1) is not uncommon (see 6.1.3 and 6.1.4). Variation between laboratories and sampling protocols is too large to allow adequate quantification of legionella by current methods, and experts do not agree on the concentration of this bacterium in various water supplies that represents a hazardous situation. The WHO Legionella and the Prevention of Legionellosis provides examples of limit values for corrective action in piped water systems and of target, alert, and maximum limit values for health-care settings. Legionella cells detected by DFA (see 6.2.2) or PCR (see 6.2.3) may be viable or non-viable by the culture method (see 6.2.1). Pontiac fever has been associated with exposure to non-viable legionella (see 6.3, 6.5). However, only viable legionella can cause Legionnaires' disease (see 6.3 and 6.4).

6.2.5 *Air Monitoring for Legionella*—Investigators have detected legionella from air samples collected >250 m from sources associated with Legionnaires' disease outbreaks **(6)**. However, do not rely on air sampling to measure potential exposure to legionella because of the high likelihood of failure to detect the bacterium. Inspectors may obtain false-negative test results if the concentration of airborne legionella is below an air sampling method's detection limit. Detection methods that rely on culturing legionella (see 6.2.1) may fail to isolate it from air samples if the bacterium loses culturability while airborne, during the collection procedure, during sample storage or transport to a laboratory, or during the culturing process. Methods not based on bacterial multiplication (for example, DFA and PCR tests, see 6.2.2 and 6.2.3) may detect legionella in air samples that test negative by the culture method.

6.3 *Legionellosis*—The term *legionellosis* is used for any disease caused by or associated with legionella (see 6.1). Inhalation of airborne legionella and aspiration of the bacterium into the lungs is associated with two types of respiratory illness, that is, Legionnaires' disease and Pontiac fever (see 6.4 and 6.5). Possible explanations for two disease syndromes caused by or associated with the same bacterium include the inability of some legionellae to multiply in human tissue (for a variety of reasons, including virulence, host range, or viability of the bacteria) and differences in host susceptibility. Exposure to the same environmental source has resulted in pneumonia and a nonpneumonic, Pontiac fever-like illness **(7)**. Exposure to legionella may occur indoors or outdoors, in residences, workplaces, or public settings, but infection is not transmitted from person to person. Legionnaires' disease may occur as isolated, sporadic cases or as outbreaks when several persons are exposed to the same source and become infected (see 6.3.3). In contrast, Pontiac fever, by definition, is an epidemic disease, that is, it is recognized only when there are two or more cases (see 6.3.3). Refer to the ASM Manual of Clinical Microbiology, the 2003 CDC Guidelines for Preventing Health-Care Associated Pneumonia, the WHO Legionella and the Prevention of Legionellosis, and Refs **(2 and 3)** for background information on legionellosis.

6.3.1 *History of Legionellosis*—In 1977, the CDC identified a bacterium as the causative agent of a pneumonia outbreak at a 1976 American Legion Convention in Philadelphia. This bacterium later was named *Legionella pneumophila*. The 1976 outbreak resulted in more than 200 Legionnaires' disease cases and 34 deaths among the more than 4000 convention attendants. Although legionella caused disease before 1976, laboratories failed to isolate or detect the bacterium because of its unusual growth requirements and poor staining characteristics (see 6.1).

6.3.2 *Incidence of Legionellosis*—Legionnaires' disease is a serious but fairly common form of pneumonia (see 6.4) responsible for an estimated 0.5 to 5 % of adult hospitalizations for community-acquired pneumonia. Extrapolation from a

prospective study of sporadic, community-acquired pneumonia due to legionella yielded an estimate of 8000 to 18 000 Legionnaires' disease cases annually nationally in the United States (**2**). The number of reported cases (see 9.2) is much lower because many patients do not require hospitalization and appropriate confirmatory laboratory tests rarely are done (see 6.4, 6.6). The incidence of Pontiac fever is not known, because it is indistinguishable from influenza and other common viral syndromes and is recognized only in epidemic form, but Pontiac fever also may be fairly common.

6.3.3 *Legionellosis Outbreaks and Sporadic Cases*—A legionellosis outbreak is defined as (*1*) the occurrence of two or more cases linked by time of onset and location; or (*2*) the occurrence of cases in excess of the number expected in a given time period and locale based on previously observed incidence of the disease. At least 65 to 80 % of Legionnaires' disease cases reported in the United States and the United Kingdom apparently occur as sporadic infections, that is, isolated events in which no other cases are identified (see 9.1, 9.3.3). Underreporting of sporadic legionellosis cases probably is even higher than underreporting of cases that occur in clusters (see 6.3.2, 9.2). Legionella may cause a large percentage of hospital-acquired pneumonia cases (see 6.4.5).

6.3.4 *Sources Implicated in Legionellosis Outbreaks*—Legionellosis outbreaks have been associated with exposure to contaminated aerosols generated by cooling towers, evaporative condensers, spas, respiratory therapy and dental equipment, showers, water faucets, decorative fountains, ultrasonic mist machines, and damp potting soil.

6.3.5 *Legionella Transmission*—The likelihood of legionella transmission and subsequent infection is related to (*1*) the presence of legionella in a water system; (*2*) spraying or splashing of contaminated water and transfer of legionella to the air; (*3*) air temperature and moisture content; (*4*) the presence of amebae and other protozoa that may protect the legionella; (*5*) the intensity and duration of a person's exposure to airborne legionella; and (*6*) an exposed person's susceptibility (see 6.4.2, 6.5.2). The inoculum required for human infection or disease is not known.

6.4 *Clinical Aspects of Legionnaires' Disease*—Refer to the ASM Manual of Clinical Microbiology, the CDC 2003 Guidelines for Preventing Health-Care Associated Pneumonia, the WHO Legionella and the Prevention of Legionellosis, and Ref (**3**) for information on clinical aspects of Legionnaires' disease.

6.4.1 *Symptoms*—Legionnaires' disease is a form of pneumonia that can present with a range of signs and symptoms, for example, mild cough and low fever to rapidly progressive pneumonia and coma. Early symptoms include loss of appetite, malaise, muscle pain, and headache; later symptoms include high fever (39 to 40.5°C), nonproductive cough, shortness of breath, and delirium. Legionnaires' disease patients may report gastrointestinal symptoms including vomiting, diarrhea, nausea, and abdominal pain.

