The National Institutes of Health | Division of Technical Resources | Office of Research Facilities

Design Requirements Manual **News to Use**

February 2022

Vol. 02, No. 59

The formulae $\frac{\partial \rho \bar{U}_i}{\partial t}+\frac{\partial}{\partial x_j}(\rho \bar{U}_i \bar{U}_j)=-\frac{\partial \bar{P}}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu \frac{\partial \bar{U}_i}{\partial x_j}\right)+g_i(\rho-\rho_0)$ *for building* $\frac{\partial}{\partial x_j}(\rho \bar{U}_i \bar{U}_j)=-\frac{\partial \bar{P}}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu \frac{\partial \bar{U}_i}{\partial x_j}-\rho \overline{u_i u_j}\right)+g_i(\rho-\rho_0)$ *state of the art* $\frac{\partial}{\partial x_i}(\rho \bar{U}_i \bar{H})=\frac{\partial}{\partial x_i}\left(\lambda \frac{\partial \bar{T}}{\partial x_i}-\rho \overline{u_i h}\right)$ *biomedical research facilities.*

Modular Construction for Cleanroom Facilities

Modular cleanroom facilities are an alternative to standard cleanroom facilities that is appealing for several reasons, including shorter onsite construction time and the ability to use materials of construction and material sizes that are impractical for field construction. There are potential drawbacks to consider, however, such as limited ability to factory test some utilities, the potential need to construct a shell building or open the façade of an existing building to slide the modules inside, and tight installation clearances. Although cost savings are often touted as a selling point of modular construction, these savings may not be realized based on a variety of factors. Designers should therefore perform a thorough cost-benefit analysis of modular cleanroom facility types to decide what is most appropriate for the project. The two basic types of modular cleanroom construction are panelized systems and factory-built modular unit systems; this article will review the fundamentals, pros, and cons of each.

Modular Panelized Systems

The site available for project development often precludes the installation of pre-assembled modular solutions. Panelized systems, including cleanroom or walkable cleanroom ceiling panels, liner panels, and modular wall panel systems, may be a good solution in such circumstances. These panels are faced with hard, cleanable materials and are typically gasketed and/or cold-welded to form a contiguous, continuous surface. Panelized systems exceed the quality typical of stick-built field construction because of the availability of ceiling-wall and wall-wall coves and integration with flush window and door systems.

It is important to understand that using a modular panelized system is not as simple as changing architectural finish systems – there is a significant learning curve to implementing them properly, especially for full wall panel systems. For example, most wall panel systems provide a very narrow depth, often 50.8 mm (2”) in overall thickness, which maximizes usable area in the room. However, these systems require significant pre-planning of electrical power and low-voltage systems due to shallow, or in some cases lack of, backbox space. Some manufacturers utilize integral vertical raceways in their panels, but because line and low-voltage systems cannot share the same raceways, coordination is critical and often requires simultaneous consideration of both faces of the wall, especially where devices are desired at the same elevation. It can also be challenging to provide in-service covers for loads which must remain connected during cleaning, as their projection from the surface of the wall makes them particularly susceptible to cart damage. Air and pest-resistant sealing where utilities enter raceways and fire-stopping within raceways can also be difficult to install and inspect properly. Occasionally, terminal devices themselves exceed the available wall thickness. In such cases, custom fabricated stainless steel enclosures, or similar, are installed to provide sufficient mounting depth. Modular panelized systems provide a rapidly installable, hard, cleanable surface, but some are easily damaged, so the installation labor savings may be eroded by operational costs.

Modular Unit Systems

Modular solutions can range from mobile trailers to large, fixed assemblies of “shipping container” type units; the latter are bolted together and can expand over multiple floors with many units per floor, often wrapped within a shell building which serves as the primary weather-resistant envelope for the facility. Typically, the architectural finishes of modular cleanrooms utilize modular panelized assemblies, providing outstanding quality of architectural fit and finish.

