

Assessing Risk of *Legionella*

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Legionella is the causative agent of legionellosis and can be isolated from environments such as rivers, streams, lakes, and man-made water systems. *Legionella* concentrations generally are highest on surfaces where biofilm is present and protozoa serve as hosts for replication.¹ To become infected with *Legionella*, a susceptible individual must inhale or aspirate aerosols (generally less than 10 µm in size) containing sufficient numbers of virulent *Legionella* cells.

Outbreaks of legionellosis have been traced to water systems including domestic water services (tanks, showers, faucets, stagnant warm pipes), cooling towers and evaporative condensers, process waters, spas/whirlpools, nebulizers, vegetable misters, ice machines, decorative fountains, and other aerosol producing sources.^{1,2} *Legionella pneumophila* became a recognized public health concern in 1976 after 34 people died and 221 people became ill following the Legionnaires' convention in Philadelphia. Since then, scores of articles have been published regarding this organism and infection.³

Sporadic outbreaks of legionellosis continue to occur. Legionellosis outbreaks have occurred recently at a 1999 flower show in the Netherlands, an aquarium opening in Melbourne, Australia (2000), and in the communities of Murcia, Spain (2001), Barrow-in-Furness, England (2002), Hereford England (2003), and Pas-de-Calais, France (2004).⁴⁻⁹ An estimated 8,000 to 18,000 cases occur each year in the United States,¹⁰ but only a fraction of these are reported.

Most legionellosis cases are sporadic. Twenty-three percent are nosocomial (acquired during hospitalization) and 10% to 20% can be linked to outbreaks.¹¹ Eu-

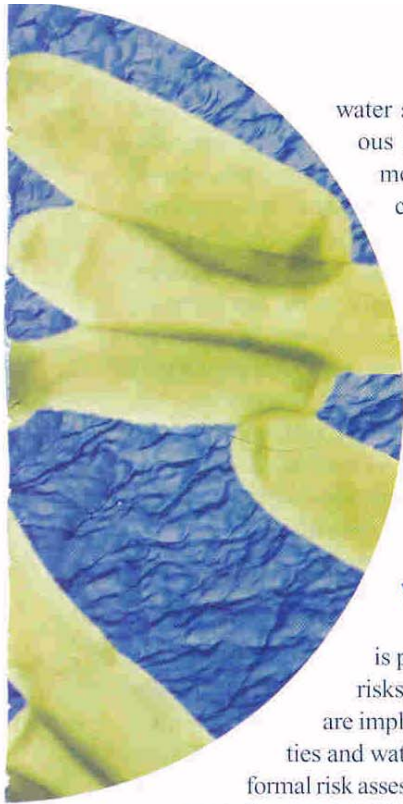
ropean Union (EU) estimates of incidence vary from 1 to 20 cases per million people, depending on reporting procedures in individual European countries. The true number of cases may be 20 times greater than this figure since only a small fraction of cases are reported to public health authorities.¹⁰ Studies that have tried to estimate the true incidence of community-acquired Legionnaires' disease have found that *Legionella* species cause between 2% and 16% of community-acquired pneumonia cases in industrialized countries.¹²

The incidence of legionellosis is of significant concern to public health authorities and to facility owners and managers responsible for the operation and maintenance of industrial and building

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Photo: CDC, transmission electron micrograph of *Legionella pneumophila*.



water systems. This concern has led various industrial associations and government bodies to formulate *Legionella* control guidelines. Interpreting and implementing these guidelines for an entire facility or a specific water system can be complex. This task, however, is incumbent on facility owners or managers and must be performed to successfully manage the risk and liability associated with waterborne pathogens. The essential first step is risk assessment.

Why Assess Risk of Legionellosis?

Fortunately, exposure to *Legionella* is preventable, but only if health-related risks are assessed and preventive practices are implemented. Unfortunately, of the facilities and water systems that would benefit from a formal risk assessment, only small fractions have been properly assessed. Even in countries with strict guidance on health risk reduction, no formal risk assessment structure often is required. The complexity of risk assessment and the perceived low priority of health risk management have, in some instances, led facility owners and managers to delay risk assessment. However, practical experience and observations suggest that prioritizing risk assessment and developing a risk reduction plan for legionellosis is prudent and justified.