6.4.2 *Risk Factors*—Legionnaires' disease is usually an opportunistic infection occurring most often in older persons (≥50 years of age), males (male:female ratio approximately 2.5:1), and those who smoke cigarettes, have chronic cardiovascular or pulmonary conditions, renal disease or malignancy, or are immunocompromised. Persons may be immunocompromised due to illness (for example, cancer) or medical treatment (for example, radiation therapy or medication). Medications that may increase a person's susceptibility to Legionnaires' disease are those that suppress the immune system, including prolonged use of steroids, many cancer chemotherapy treatments, and medications used to prevent rejection of transplanted organs. Other risk factors include health-care or hospital visits, use of well water, and overnight travel outside the home.

6.4.3 *Incubation Period*—The incubation period for Legionnaires' disease is generally two to ten days, with a median of approximately four days.

6.4.4 *Treatment*—Prompt treatment can cure 95 to 99 % of Legionnaires' disease cases in otherwise healthy persons. Historically, erythromycin has been the drug of choice, but azithromycin and many fluoroquinolones (for example, levofloxacin) may be superior and have fewer side effects. The latter two agents are licensed by the U.S. Food and Drug Administration for the treatment of Legionnaires' disease and are considered preferable to erythromycin. The use of rifampin in addition to newer antibiotic regimens is not recommended.

6.4.5 *Attack Rate*—Usually fewer than 5 % of persons exposed in community-acquired Legionnaires' disease outbreaks become ill.

6.4.6 *Sequelae*—Patients recovering from Legionnaires' disease may continue to suffer fatigue and respiratory symptoms for several months.

6.4.7 *Mortality*—Ten to 15 % of persons with community-acquired Legionnaires' disease die due to progressive pneumonia and shock. The fatality rate has been as high as 39 % for hospitalized cases and generally is higher in those with compromised immunity.

6.5 *Clinical Aspects of Pontiac Fever*—The pathogenesis of Pontiac fever is unclear. Legionella has never been isolated (see 6.6.2.4) from clinical specimens of persons with Pontiac fever. The association between Pontiac fever and legionella is based on detection of antibodies in the blood or antigen in the urine (see 6.7) and a history of exposure to legionella-containing environmental aerosols, which also may contain bacterial toxins, for example, endotoxins (lipopolysaccharide-protein complexes in the outer membranes of gram-negative bacteria) (see 6.3.4). Refer to the ASM Manual of Clinical Microbiology, the CDC 2003 Guidelines for Preventing Health-Care Associated Pneumonia, and the WHO Legionella and the Prevention of Legionellosis for information on the clinical aspects of Pontiac fever.

6.5.1 *Symptoms*—Pontiac fever is a self-limited, short-duration, non-fatal illness. Symptoms include chills, headache, muscle pain, and other influenza-like complaints as well as productive cough.

6.5.2 *Risk Factors*—Pontiac fever often affects otherwise healthy persons' without underlying medical conditions.

6.5.3 *Incubation Period*—The period between exposure and symptom onset in Pontiac fever is generally 24 to 48 h.

6.5.4 *Treatment*—Persons with Pontiac fever recover completely in two to five days without medical intervention.

6.5.5 *Attack Rate*—The attack rate in Pontiac fever outbreaks may be as high as 95 %.

6.5.6 *Sequelae*—Recovery from Pontiac fever is complete without further complications or complaints.

6.5.7 *Mortality*—Death has not occurred due to Pontiac fever.

6.6 *Diagnosis of Legionnaires' Disease*— Refer to the ASM Manual of Clinical Microbiology, the ASM Manual of Molecular and Clinical Laboratory Immunology, Seventh Edition, the CDC 2003 Guidelines for Preventing Health-Care Associated Pneumonia, and the WHO Legionella and the Prevention of Legionellosis for a discussion of the diagnosis of Legionnaires' disease.

6.6.1 *Case Definition*—The CDC's surveillance case definitions for suspect and confirmed legionellosis are clinically compatible cases that meet at least one of the presumptive (suspect) and confirmatory laboratory criteria, respectively (see 6.6.2). Travel-associated cases have a history of having spent at least one night away from home, either in the same country of residence or abroad, in the ten days before illness onset. Laboratory tests are necessary to confirm a diagnosis of Legionnaires' disease because the symptoms and roentgenographic patterns of this form of pneumonia are not unique. See also the WHO Legionella and the Prevention of Legionellosis for case definitions of confirmed, presumptive, health-care acquired (nosocomial), travel-associated, and domestically acquired cases as well as travel-associated clusters and community clusters and outbreaks.

6.6.2 *Laboratory Criteria*—A diagnosis of suspect legionellosis can be made by any one of the following laboratory findings (*1*) seroconversion (*a*) fourfold or greater rise in antibody titer to specific species or serogroups of legionella other than *L. pneumophila* Serogroup 1 (for example, *L. micdadei* or *L. pneumophila* Serogroup 6) or (*b*) fourfold or greater rise in antibody titer to multiple species of legionella using pooled antigens and validated reagents (see 6.6.2.1); (*2*) detection of specific legionella antigen or staining of the organism in respiratory secretions, lung tissue, or pleural fluid by DFA, immunohistochemistry (IHC), or other similar method, using validated reagents (see 6.6.2.2); or (*3*) detection of legionella by a validated nucleic acid assay (see 6.6.2.3). A diagnosis of confirmed legionellosis can be made by any one of the following laboratory findings (*1*) culture: isolation of any legionella organism from respiratory secretions, lung tissue, pleural fluid, or other normally sterile body fluid (see 6.6.2.4); (*2*) urine antigen test: detection of *L. pneumophila* Serogroup 1 antigen in urine using validated reagents (see 6.6.2.5); or (*3*) seroconversion: fourfold or greater rise in specific serum antibody titer to *L. pneumophila* Serogroup 1 using validated reagents (see 6.6.2.1).

6.6.2.1 *Seroconversion (Legionella Antibody Titer in Blood)*—An antibody test detects legionella antibodies in blood serum; specificity: 99 % for a controlled and carefully performed test for *L. pneumophila* Serogroup 1; sensitivity: 70 to 80 %, possibly higher in Legionnaires' disease outbreaks (see 6.6.2.6). Laboratories report serum antibody titer as the reciprocal of the highest two-fold dilution showing a positive reaction. For example, a titer of 256 would show positive reactions at dilutions of 1/64, 1/128, and 1/256, but not at 1/512. A four-fold or greater rise in antibody titer to at least 128 in a blood sample collected in the convalescent phase of a patient's illness as compared to an acute-phase sample demonstrates recent infection. Store sera until one technician can test paired acute- and convalescent-phase samples on the same day using the same reagents.