Most modular cleanrooms are designed to provide their own air-side HVAC utilities while receiving other utilities, such as electricity, steam, and chilled water, from local sources. While this provides redundancy, reliability, and efficiency, most factories cannot supply these utilities to the pre-assembled modular for Factory Acceptance Testing (FAT) and adjusting, which may result in protracted Site Acceptance Testing (SAT), adjusting, and balancing. In some cases, it is difficult to address design deficiencies that are discovered during SAT due to the compactness of the construction, resulting in potential cost and schedule impacts. Alternatively, mechanical plans could be designed to be less integrated into the site utilities, which shifts the discovery of latent defects more towards the FAT period; however, this may result in increased construction and operating costs. A modular facility’s building automation system (BAS) should be selected and configured for compatibility with the owner’s BAS to ensure connectivity, monitoring and reporting continuity, and operational control. To the extent practicable, probes and sensors should be duct-mounted in accessible locations to facilitate calibration and replacement as necessary without suite entry by facility maintenance staff and contractors during operation. Modular unit systems tend to be expensive, with some savings realized through shorter on-site mobilization.

Conclusion

Modular elements can play a key role in the quest to improve the quality of cleanroom construction. However, they are not a one-size-fits-all solution; careful forethought and planning are necessary to implement them successfully, and the learning curve for designing facilities with modular elements should not be underestimated.

Additional Reading

1. 1. NIH Design Requirements Manual, Chapter 13

‘Design Requirements Manual (DRM) News to Use’ is a monthly ORF publication featuring salient technical information that should be applied to the design of NIH biomedical research laboratories and animal facilities. NIH Project Officers, A/E’s and other consultants to the NIH, who develop intramural, extramural and American Recovery and Reinvestment Act (ARRA) projects will benefit from ‘News to Use’. **Please address questions or comments to:** shawm@nih.gov

Further details on this month’s topic are available on the DRM website DRM Chapter 13, Aseptic Processing Facilities
https://www.orf.od.nih.gov/TechnicalResources/Pages/DesignRequirementsManual2016.aspx

The National Institutes of Health | Division of Technical Resources | Office of Research Facilities

Design Requirements Manual **News to Use**

April 2022

Vol. 02, No. 60

The formulae $\frac{\partial \rho U_i}{\partial t}+\frac{\partial}{\partial x_j}(\rho U_j U_i)=-\frac{\partial P}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial U_i}{\partial x_j}\right)+g_i(\rho-\rho_0)$ *for building* $\frac{\partial}{\partial x_j}(\rho\overline{U}_j\overline{U}_j)=-\frac{\partial \overline{P}}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial \overline{U}_i}{\partial x_j}-\rho\overline{u_i u_j}\right)+g_i(\rho-\rho_0)$ *state of the art* $\frac{\partial}{\partial x_i}(\rho\overline{U}_i\overline{H})=\frac{\partial}{\partial x_i}\left(\lambda\frac{\partial \overline{H}}{\partial x_i}-\rho\overline{u_i h}\right)$ *biomedical research facilities.*

Radio Frequency/Electromagnetic Attenuated Design

When designing a room to house equipment that is sensitive to radio frequency (RF) and electromagnetic (EM) energies, architects and engineers should never assume the equipment can adequately filter and/or self-shield from exterior signal sources. The design team must understand the source of these external signals; their power, frequency, and periodicity; and the thresholds at which attenuation is required, either by siting (e.g., distance) or attenuation (achieved through source or receiver shielding or other construction).

RF/EM Signals and Sources

RF/EM signals degrade over distance in accordance with the inverse square law, meaning that signal intensity decreases at a rate equal to the square of the distance from the source. This type of signal reduction is referred to as free space loss. Understanding free space loss is useful during site selection, where proximity to motors, transformers, and similar high-energy electromagnetic sources can be a site selection criterion. Where adequate standoff distance cannot be achieved, the source may be able to be relocated or attenuated. However, not all sources of electromagnetic radiation are obvious. Any large moving ferrous metal mass, like elevator cars, trucks, or dumpsters, may generate detectable interference. When dealing with instruments sensitive to RF/EM fields, such as MRI patient scanners or NMR research magnets, it is often necessary to perform an RF field survey (some equipment may be self-shielding, but a survey is always recommended).