To health and safety professionals, the risk assessment process is a natural beginning to lay foundation for the ongoing risk management plan. As the general awareness of the risks associated with *Legionella* and other waterborne pathogens increases, there is an increasing duty of care to undertake risk assessments. Potential problems with delaying risk assessment may include:

- On-site and community health hazards,
- Liability exposure or regulatory sanctions, and
- Mitigation efforts that lead to costly and/or ineffective risk reduction schemes.

One initial step to assess risk is to ask, "Can we eliminate this water system?" Where water systems remain in proximity to people, formation of a risk reduction plan is recommended by many industry and government guidelines. Review of the available guidelines reinforces that it is the facility owner's responsibility to protect employees and other personnel, although the process of risk assessment may be delegated. This responsibility typically appears under health and safety at work

legislation or equivalent national law. Duty holders must take reasonable steps to identify and assess the risk within the workplace, ensure those involved in risk assessment are competent and aware of their duties, and implement corrective and precautionary measures.

In some countries, such as the United Kingdom, certain health and safety regulations require employers to make employee representatives, health and safety representatives, or trade unions aware of risks and control measures and to provide health and safety training. In the United States, the Occupational Safety and Health Administration (OSHA) has authority under the "General Duty" clause to issue fines and citations if facilities are found to be negligent.

Ultimately, the motivations for performing legionellosis risk assessment vary among facility operators, managers and supervisors. The decision to assess risk in some countries may be quite personal where the threat of prosecution is present for facility owners and operators who are responsible for the creation of foreseeable risk, but do not take sufficient measures to assess and reduce the risk of legionellosis.

Can the Risks be Quantified?

"Risk" may be defined in the context of legionellosis risk assessment as the probability that disease will occur as a consequence of exposure to the causative agent(s) (e.g., pathogenic *Legionella* species). The following would be required to quantify this risk in terms of hazard and exposure:

- Information on the hazard associated with *Legionella*;
- Quantification of the hazard (*Legionella* bacterial cells) through dose-response assessments;
- Determination of the extent and duration of human exposure to *Legionella*, including extent of dispersal in an environment and availability for exposure occurrence; and
- Characterization of the possible consequences resulting from exposure.

For chemical hazards, scientists have performed detailed studies regarding the impact of chemical exposure on human health. Based upon this research, exposure levels for many chemicals have been established. These permissible exposure levels are based upon statistical evaluation of the adverse response of individuals to specific chemicals. If such exposure levels were available for biological agents such as *Legionella*, risk assessments for legionellosis could be made quantitative.

While there have been some animal model studies and investigations of legionellosis outbreaks that have suggested *Legionella* concentrations that cause infections, no permissible exposure levels exist for *Legionella* or many other microbial pathogens. Although various guidelines suggest "action levels" for *Legionella* concentrations in water, these

levels are based primarily upon practical issues such as the detection limits of available *Legionella* assays. In dynamic systems such as cooling water, action levels are particularly difficult to define and much work still must be done to explain the significance of various *Legionella* concentrations. Permissible exposure levels for most biological contaminants cannot be recommended for the following reasons:

- The mixture of biological contaminants is complex and varies from setting to setting. The interaction among all biological agents that may be present makes exposure assessment even more problematic.
- The methods of measuring viable and non-viable biological contaminant mixtures do not translate to meaningful numbers that can be used for exposure assessment.
- The susceptibility of exposed persons varies too greatly to establish safe exposure levels for most people.

Assumptions are still required for legionellosis risk assessment due to the lack of basic information regarding *Legionella* pathogenicity, population susceptibility, dose-response relationships, and extent of exposure. Therefore, legionellosis risk assessment is qualitative, rather than quantitative. However, legionellosis is recognized as a significant public health risk, and recommended practices exist that reduce the risk (the probability) of legionellosis outbreaks associated with water systems.

The qualitative nature of legionellosis risk assessment does not prohibit the use of risk ratings or scoring systems. Such systems are available in risk assessment formats from several providers and public guidelines.^{13,14} Scoring or rating systems that measure the presence or absence of certain factors and the extent to which specific risk reduction measures have been implemented (measurement of compliance with recommended practices for legionellosis risk reduction) can be useful in risk communication. Such scoring and ranking systems involve an element of judgment by technical experts, but can be based upon scientific and practical knowledge of the factors that influence *Legionella* proliferation, dissemination, and exposure. By using a rating system, positive steps toward risk reduction can be documented and resources focused on implementing recommendations with the greatest impact on reducing risks. When the risk assessment is reviewed (typically on an annual basis or if significant system changes are made), the system scores or rating also can be updated to document improvements in risk reduction.