6.6.2.2 *Direct Fluorescent-Antibody (DFA) Test*—Laboratories may detect *L. pneumophila* Serogroup 1, with a DFA stain, directly in lung aspirates or tissue sections; specificity: approaches 100 % for a controlled and carefully performed clinical test; sensitivity: 25 to 70 % of culture-proven cases (see 6.6.2.6) (optimal sensitivity and specificity require exacting staining procedures and experience). A DFA test may give false-negative results early in the disease process when few organisms are present or if the test reagent does not include antibodies specific to the legionella causing a patient's infection. False-positive tests with polyclonal antibodies can result from cross-reactions with nonlegionella bacteria including *Pseudomonas aeruginosa*, *Pseudomonas fluorescens*, *Bacteroides fragilis*, *Staphylococcus aureus*, *Bordetella pertussis*, *Bacillus* species, lactobacillus-like bacteria, and candida-like yeasts.

6.6.2.3 *Nucleic Acid Assay*—Reference and research laboratories have successfully detected *L. pneumophila* nucleic acid in sputum, urine, and blood using PCR-based detection; sensitivity: 30 to 100 %; specificity: >90 %.

6.6.2.4 *Legionella Isolation*—The most definitive test to confirm the presence of legionella in a patient is the isolation of viable bacteria from sputum, bronchial brush or washing, transtracheal aspirate, or other clinical or autopsy specimen; specificity: near 100 %; sensitivity: 20 to 80 % (see 6.6.2.6). Collect samples before a patient begins antibiotic treatment, if possible. The specific species, serogroup, and subtype (see 6.1.1 and 6.1.2) to which a clinical legionella isolate belongs may be identified with a DFA (see 6.6.2.2) or other test. Preserve clinical legionella isolates for possible further examination by public health authorities and for more specific identification by methods that may not be available commercially (see Section 5, 5.3.2). Specimens should be held until the finding has been reported to the local health authority (see 9.2) and subsequent investigations have been completed (see Section 9).

6.6.2.5 *Urine Antigen Test*—Laboratories can detect *L. pneumophila* Serogroup 1 antigens in the urine of active and recently recovered Legionnaires' disease patients; specificity: 99 to 99.9 %, although false-positive results may account for a few percent of all positive results; sensitivity: approximately 70 % (see 6.6.2.6). The tests detect antigens on bacterial cells the body passes into the urine during the disease process and for as long as several months thereafter. This test does not detect infection with species other than *L. pneumophila* or serogroups other than serogroup 1.

6.6.2.6 *Precautions on Diagnosing Legionnaires' Disease*—No laboratory test for Legionnaires' disease diagnosis is 100 % sensitive, that is, infection is not ruled out even if one or more of the above tests are negative. The earlier in the course of an illness a culture, DFA stain, or urine antigen test

is performed the better the chances of Legionnaires' disease detection. A single serological test is less useful in the first weeks of acute Legionnaires' disease than three to six weeks after symptom onset when the infected person has produced detectable levels of legionella antibodies (see 6.6.2.1).

6.7 *Diagnosis of Pontiac Fever*—Refer to the ASM Manual of Clinical Microbiology and the WHO Legionella and the Prevention of Legionellosis for a discussion of the diagnosis of Pontiac fever. Pontiac fever is diagnosed, in association with a flu-like illness (see 6.5), by an antibody titer of 256 or higher (see 6.6.2.1) to *L. pneumophila* or to an environmental legionella isolate from a source to which the patient was exposed (see 6.1.3, 6.1.4, 6.2.1, 6.3.4, 8.2) or by detection of *L. pneumophila* Serogroup 1 antigens in urine (**8**) (see 6.6.2.5).

7. Procedure—Environmental Inspections of Water Systems to Identify Potential Legionella Sources, and General Measures to Control Legionella

7.1 This section outlines an inspection considered appropriate (*1*) for water systems associated with multiple legionellosis cases; and (*2*) periodically (for example, every one, five, or ten years) for other systems. Factors important in the prevention of situations that may lead to legionella transmission include (*1*) understanding of the environmental conditions that support legionella multiplication (see 6.1.4); and (*2*) awareness of the types of water systems and equipment that may harbor legionella and may generate aerosols (see 7.3.1 – 7.3.6). The purpose of a water system inspection may be (*1*) to identify and examine water systems in which legionella could multiply and from which the bacterium could become airborne; and (*2*) to suggest control measures to correct observed and potential problems. Refer to the ASHRAE Codes and Standards, Cooling Towers, Water Treatment, Minimizing the Risk of Legionellosis Associated with Building Water Systems (12–2000), and Ventilation for Acceptable Indoor Air Quality (62.1-2007); the CDC 2003 Guidelines for Preventing Health-Care Associated Pneumonia; the 2003 Occupational Safety and Health Administration (OSHA) Technical Manual, Section III: Chapter 7, Legionnaires' Disease; the WHO Legionella and the Prevention of Legionellosis; and Ref (**9**) for information on environmental inspections of water systems for legionella and general control measures.

7.2 *Gathering Preliminary Information on Water System Design, Operation, and Maintenance:*

7.2.1 *System Design*—Review up-to-date blueprints or schematic drawings of facility water and ventilation systems. Use *as built* plans if systems differ from their original designs.

7.2.2 *System Operation and Maintenance*—Examine operation and maintenance records for all water systems including hot water supplies and water-cooled heat-transfer equipment (see 10.2.5). Review records of water temperature and biocide concentration measurements, of dates and types of water treatment, and of dates and results of visual inspections and water quality tests. Inquire about recent major maintenance on water systems or changes in their operation or use.

7.3 *Walkthrough Visit*—Ask a facility engineer or maintenance staff member familiar with the water system to assist during walkthrough visits. Inspect hot and cold water systems including heaters, chillers, storage tanks, distribution piping, water treatment equipment, connections protected by back-flow preventers, and the like (see 7.3.1.2). Carry a thermometer, flashlight, note paper, and camera or video recorder on walkthrough visits. Request that equipment be turned off while examining it, if possible. Wear disposable garments, slip-proof footwear, and eye protection while examining areas that are wet, potentially contaminated, or recently treated with biocides, disinfectants, detergents, or other chemicals. Wear a respirator that is at least as effective as an OSHA–approved N95 filtering facepiece respirator when working near potentially contaminated equipment that might generate aerosols.

7.3.1 *General Water Supply:*

7.3.1.1 *Water Stagnation*—Identify portions of systems in which water may stagnate, for example, storage tanks, unused plumbing sections, and faucets operated less often than monthly (see 10.3.5, 10.4.6).

7.3.1.2 *Connections Between Potable and Non-Potable Water Systems*—Look for connections between potable water supplies and waters used for cooling and supplying fire sprinklers and other devices (see 10.4.5). Examine the condition and types of devices used to prevent back flow at these connections. Ask if the facility has experienced a water-pressure loss, for example, due to line breakage or street repairs, because failure of a back-flow preventer during a pressure loss can contaminate a water supply.