Attenuation Design

Attenuation is measured in decibels (dB) and varies with the frequency of the RF signal source as well as the type and density of intervening materials. This type of attenuation, referred to as path loss, is measured by comparing the signal power on both sides of a material/assembly. A typical office wall, consisting of a 16 mm (5/8") layer of gypsum board on each side of a 92 mm (3-5/8") steel stud, will reduce an RF signal by approximately 3-6 db. Path loss may be calculated to generate an approximation of the attenuation; however, this can become complex in some indoor conditions, as typically design must also account for signal reflection (also known as obstacle attenuation). All components of the attenuation barrier must be bonded to each other and to a common ground to minimize voltage potential between components while effectively reducing signal strength from exterior sources. Penetrations through an attenuated assembly can potentially create pathways for signals of specific wavelengths to penetrate the attenuated construction into the room. Large openings for HVAC supply and return/exhaust ducts may be protected by installing waveguides in the airstream at the point the duct crosses through the attenuation barrier. Waveguides used for this purpose are typically a honeycombed metal grating with a specific cross section intended to block the passage of the frequencies requiring attenuation. However, waveguides contribute to duct pressure drop, which must be considered in the HVAC design. Small openings for plumbing pipes and electrical conduits are typically equipped with dielectric unions/connectors/filters to prevent transmission along conductive paths. Fluids carried within these pipes are generally inefficient at re-radiating RF energy and are ignored, except in cases involving the most sensitive receivers. Windows through attenuation barriers are generally fixed and filled with metallic screening, which is bonded to the attenuation barrier. The inside and outside window frames are electrically decoupled to prevent transmission of RF signals through the frame itself.

Doors serving RF/EM attenuated rooms can be very complex systems. Typically, doors/frames utilize conductive "fingers" that are engaged, either mechanically or pneumatically, on all four sides of the door to create a continuous enclosure (e.g., Faraday cage). These doors must be configured to open outward to minimize the risk of trapping personnel inside due to a sudden overpressure "quench." A quench occurs when cryogen, which is used to supercool magnets that are often installed within these types of enclosures, overheats and rapidly sublimates from liquid to gas, explosively expanding in volume (e.g., overpressure) which could prevent opening of a door configured to open inwards.

Summary

Continuity of attenuation barriers, grounding, and sensitivity of the receiver and site selection (determined via RF survey) are all critical considerations in the design of RF/EM attenuated rooms. Designing with these factors in mind ensures that attenuation is thorough and effective, and that sensitive equipment can operate with full efficacy.

Further Reading/Resources

1. The National Institutes of Health (NIH). *Design Requirements Manual,* https://www.orf.od.nih.gov/TechnicalResources/Pages/DesignRequirementsManual2016.aspx

2. National Institute of Standards and Technology, NIST Construction Automation Program, Report No. 3, Electromagnetic Signal Attenuation in Construction Materials nist.gov/publications/electromagnetic-signal-attenuation-construction-materials

'Design Requirements Manual (DRM) News to Use' is a monthly ORF publication featuring salient technical information that should be applied to the design of NIH biomedical research laboratories and animal facilities. NIH Project Officers, A/E's and other consultants to the NIH, who develop intramural, extramural and American Recovery and Reinvestment Act (ARRA) projects will benefit from 'News to Use'. **Please address questions or comments to:** shawm@nih.gov

Further details on this month's topic are available on the DRM website DRM Chapter 2, Planning and Programming
https://www.orf.od.nih.gov/TechnicalResources/Pages/DesignRequirementsManual2016.aspx

The National Institutes of Health | Division of Technical Resources | Office of Research Facilities

Design Requirements Manual **News to Use**

June 2022

Vol. 02, No. 61

The formulae $\frac{\partial \rho \bar{U}_i}{\partial t}+\frac{\partial}{\partial x_j}(\rho \bar{U}_i \bar{U}_j)=-\frac{\partial \bar{P}}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu \frac{\partial \bar{U}_i}{\partial x_j}\right)+g_i(\rho-\rho_0)$ *for building* $\frac{\partial}{\partial x_j}(\rho \bar{U}_i \bar{U}_j)=-\frac{\partial \bar{P}}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu \frac{\partial \bar{U}_i}{\partial x_j}-\rho \overline{u_i' u_j'}\right)+g_i(\rho-\rho_0)$ *state of the art* $\frac{\partial}{\partial x_i}(\rho \bar{U}_i \bar{H})=\frac{\partial}{\partial x_i}\left(\lambda \frac{\partial \bar{T}}{\partial x_i}-\rho \overline{u_i' h'}\right)$ *biomedical research facilities.*

Controlling Legionella in Healthcare Facility Water Systems: Use of Copper-Silver Ionization

Legionella is a genus of naturally occurring bacteria typically found in fresh water supplies which can proliferate anywhere building plumbing systems are not properly designed, constructed, operated, maintained and routinely monitored. According to the Centers for Disease Control, reported cases of *Legionella* infection have increased by over 500% between 2000 and 2017. *Legionella* exposure is a particular concern in healthcare facilities, where immunocompromised patients are more susceptible to pathogens than healthy people.