Factors Included in the Assessment

The risk of legionellosis is a function of many factors. These factors can be grouped into three categories: 1) proliferation potential, 2) aerosol exposure, and 3) population susceptibility (Figure 1).¹⁵ Within the proliferation category, factors such as water stagnation, water temperature, biocide use, water pH, biofilm accumulation, cleaning and disinfection procedures, source water quality, and monitoring strategies are important. The relative virulence of *Legionella* is also important to consider when test results are available. Within the species *Legionella pneumophila* this is difficult to do, but many of the other *Legionella* species have rarely, if ever, been associated with disease. Thus, the species of *Legionella* growing in water systems also can be important for risk assessment.

To assess the aerosol exposure from a system, drift control, system location, system maintenance, venting, and leak detection may be included, depending on the system type. For example, the assessment of aerosol exposure in a cooling tower and decorative fountain may include different factors, but all will be focused on the production, release and dissemination of small water droplets.

Assessment of population susceptibility can be a sensitive issue, particularly since susceptibility to legionellosis is related to

factors such as age and health. Information in this category may be protected, and therefore inappropriate for collection. However, a reasonable estimation of risk for this category can be made by assessing the population as a whole. This may include factors such as population proximity to the water system, the numbers of people exposed to the system, individual health histories, training programs for operators and contractors, and awareness programs for those who may be exposed.

Previous cases of legionellosis also should be considered as a critical risk assessment factor. Additional detail in this regard is beyond the scope of this article, and the “weighting factors” between these considerations is a complex issue that is handled differently among risk assessment schemes. In the final analysis, all the factors are of some importance and decisions on what factors to address first are site-specific. For this reason, risk assessment results are best when generated using a comprehensive list of factors/questions that are explored on-site in a partnership between the risk assessor and the system operating experts.

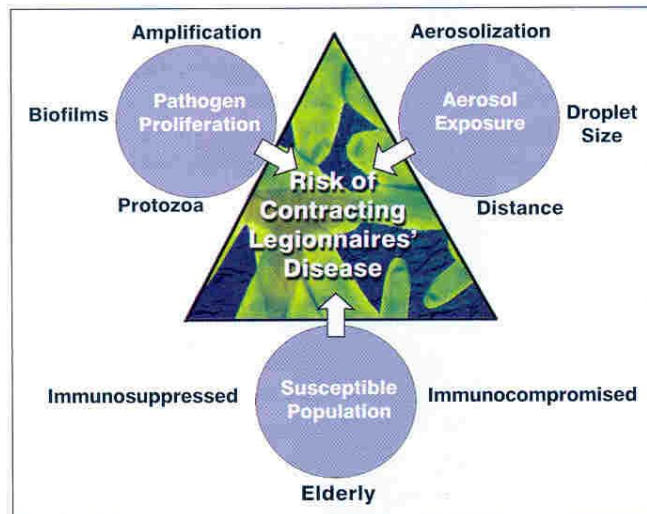


Figure 1: Factors that affect legionellosis risk.

Practical Considerations for Risk Assessment

Assessment of biological contaminant exposure relies upon the judgment of personnel with knowledge regarding buildings and systems and upon systematic analysis of risk factors. Using this knowledge and a thorough understanding of system engineering and operating conditions, the trained risk assessor can conduct investigations and formulate recommendations to address factors that contribute to *Legionella* proliferation and exposure (Table 1). A variety of general features influence the quality of a risk assessment, thereby impacting utility of the risk reduction plan.

1. Risk assessor knowledge. The person who conducts the risk assessment, formulates the resulting recommendations and prepares the report should be trained in risk assessment. A risk assessor should have specific training on legionellosis risk reduction and should participate in ongoing training and education.

2. On-site assessment. A simple “self assessment” by system operators is rarely an adequate approach to risk assessment. A self assessment may not be comprehensive (cover all water systems that may pose a risk including domestic, process, and industrial water), is subject to bias, and may not include all the factors that influence risk. A “new set of eyes” to inspect and assess systems can uncover information and situations that would otherwise go unnoticed.

3. Standardized approach to the survey process. To ensure that all appropriate factors are considered in a risk assessment and that the assessment process is consistent among varied facilities and locations, the factors considered in an assessment should be standardized. This includes the use of standard questions in the context of a risk model for the microorganism of interest such as *Legionella*. In the absence of a standardized approach to assessment, similar facilities may have quite different assessment results.