7.3.1.3 *Hot and Cold Water Line Separation*—See if hot and cold water lines are separated physically or if hot water lines are insulated to prevent heat transfer (see 10.3.3, 10.4.3).

7.3.2 *Hot Water Supply:*

7.3.2.1 *Hot Water Holding Temperature*—Measure and record water temperature at the top, middle, and bottom of each storage unit fed by a hot water heater, if possible, or measure the initial and final equilibrium water temperature as the water leaves a drain or outlet port. It may be necessary to run water for several minutes before the temperature stabilizes. Store hot water at or above 60°C (see 7.4, 10.3.2) to limit legionella multiplication. Water temperature should be measured with a reliable thermometer because a water heater's temperature gage may not be accurate and heat stratification may result in unrepresentative readings.

7.3.2.2 *Hot Water Delivery Temperature*—Measure and record water temperature in hot water lines throughout a facility, for example, at faucets nearest, intermediate, and most distant from the hot water heater or storage tank. Record initial and final equilibrium water temperatures in hot water supply lines. It may be necessary to run a faucet for several minutes before water temperature reaches its maximum at distant locations in a system. Deliver hot water at a temperature of 50°C or higher, if permitted (see 7.4, 10.3.2).

7.3.2.3 *Hot Water Sample Appearance*—Note the presence of rust, scale, and other material in samples drawn to measure hot water temperature (see7.3.2.1 and 7.3.2.2), which may indicate infrequent use, corrosion, or biofilm formation.

7.3.3 *Cold Water Supply:*

7.3.3.1 *Cold Water Storage Temperature*—Measure and record the temperature of water drawn from each cold water storage unit. Store cold water at or below 20°C (see 7.4, 10.4.2) to limit legionella multiplication. Examine storage tanks for cold water systems used as reserve capacity or to maintain hydrostatic pressure. Protect these systems from temperatures below 0°C and above 20°C, and cover them to prevent contamination with organic debris and organisms that may support legionella multiplication.

7.3.3.2 *Cold Water Delivery Temperature*—Measure and record water temperature in cold water lines throughout a facility, for example, at faucets nearest, intermediate, and most distant from the main cold water source or storage tank. Record initial and final equilibrium water temperature in cold water supply lines. It may be necessary to run a faucet for several minutes before water temperature reaches its minimum at distant locations in a system. Protect cold water lines from heat sources to limit legionella multiplication.

7.3.3.3 *Cold Water Sample Appearance*—Note the presence of rust, scale, and other material in samples drawn to measure cold water temperature (see 7.3.3.1 and 7.3.3.2), which may indicate infrequent use, corrosion, or biofilm formation.

7.3.4 *Heating, Ventilating, and Air-Conditioning (HVAC) Systems*—Examine humidifiers, cooling towers, evaporative condensers, air washers, and similar equipment (see 7.3.5, 10.5). Note the locations of outdoor air intakes for HVAC systems relative to aerosol sources such as the air exhausts for water-cooled heat-transfer systems (see 7.3.5.2, 10.2.1.3, 10.5.1).

7.3.5 *Water-Cooled Heat-Transfer Systems:*

7.3.5.1 *Visual Evaluation*—Examine cooling towers, evaporative condensers, and similar water-cooled heat-transfer equipment for visible evidence of algal growth, biofilm, rust, scale, and other signs of contamination or poor maintenance. Examine the general physical and mechanical condition of water-cooled heat-transfer equipment and determine the presence and condition of drift eliminators (see 10.2.1.2 and C1080).

7.3.5.2 *Air Supplies and Exhausts for Water-Cooled Heat-Transfer Systems*—Examine the air supplies for heat-transfer units and the proximity to them of sources that could supply nutrients for legionella multiplication (see 7.3.5.3). Observe the location of air exhausts for water-cooled heat-transfer systems relative to outdoor air intakes for HVAC systems (see 7.3.4, 10.2.1.3, 10.5.1).

7.3.5.3 *Construction and Excavation Operations and Other Sources of Organic Materials*—Look for construction or excavation operations that could generate dust or plant or animal debris that when washed into a cooling system's water could supply nutrients to support legionella multiplication (see 7.3.5.2).

7.3.5.4 *Water Sumps*—Evaluate the condition of sumps that collect water from cooling towers, evaporative condensers, and similar equipment. Measure water temperature for systems in use at the time of a walkthrough visit.

7.3.6 *Miscellaneous Water Systems*—Examine miscellaneous water sources such as decorative fountains, tepid-water eye washes, safety showers, produce (that is, fruit and vegetable) misters, spray irrigation systems for lawns and plants, cooling waters for industrial purposes, spray-cooled cutting machines, molding presses, pasteurizers, roof sprays for humidity control and cooling, storage tanks for fire-sprinkler systems, and spas, whirlpool baths, and jacuzzis (see 10.6 and 10.7).

7.4 *Assessment of the Results of Preliminary Inspections and Recommendation of Control Measures*—Use the results of the reviews described in 7.2 and 7.3 to decide if further action is needed to reduce the risks of legionella multiplication in a water system and of human exposure to airborne legionella. Measures to control legionella in the environment include correction of improper design, operation, or maintenance of water supplies and water-cooled heat-transfer equipment (see Section 10) and maintenance of proper hot and cold water temperatures.

8. Procedure—Environmental Sampling for Legionella

8.1 This section describes collection of environmental samples during or following water system inspections to identify possible legionella sources (see Section 7). Contact a laboratory to obtain new containers or cleaned and sterilized ones and to arrange for sample transport and analysis. Refer to Practices D887, D3370, and D4840, Guide D3856; the APHA Standard Methods for the Examination of Water and Wastewater; the CDC 2003 Guidelines for Environmental Infection Control in Health-Care Facilities; the 2003 Occupational Safety and Health Administration (OSHA) Technical Manual, Section III: Chapter 7, Legionnaires' Disease: 7–2, Physical Survey and Water Sampling Protocol; and the WHO Legionella and the Prevention of Legionellosis for information on environmental sampling for legionella.

8.2 *Environmental Sampling Sites*—Estimate the number of samples to be collected based on a facility's size and the number of water systems identified as potential legionella sources (see Section 7). Consider collecting samples from the following environmental sources (*1*) incoming water supplies; (*2*) water storage tanks and hot water heaters; (*3*) hot and cold water faucets and shower heads; (*4*) water-cooled heat-transfer equipment; and (*5*) humidifiers, spas, decorative fountains, and other water systems (see 7.3.6) suspected of harboring legionella or linked epidemiologically with legionellosis patients (see 9.3.1 – 9.3.3).