Several organizations have developed standards and guidance for operation and surveillance of building water systems to minimize the presence of *Legionella* (e.g., ANSI/ASHRAE Standard 188, ASHRAE Guideline 12, CDC Toolkit for Controlling *Legionella*). There are additional engineering controls that can be evaluated for their capacity to limit the replication and proliferation of microorganisms (including *Legionella*) in building water systems. These include chlorine, chlorine dioxide, monochloramine, ozone and UV light. This article focuses on copper-silver ionization (CSI) disinfection, which is a technology that has been successfully applied in hospitals and other critical care facilities for more than 20 years.

CSI Process

Copper and silver ions are generated through electrolysis. Direct electric current passes between cathodes and sacrificial anodes (containing copper and silver metals) that are contained in flow cells, releasing copper and silver ions into the water as it flows past. The quantity of ions that are released is controlled by the electrical current applied to the anodes and the water flow rate. CSI is implemented at the building water service entrance, downstream of particulate filtration (where installed) and typically in a side steam configuration for large facilities. When the water flows through the distribution system, the positively charged ions bind themselves to the negatively charged cell walls of organisms in the water. This causes disruption of cellular membranes and enzymatic processes, ultimately resulting in organisms experiencing inhibited respiration and a loss of replication ability.

CSI Implementation

CSI testing should augment the existing water surveillance and monitoring plan that should currently be in place for healthcare facilities as required for hospitals by the Centers for Medicare & Medicaid Services. Ion levels are typically maintained in the lower ranges of 0.2-0.8 mg/L for copper and 0.01-0.08 mg/L for silver. After CSI equipment is installed, it is important to perform frequent testing to monitor copper and silver ion levels at several use point locations in each water distribution system. This helps to develop baseline system data and ensure ion levels remain below the Environmental Protection Agency limits of 1.3 ppm and 0.15 ppm for copper and silver respectively.[1] However, copper-silver ions can be affected by the physical and chemical properties of the water, especially its free chlorine content, which can combine with silver ions and thus reduce ion availability. This can reduce the effectiveness of the disinfection process.[2]

Legionella and other opportunistic organisms can persist in biofilms, rendering treatments to control them less effective. When applying CSI to new or existing plumbing systems, it is important to sanitize and flush the system prior to activation in order to remove sediment and reduce biofilms to the greatest extent possible. It can be very difficult to fully clean biofilm from the piping system, which is why systems should be properly maintained to prevent conditions where biofilms develop and proliferate.

CSI disinfection can effectively reduce the number of *Legionella* (and fungal) positive samples in treated systems. However, it does not fully eradicate pathogens. No single method can achieve complete pathogen eradication, but maintaining high temperatures (>120°F) in hot water systems maximizes the effectiveness of the ionization approach.[3]

References

1. Environmental Protection Agency. (2009). *National primary drinking water regulations* (Publication No. EPA-816-F-09-004). https://www.nrc.gov/docs/ML1307/ML13078A040.pdf
2. June, S.G., & Dziewulski, D.M. (2018). Copper and silver biocidal mechanisms, resistance strategies and efficacy for *Legionella* control. *Journal AWWA*, *110*(12), E13-E35. https://doi.org/10.1002/awwa.1144
3. Cachafeiro, S.P., Naveria, I.M., & Garcia, I.G. (2007). Is copper-silver ionization safe for controlling *Legionella*? *Journal of Hospital Infection*, *67*, 209-216. https://doi.org/ 10.1016/j.jhin.2007.07.017