4. Global perspective and knowledge of regional and local guidelines. In recent years, guidelines regarding *Legionella* control have been published around the world. Familiarity with these guidelines is particularly important when the assessed corporate facilities are multinational. In these instances, adhering to the most stringent control practices may be suggested. National guidelines also must be considered in relation to regional or local guidelines, regulations, and building codes. These building codes often are very specific, particularly with regard to potable water systems and air-handling equipment.

5. Emphasis on recommendations, not measurement. Any proposal for risk assessment should include an outline of the information to be obtained, and an explanation of the need for any proposed microbiological measurements. While risk assessments may vary widely, a risk assessment proposal that emphasizes measuring concentrations of *Legionella* and comparing those concentrations to numerical standards is a warning sign that the assessment will not fully consider all the factors that influence legionellosis risk. The goal of the risk assessment should be to identify opportunities for improving mechanical, operational, and chemical practices, not to simply generate data.

6. Good understanding of the relationship between legionellosis and the facility structure, mechanical systems,

and human activities. For example, lack of adequate drift elimination is a contributing factor in the legionellosis risks associated with cooling towers. Evaluating performance of the drift elimination system depends on understanding the inter-action between the cooling tower operation, water chemistry, mechanical systems, and human activity in proximity to the cooling system. Mechanical engineers, industrial hygienists, or infection control experts may approach this analysis differently. However,

a risk assessor with sufficient experience will bridge this gap and provide accurate assessment and practical recommendations for pathogen risk reduction.

Holding the Gains

A risk assessment document should provide details of each assessed water system, a summary of findings, and the state of compliance with recommended control practices. Recommendations for risk reduction then can be based upon the risk assessment. Commitment to risk assessment implies commitment to an ongoing risk reduction plan. Formulation, implementation and monitoring of this plan helps to demonstrate due diligence for reducing risks. When properly implemented, the risk assessment and the risk management plans become living documents that are updated on a regular basis.

Routine environmental analysis (e.g., *Legionella* test, temperatures, oxidant residuals, etc.) as determined from the risk assessment is critical for monitoring the effectiveness of preventive practices or control measures. Risk assessment should be considered a prerequisite to *Legionella* testing. Negative *Legionella* test results are not equivalent to low legionellosis

1. Familiarize site management with *Legionella* control guidance documents.
2. Perform an on-site risk assessment using a qualified assessor.
3. Use a standardized approach to risk assessment.
4. Include assessment of population susceptibility, aerosol exposure potential, and growth potential for *Legionella* in every risk assessment.
5. Implement mechanical, operational, and chemical control measures that originate from the risk assessment.
6. Begin *Legionella* testing only after a risk reduction plan is prepared, unless regulatory or outbreak situations require testing.
7. Use *Legionella* testing to confirm that control measures are effective.
8. Periodically review the risk reduction plan to ensure that control measures remain appropriate.

Table 1: Risk management suggestions for legionellosis.

risk and should not lead to complacency in risk reduction.

Positive *Legionella* test results (in the absence of a risk reduction plan) have lead occasionally to panicked responses that were disruptive and expensive. Positive *Legionella* test results cannot be used alone to determine the risk of legionellosis.

Legionella testing is best performed as part of a comprehensive risk reduction plan that follows risk assessment. *Legionella* test results have more meaning within the context of a risk assessment. Analytical data then can be best used to confirm that control measures have been effectively applied and to identify contaminated areas in a water system.

Routine maintenance practices as determined from a risk assessment also are critical for prevention of microbial growth. These practices must be performed regularly and documented. Examples of routine maintenance practices may include cleaning and disinfecting cooling towers, air handler coils, showerheads, and water storage tanks. They may also include routine flushing of water tanks or "deadleg" plumbing and fixtures. In some instances, chemical intervention strategies including secondary disinfection of domestic water systems may be recommended.

A multidisciplinary team consisting of operations managers, health and safety personnel including infection control or industrial hygiene personnel, system engineers and maintenance staff should be formed to take responsibility for implementing the risk reduction plan. Ideally, this team will meet periodically (quarterly or more frequently initially) to ensure that risk reduction recommendations from the risk assessment are fully implemented and documented, and that the benefits of the risk reduction plan are properly communicated to facility owners, occupants, and the community.

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