8.2.1 *Water Storage Tanks and Hot Water Heaters*—Aseptically collect water samples from the bottom drains and outlet pipes of water storage tanks and hot water heaters.

8.2.2 *Water Faucets and Shower Heads*—Aseptically collect water samples from hot and cold water faucets and shower heads throughout a facility, for example, at faucets nearest, intermediate, and most distant from water heaters, storage tanks, and connections with municipal water supplies. Collect the first water that leaves an outlet after opening the tap and another sample after water temperature stabilizes (see 7.3.2.2, 7.3.3.2). Use sterile swabs to sample faucets and shower heads, and transport swabs submerged in sample water.

8.2.3 *Water-Cooled Heat-Transfer Equipment*—Sample the make-up water supply for water-cooled heat-transfer systems

and for associated storage tanks, sumps, and reservoirs. Collect additional water samples at locations distant from the make-up water outlet and where water enters sprayers or misters, if possible. Include samples of sludge, sediment, and biofilm.

8.2.4 *Humidifiers, Spas, Decorative Fountains, and Other Equipment*—Collect water from tanks and reservoirs of humidifiers, spas, decorative fountains, and other equipment and from their supply waters for comparison. Include samples of sludge, sediment, and biofilm.

8.3 *Environmental Sample Collection:*

8.3.1 *Sample Volume*—Collect at least 10 to 100 mL of water from cooling towers and other water-cooled heat-transfer systems, which may contain elevated concentrations of legionella. Collect more than 1 L of potable waters, which may contain lower concentrations of legionella. Use new containers or cleaned and sterilized ones to collect samples.

8.3.2 *Sample Description*—Measure water temperature immediately before or after sample collection. Wipe thermometers with 70 % alcohol and air dry, or use other appropriate disinfectant, between samples, if thermometers come in contact with the sample water. Note the presence of rust, scale, and other material in samples (see 7.3.2.3, 7.3.3.3, 8.3.5).

8.3.3 *Filling Sample Containers*—Keep collection containers closed until ready to fill and reclose them immediately after sample collection. Collect separately the first water leaving a faucet or drainage port and later flushes (see 8.2.2). Rinse collection containers several times with sample water before filling, when not collecting a first flush and when the containers do not contain a dechlorinating agent (see 8.3.4), to condition the containers and remove possible interfering compounds. Leave ample air space (2 to 3 cm) in containers to facilitate mixing and resuspension of settled material at the laboratory.

8.3.4 *Stopping Residual Biocide Action*—Sodium thiosulfate may be added at the time of sample collection to neutralize residual chlorine and to prevent continued biocidal action during sample transport and storage. Refer to the APHA Standard Methods for the Examination of Water and Wastewater for further information. Neutralization of low chlorine concentrations, for example, those typically found in potable water supplies, may not be necessary as legionella is fairly resistant to chlorine (see 6.1.4, 6.1.5) and unrestricted growth of other microorganisms may interfere with legionella isolation. Refer to manufacturers' recommendations for neutralization of other biocides.

8.3.5 *Sample Identification*—Record the following for each sample (*1*) facility name; (*2*) initials of person collecting sample; (*3*) sampling site description; (*4*) sampling date and time; (*5*) sample identification number; and (*6*) sample temperature, volume, and appearance. Document all custody transfers and storage conditions from the time of sample collection to final disposition. Refer also to Practice D4840.

8.4 *Environmental Sample Transport and Storage*—Let samples reach ambient temperature and protect them from extreme temperatures during transport and storage, for example, temperatures below 3°C and above 30°C. Seal the necks of collection containers with tape, wrap them in absorbent paper, and place them in individual plastic bags if not delivered by hand to a testing laboratory. Samples should reach the laboratory within 24 h of collection. Hold samples at room temperature at the testing laboratory and process them within 24 h of receipt (ideally within 48 h of collection). Samples that cannot be processed within 72 h from the time of collection should be refrigerated.

8.5 *Personal Protection During Environmental Sample Collection*—Request that equipment be turned off while samples are being collected, if possible. Wear disposable garments, slip-proof footwear, and eye protection while working in areas that are wet, potentially contaminated, or recently treated with biocides, disinfectants, detergents, or other chemicals. Wear a respirator that is at least as effective as an OSHA-approved N95 filtering facepiece respirator when working near potentially contaminated equipment that might generate aerosols.

9. Procedure—Epidemiological Investigations of Possible Legionellosis Outbreaks

9.1 Factors important to the rapid recognition of a legionellosis outbreak, identification of its cause, and initiation of appropriate interventions are (*1*) understanding of the types of exposures that can result in legionellosis (see 6.3.4 and 6.3.5); (*2*) accurate recognition and diagnosis of legionellosis when it occurs (see 6.4 – 6.7); and (*3*) prompt action on the part of physicians, public health authorities, employers, facility owners and operators, and others when notified of such illness. Reasons to investigate possible legionellosis outbreaks include (*1*) prevention of further exposures; (*2*) initiation of procedures to identify other persons with legionellosis so they receive appropriate diagnosis and treatment; and (*3*) assessment of possible common exposures among persons who contracted legionellosis within a limited time period (for example, weeks to months) and geographic region (for example, a building, limited area within a building, or up to several kilometres around a potential source).

9.2 *Identification of Possible Legionellosis Outbreaks*—Reporting of suspected or confirmed Legionnaires' disease to local health authorities, for example, city or county health officers or state epidemiologists, is mandatory in most states in the United States (Table 1, Step 1). Standard reporting forms are available from the CDC website (www.cdc.gov) or the Respiratory Diseases Branch, Atlanta, GA as well as the WHO Legionella and the Prevention of Legionellosis. Clinical laboratories must report test results indicative of the presence of Legionnaires' disease to local health authorities in almost all states. Physicians and laboratories should alert local health authorities of apparent outbreaks of Pontiac fever. Test persons suspected of having legionellosis as described in 6.6 and 6.7 (Table 1, Step 2). Refer to the APHA Public Health Law Manual and to relevant local laws and codes for information on reporting the suspicion or diagnosis of legionellosis. Refer to the CDC 2003 Guidelines for Preventing Health-Care-Associated Pneumonia and the WHO Legionella and the Prevention of Legionellosis for guidance on responding to laboratory-confirmed health-care associated legionellosis. Public health authorities, employers, and employees may request assistance from the federal or state OSHA, if exposure may have occurred at a workplace. Refer to the 2003 Occupational

TABLE 1 Flowchart for Epidemiological Investigation of Possible Legionellosis Outbreak

Possible Legionellosis Case Reported
Step 1: Contact the institutional health-care provider, if any, and the local public health department.
Step 2: Establish whether or not the diagnosis can be confirmed.
- If the diagnosis is not confirmed, perform no further epidemiological investigation.[A]
Step 3: If the diagnosis is confirmed, identify other cases of illness compatible with legionellosis.
- If no other case is identified, perform no further epidemiological investigation.[A]
Step 4: If one or more additional cases of legionellosis is identified, obtain clinical specimens for diagnostic testing.
- If the diagnosis is not confirmed, continue the epidemiological surveillance for one to two months.[A]
- If the diagnosis is confirmed, initiate a full epidemiological investigation and environmental inspection.