'Design Requirements Manual (DRM) News to Use' is a monthly ORF publication featuring salient technical information that should be applied to the design of NIH biomedical research laboratories and animal facilities. NIH Project Officers, A/E's and other consultants to the NIH, who develop intramural, extramural and American Recovery and Reinvestment Act (ARRA) projects will benefit from 'News to Use'. **Please address questions or comments to:** shawm@nih.gov

Further details on this month's topic are available on the DRM website DRM Section 8.2 Plumbing Fixtures and Equipment
https://www.orf.od.nih.gov/PoliciesAndGuidelines/BiomedicalandAnimalResearchFacilitiesDesignPoliciesandGuidelines/Pages/DesignRequirementsManual2016

The National Institutes of Health | Division of Technical Resources | Office of Research Facilities

Design Requirements Manual **News to Use**

August 2022

Vol. 02, No. 62

The formulae $\frac{\partial \rho \bar{U}_i}{\partial t}+\frac{\partial}{\partial x_j}(\rho \bar{U}_i \bar{U}_j)=-\frac{\partial \bar{P}}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu \frac{\partial \bar{U}_i}{\partial x_j}\right)+g_i(\rho-\rho_0)$ *for building* $\frac{\partial}{\partial x_j}(\rho \bar{U}_i \bar{U}_j)=-\frac{\partial \bar{P}}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu \frac{\partial \bar{U}_i}{\partial x_j}-\rho \overline{u_i' u_j'}\right)+g_i(\rho-\rho_0)$ *state of the art* $\frac{\partial}{\partial x_i}(\rho \bar{U}_i \bar{H})=\frac{\partial}{\partial x_i}\left(\lambda \frac{\partial \bar{T}}{\partial x_i}-\rho \overline{u_i' h'}\right)$ *biomedical research facilities.*

Combatting *Legionella* in Healthcare Facilities

Part I: Overview

Legionella is a genus of rod- or coccoid-shaped gram-negative bacteria that was discovered in 1976. Today, the genus consists of more than 65 different species. *Legionella* is generally found in freshwater environments as well as engineered water sources like cooling towers, showers, and plumbing networks. While all species of *Legionellae* can cause disease in humans, most of the infections are caused by the species known as *Legionella pneumophila*. Within this species, serogroup 1 strains are the most associated with infection. The *pneumophila* species can affect humans when inhaled via aerosol, causing a form of pneumonia called Legionnaires' disease (LD).

LD is on the rise in the United States. A combination of engineering, hygiene measures, and clinical strategies should be applied to make hospital water safe for vulnerable patients. There are a variety of different technologies currently available for controlling *Legionella* in healthcare facilities, such as supplemental disinfection systems (e.g., copper-silver ionization, chlorine dioxide, sodium hypochlorite, and monochloramine), temperature controls, or physical barriers.

The purpose of this series of articles is to provide the latest information on *Legionella*, an update on control and management practices at healthcare facilities, and an overview of engineering aspects in building water systems aimed at controlling and preventing *Legionella* growth.

Water Management Programs in Healthcare Facilities

Healthcare facilities can have complex water systems that could promote pathogen growth if not properly maintained. Water management programs should therefore be effective at limiting *Legionella* and other opportunistic pathogens and need to be continuously evaluated and monitored to maintain this effectiveness. The Centers for Disease Control and Prevention (CDC) prepared a Water Management Program (WMP) Toolkit that can help develop and implement a water management program to reduce a building's risk for the growth and spread of *Legionella*. An effective WMP should identify areas or devices in buildings where *Legionella* might be present so that appropriate risk-management actions can be taken. Water management programs should incorporate the industry standard requirements for medium to large buildings according to ASHRAE 188. There must be continuous coordination among members of the healthcare facility's water management program to identify problem areas, take corrective actions, and evaluate mitigation steps. Figure 1 illustrates the interactive relationship between healthcare facilities and water management programs at the chemical/microbiological inspection and plumbing improvement levels. A yearly audit on water management programs is also a valuable maintenance element.