[A] Termination of an epidemiological investigation does not preclude initiation or continuation of an environmental inspection for possible sources of legionella multiplication or of exposure to legionella.

Safety and Health Administration (OSHA) Technical Manual, Section III: Chapter 7, Legionnaires' Disease: 7–4, Legionnaires' Disease Case Identification.

9.3 *Determining if Legionellosis Occurred in the Past:*

9.3.1 *Identification of Possible Exposures*—An epidemiologist or trained nurse or physician should question persons with legionellosis (see 9.2) regarding possible exposures to potential legionella sources (see 6.3.4). Obtain an exposure history from a patient's health-care provider or a reliable family member, co-worker, or colleague, if a patient cannot respond directly.

9.3.2 *Determination of When and Where Exposure May Have Occurred*—Exposure histories (see 9.3.1) should cover the period immediately preceding symptom onset, that is, ten days before the onset of Legionnaires' disease symptoms (see 6.4.3) and two days before the onset of Pontiac fever symptoms (see 6.5.3).

9.3.3 *Searching for Other Persons Who Had Legionellosis*—Public health authorities should search for legionellosis (*1*) at the residences and workplaces of legionellosis patients; (*2*) among other persons with whom patients may have shared an exposure, for example, classmates, social contacts, and other visitors to facilities that the patients frequented; and (*3*) in the surrounding community. Interview contacts ill for two or more days, and look for clustering of legionellosis-like illness in time or space. Use standardized questionnaires to identify persons who may have had legionellosis and to interview the health-care providers of patients seen for illnesses compatible with legionellosis (see Appendix Table X1.1 and Table X1.2, forms available from the CDC website (www.cdc.gov) or the Respiratory Diseases Branch, Atlanta, GA, as well as the WHO Legionella and the Prevention of Legionellosis).

9.3.4 *Confirmation of Suspected Legionellosis*—Public health authorities should attempt to confirm apparent legionellosis by collecting and testing appropriate clinical specimens (Table 1, Step 3). Advise persons possibly exposed to *L. pneumophila* Serogroup 1 to submit urine specimens for antigen testing (see 6.6.2.5). Collect both acute and convalescent blood samples from suspected patients, at least two and preferably six to nine weeks apart, to detect a rise in legionella antibody titer (see 6.6.2.1). Less ideally, collect a single convalescent blood sample. Diagnosis based only on a convalescent sample is of limited value because antibodies to *L. pneumophila* Serogroup 1 occur at a titer of ≥1:128 in 1 to 20 % of the general population. Therefore, testing persons with no history of legionellosis-like illness generally is not warranted (see 6.6.2.6).

9.4 *Determining if Legionellosis Continues to Occur:*

9.4.1 *Surveillance for New Legionellosis Cases*—Public health authorities should inform local health-care providers of legionellosis outbreaks so physicians seeing patients with compatible illness will perform the necessary confirmatory tests and provide appropriate treatment. An epidemiologist or trained nurse or physician should interview persons suspected of having legionellosis (see 6.4.1, 6.5.1) and look for clustering of illness in time or space (see 9.3).

9.4.2 *Surveillance Period*—Continue surveillance for new legionellosis cases (see 9.4.1) for one to two months after initiation of an investigation or after investigation of the last suspected case (see Section 11 and Table 1, Step 4).

9.4.3 *Confirmation of Legionellosis in Suspected New Cases*—Attempt to confirm apparent legionellosis in suspect patients by testing appropriate clinical specimens (see 6.6 and 6.7, and Table 1, Step 4).

9.5 *Action Needed if an Epidemiological Investigation Identifies Additional Legionellosis Cases*—Initiate a full epidemiological investigation and environmental inspection of possible legionella sources if the search outlined in 9.3 or 9.4 identifies additional persons with legionellosis (see 5.4). Initiate immediate control measures (see Section 10) on water systems identified as possible sources of legionella exposure if a legionellosis outbreak appears to be ongoing. If an investigation uncovers additional cases only retrospectively and no infections occurred since study initiation, investigators may delay implementation of control measures for suspected legionella sources until environmental test results (see Sections 7 and 8) are available.

10. Procedure—Control Measures for Water Systems

10.1 The goal of a control program for a water system is to maintain clean equipment and to avoid conditions that allow legionella to multiply. The total eradication of this bacterium from water systems may not be possible or even necessary except in certain settings, for example, some health-care environments. Refer to the ASHRAE Codes and Standards, Cooling Towers, Water Treatment, Minimizing the Risk of Legionellosis Associated with Building Water Systems (12–2000), and Ventilation for Acceptable Indoor Air Quality (62.1-2007); the CDC 2003 Guidelines for Preventing Health-Care Associated Pneumonia; 2003 Occupational Safety and Health Administration (OSHA) Technical Manual, Section III: Chapter 7, Legionnaires' Disease: 7–5, Water Treatment Protocols for Facilities that Have Experienced a Legionnaires' Outbreak; the WHO Legionella and the Prevention of

Legionellosis, and Ref (**8**) for information on general and emergency control measures for water systems.

10.2 *Control Measures for Water-Cooled Heat-Transfer Systems:*

10.2.1 *Equipment Design and Location*—Select designs and locate water-cooled heat-transfer equipment to facilitate water temperature control and prevent accumulation of organic material.

10.2.1.1 *Construction Materials*—Use durable, biocide-resistant materials for wet surfaces in water-cooled heat-transfer systems. Ensure that equipment will be accessible and will be easy to drain and clean. See that air flow through each system is uniform.

10.2.1.2 *Drift Eliminators*—Install high-efficiency drift eliminators on aerosol-generating water-cooled equipment to reduce release of bacteria in exhaust air streams.

10.2.1.3 *Location of Equipment Exhausts*—Locate exhausts from water-cooled heat-transfer systems so as to avoid entrainment of contaminants into the outdoor air intakes of HVAC systems serving the same and neighboring buildings (see 10.5.1).

10.2.2 *Equipment Operation, Maintenance, and Inspection*—Consult equipment suppliers or manufacturers to learn how to operate water-cooled heat-transfer equipment properly and follow those instructions. Appropriate use of scale and corrosion inhibitors, anti-foaming agents, and biocides (see 10.2.3) may be part of routine operation and maintenance. Good maintenance of water-cooled heat-transfer systems may not only limit legionella multiplication but also may improve equipment efficiency and extend service life. Inspect water-cooled heat-transfer systems regularly (for example, weekly or monthly) to confirm that equipment is operated and maintained as intended.

10.2.3 *Biocide Use*—The addition of chemical biocides often is necessary to control multiplication of bacteria, protozoa, and algae in water-cooled heat-transfer systems, however, control of other microorganisms does not necessarily indicate control of legionella. Obtain information on appropriate biocide selection and use for legionella control from equipment manufacturers or from companies experienced with the particular system in question. Consider the simultaneous use of more than one biocide and automatic biocide delivery. Refer also to Test Method E645.

10.2.4 *Periodic Cleaning*—Clean and disinfect water-cooled heat-transfer equipment periodically, for example, monthly, quarterly, semi-annually, or annually, as needed. Cleaning may entail physical or chemical removal of sludge, sediment, biofilm, algae, fungi, rust, scale, or corrosion. Clean and disinfect new equipment and equipment idle for extended periods, for example, six or more months. Drain and clean systems before shut down.

10.2.5 *Recordkeeping*—Develop detailed descriptions of all water-cooled heat-transfer systems, including all equipment cooled by a system and details of the make-up water supply. Keep, readily available, written procedures describing proper system operation and maintenance and indicating use of scale and corrosion inhibitors, anti-foaming agents, and biocides (see 10.2.2 and 10.2.3). Record the dates and results of equipment inspections, maintenance, cleaning, and testing (see 10.2.2, 10.2.4).

10.3 *Control Measures for Potable Hot Water Supplies:*

10.3.1 *Hot Water Tank Capacity*—See that the capacity of hot water tanks meets a facility's needs. Excessive hot water demand can result in delivery of insufficiently heated water, whereas demand far below available capacity can result in water stagnation. Design systems to circulate hot water, if possible, and minimize dead legs to reduce water stagnation.

10.3.2 *Hot Water Temperature*—Maintain hot water storage temperature at or above 60°C and deliver water to all outlets at or above 50°C, if permitted. Employ appropriate safeguards, for example, thermostatically controlled mixing valves, if scalding is a concern as a result of delivering water above 50°C (refer also to F444 and F445).

10.3.3 *Water Line Insulation*—Physically separate hot water lines running near cold water lines or insulate hot water lines to reduce heat transfer. Insulation of hot water lines also helps maintain distribution and delivery temperatures (see 7.3.1.3).

10.3.4 *Gaskets, Sealants, and Plumbing Fixtures*—Do not use materials known to encourage biofilm formation or legionella multiplication (for example, natural rubber and silicone) in gaskets, seals, or plumbing fixtures for potable hot water supplies.

10.3.5 *Unused Equipment*—Flush unused hot water tanks, delivery lines, and similar equipment periodically (for example, monthly, semi-annually, or annually) or disconnect them from the main water supply and drain them (see 7.3.1.1).

10.3.6 *Heat Shock Pasteurization*—It may be advisable, in facilities such as health-care settings, to pasteurize hot water systems periodically (for example, monthly, semi-annually, or annually) by heating the water to at least 70°C for 2 to 24 h and flushing each outlet for at least 5 min with the superheated water (see also 10.3.7).

10.3.7 *Chlorination*—It may be advisable, in facilities such as health-care settings, to shock-chlorinate hot water systems periodically (for example, monthly, semi-annually, or annually) by raising the free residual chlorine concentration to 10 mg L^{-1} (ppm) and flushing each outlet until the odor of chlorine is detected (see 10.3.6). Chlorine is corrosive and will shorten the service life of metal plumbing. Chlorine's biocidal activity is sensitive to pH, decreasing rapidly above pH 7. Therefore, adjust pH to between 6 and 7 to use the lowest effective dose of chlorine. Refer also to Test Methods D512, D1067, and D1293.

10.4 *Control Measures for Potable Cold Water Supplies:*

10.4.1 *Cold Water Tank Capacity*—See that the capacity of cold water tanks meets a facility's needs and that storage time does not exceed 24 h. Demand far below available cold water capacity can result in water stagnation, and poor insulation can result in elevated water temperature (see 10.4.2).

10.4.2 *Cold Water Temperature*—Keep cold water temperatures at or below 20°C to limit legionella multiplication.

10.4.3 *Water Line Insulation*—Physically separate cold water lines running near hot water lines, or insulate hot water lines to reduce heat transfer (see 7.3.1.3).

10.4.4 *Gaskets, Sealants, and Plumbing Fixtures*—Do not use materials known to encourage biofilm formation or legionella multiplication (for example, natural rubber and silicone) in gaskets, seals, or plumbing fixtures for potable cold water supplies.

10.4.5 *Cross Contamination*—Avoid contamination of cold water supplies by contact with water from other systems. Protect all connections to non-culinary processes using approved plumbing devices, for example, back-flow preventers or air gaps (see 7.3.1.2).

10.4.6 *Unused Equipment*—Flush unused cold water tanks, delivery lines, and similar equipment periodically (for example, monthly, semi-annually, or annually), or disconnect them from the main water supply and drain them (see 7.3.1.1).

10.4.7 *Chlorination*—It may be advisable, in facilities such as health-care settings, to shock-chlorinate cold water systems periodically (for example, monthly, semi-annually, or annually) by raising the free residual chlorine concentration to 20 mg L^{-1} (ppm) for 2 h or to 50 mg L^{-1} for 1 h. Run all outlets until the odor of chlorine is detected and leave the hyperchlorinated water in the system for the time stated above before flushing with fresh water. Chlorine is corrosive and will shorten the service life of metal plumbing. Chlorine's biocidal activity is sensitive to pH, decreasing rapidly above pH 7. Therefore, maintain pH between 6 and 7 to use the lowest effective dose of chlorine. Refer also to Test Methods D512, D1067, and D1293.

10.5 *Control Measures for Heating, Ventilating, and Air-Conditioning (HVAC) Systems:*

10.5.1 *Location of Outdoor Air Intakes*—Locate outdoor air intakes for HVAC systems at a sufficient height and distance from possible sources of airborne bacteria (for example, exhausts from water-cooled heat-transfer equipment) and from possible sources of dust and debris to minimize entrainment of contaminants (see 7.3.4, 7.3.5.2, 10.2.1.3).

10.5.2 *Humidifiers*—Use humidifiers that emit water vapor or steam rather than ones that produce water droplets, that is, mists, if possible. Follow manufacturers' directions on cleaning and disinfection of humidifiers.

10.5.3 *HVAC Reservoirs and Condensate Trays*—HVAC equipment that allows water to collect may provide a location for microbiological growth, but the water temperature in these sources typically does not encourage legionella multiplication (see 6.1.4) and this bacterium does not survive drying. Water in HVAC system reservoirs and condensate trays likely does not present a hazard of legionella transmission unless there is a mechanism for bacterial aerosolization from the source (see 6.3.4 and 6.3.5).

10.5.4 *Recordkeeping*—Develop detailed descriptions of all HVAC systems identifying the equipment in use and the parts of the facility each unit serves. Record the dates and results of equipment inspections, maintenance, cleaning, and testing.

10.6 *Control Measures for Spas, Whirlpool Baths, and Jacuzzis*—Typical water temperatures in these systems range between 32 and 40°C, which is in the temperature range that favors legionella multiplication (see 6.1.4). See that systems comply with applicable microbiological standards and recommended maintenance programs including biocide use and regular (for example, weekly or monthly) cleaning. Backflush, disinfect, or change water filters periodically (for example, weekly or monthly) to prevent excessive buildup of organic material. Control foaming to reduce bacterial release from bursting bubbles.

10.7 *Control Measures for Decorative Fountains*—Keep decorative fountains and similar equipment clean and operate and maintain such equipment according to the designer's or manufacturer's instructions including chlorination or other water treatment.

10.8 *Protocol for the Management of a Legionella-Related Emergency*—Refer to the CDC 2003 Guidelines for Preventing Health-Care Associated Pneumonia; the 2003 Occupational Safety and Health Administration (OSHA) Technical Manual, Section III: Chapter 7, Legionnaires' Disease–IV Investigation Protocol; and the WHO Legionella and the Prevention of Legionellosis for information on managing a legionella-related emergency.

10.8.1 Develop protocols for dealing with emergencies such as the need to shut down equipment or take water systems out of service quickly. Such emergencies may arise when water systems are implicated in legionella transmission or are found to support undesirable concentrations of the bacterium (see 6.2.4.2). Include in emergency protocols information on where to obtain building plans; instructions on arranging meetings with facility staff, building occupants, and the local community; identification of persons in charge of the coordination of media contacts (for example, television, radio, and newspapers); and a mechanism to obtain and disseminate accurate information that will answer basic questions and address concerns. Refer also to the 2003 Occupational Safety and Health Administration (OSHA) Technical Manual, Section III: Chapter 7, Legionnaires' Disease: 7–1, Employee Awareness Program.

10.8.2 Include in emergency plans a list of whom to contact at the local health department and information on where to obtain replacement equipment and supplies to clean and disinfect water systems. Coordinate with public health authorities emergency activities such as the shutting down, testing, disinfection, draining, and cleaning of equipment implicated in legionella transmission. Collect water samples for legionella detection (see Section 8) before treating implicated equipment to provide baseline information on water quality (see Section 10) and to obtain environmental legionella isolates for comparison with clinical isolates (see 6.2.1, 6.6.2.4). Also collect water samples after completion of control measures to determine their success in reducing or eliminating legionella (see 10.1 – 10.7, and Section 11).

11. Follow-up of Environmental Inspections and Epidemiological Investigations

11.1 Repeat or continue cleaning and disinfection measures on water systems (see Section 10) until the desired environmental control of legionella is achieved (see 5, 6.2.4, 7). Continue epidemiological surveillance for legionellosis (see 9.3 and 9.4) for up to 12 months after implementation of control measures to identify new infections as soon as possible should they occur.

12. Keywords

12.1 air-conditioning systems; epidemiological investigation; heating; legionella; *L. pneumophila*; legionellosis; legionellosis surveillance; Legionnaires' disease; microbiological water monitoring; outbreak investigation; Pontiac fever; ventilating; water-cooled heat-transfer equipment; water sampling; water supplies; water systems; water system inspection

APPENDIX

(Nonmandatory Information)

X1. SAMPLE QUESTIONNAIRES FOR INVESTIGATION OF POSSIBLE OUTBREAKS OF LEGIONNAIRES' DISEASE

X1.1 Tables X1.1 and X1.2 provide sample questionnaires for use in investigations of possible outbreaks of Legionnaires' disease. Such investigations should be conducted by local public health authorities, or in consultation with them, and reporting should comply with local requirements.

TABLE X1.1 Sample—Legionnaires' Disease Surveillance Questionnaire

Interviewer's name
Interview date
Interviewer's agency
Telephone number
We at (identify the public health office) are investigating a cluster of respiratory infections at a local (workplace/school/etc.). (Workplace/school/etc.) records show that you may have been absent for two or more days in a row in the past two months. If now is a convenient time, I would like to ask a few questions about your absences.
Name
Date of birth
Gender
Home telephone number
Work telephone number
Have you been absent for two or more days in a row in the past two months because of illness?
If no, conclude the interview. If yes, continue with the following questions.
Date(s) of absence
Date you first became ill
Have you recovered?
If yes, how many days were you ill?
Did you experience any of the following symptoms during your illness?
Fever (temperature above 38ºC; 100ºF)
If yes, what was your highest temperature?
Cough
If yes, was the cough productive?
Did you see a doctor for this illness?
If no, conclude the interview. If yes, continue with the following questions.
On what date(s) did you see the doctor?
What did the doctor tell you was the diagnosis?
Were you admitted to a hospital?
If yes, what hospital and when?
If necessary, may we contact your doctor regarding this illness?
Doctor's name and phone number

TABLE X1.2 Sample—Legionnaires' Disease Health Care Provider Questionnaire

Interviewer's name
Interview date
Interviewer's agency
Telephone number
Patient's name
Date of birth
We at (identify the public health office) are investigating a cluster of respiratory infections at a local(workplace/school/etc.).
(Patient's name) reports that (he/she) saw you on (date) because of an illness. I would like to ask a few questions about your evaluation of this patient.
Did the patient have pneumonia?
If no, conclude the interview. If yes, continue with the following questions.
What etiology was found for the pneumonia?
Was a chest x-ray taken?
If yes, what were the findings?
Was a specimen collected specifically for legionella culture?
If yes, what kind of specimen, when was it collected, where was it tested, and what were the results?
Was a specimen collected for legionella DFA testing?
If yes, what kind of specimen, when was it collected, where was it tested, and what were the results?
If later blood samples were collected, please provide the same information for each.
Was a urine sample collected for legionella antigen testing?
If yes, when was it collected, where was it tested, and what were the results?

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