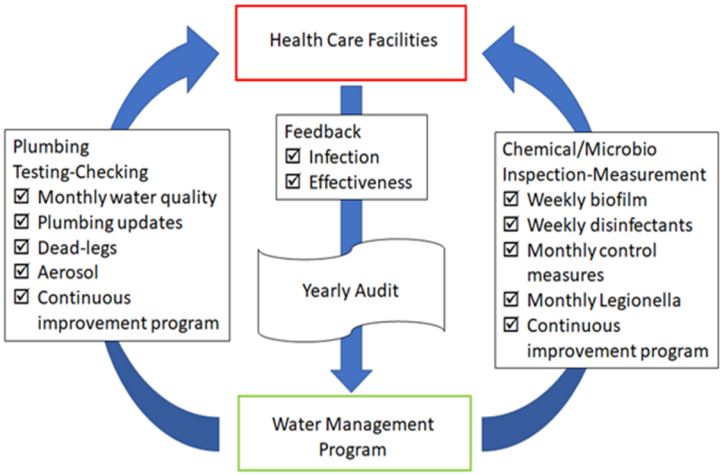

Figure 1: Interactive Relationship: Health Facilities and Water Management Program

Control Measures

There are several preventative measures and technologies available which are intended to limit bacterial growth in water supplies. Important considerations for *Legionella* control are provided in the CDC's WMP and *Legionella* Control Toolkits. Factors known to influence *Legionella* growth in water systems include temperature, disinfectant type and its active residual levels, hydraulic conditions (particularly those related to stagnation), presence of nutrients, pipe materials, presence of distal devices, and extent of aerosol formation. Most of these factors are considered during the initial building design and commissioning stages, while others can be more readily adjusted in existing buildings. Reactive measures, such as hyperchlorination, can be implemented if conditions that allow *Legionella* to grow and spread is detected when the facility is in use.

Legionella control measures include:

- Temperature control outside the organism's growth range of 25°C to 45°C (inhibits bacterial growth)
- Use of chemical disinfectants (inactivates planktonic/sessile bacteria and reduces biofilm formation)
- Ultraviolet irradiation (damages the bacteria's DNA and proteins)

- Copper-silver ionization (produces metal ions which disrupt bacterial membranes and enzymatic processes)
- Hydraulic system design and maintenance (maintains and delivers water at inhibitory temperatures, distributes disinfectants throughout the building, and limits water-age conditions)
- Limitation of organic and inorganic nutrients in water (helps control biofilm and prevent disinfectant depletion)
- Control of iron corrosion (limits the amount of iron, which is an essential nutrient for the growth of *Legionella,* in the water)
- Limitation of aerosol exposure via size-exclusion filters or laminar flow devices (prevents spread of bacteria)

The second part of this series will include more information on control measures to prevent *Legionella* growth.

Plumbing Material Selection

There are a variety of plumbing design choices that can help mitigate the risk of *Legionella*. Piping material selection is a particularly critical component of bacterial mitigation. Hot water is commonly used to control bacterial growth, so it is essential to use piping with adequate thermal ratings. Copper and stainless steel are traditionally chosen for higher-temperature applications; copper piping also has antimicrobial properties. Plastics such as chlorinated polyvinyl chloride are also an option and are additionally corrosion-resistant for chemical injections. Biostable materials can be used for any distal devices to minimize surface area available for biofilm growth where *Legionella* can proliferate.

Additional Plumbing Measures

There are multiple plumbing add-ons that can be used as additional preventative measures. Small diameter piping in the distal portion of premise plumbing helps to reduce stagnation. Additionally, if the premise plumbing is compromised by bacteria, point-of-use filtration barriers or flash disinfection devices can be installed to act as a final defense against bacterial transmission. A combination of improved design (e.g., limiting the number of outlets and removing of dead legs) and preventive flushing procedures help to maximize water circulation and thereby minimize the impact of disinfectant depletion. Thermostatic mixing valves (TMV) can be used to prevent against scalding (e.g., during showers), but they also provide surfaces for biofilm growth at temperatures optimal for *Legionella*, so designers should weigh the pros and cons of their application and prioritize TMV installation as near as possible to point-of-use filters to limit circulation of water at temperatures favorable for *Legionella* growth.

The third part of this series will contain more information on plumbing modification for *Legionella* control.

Conclusion

Proper water system maintenance is the key to preventing *Legionella* growth and LD. There are a variety of methods to reduce the risk of *Legionella* growth and spread; building owners, especially in healthcare facilities, should develop comprehensive water management programs with multiple control mechanisms for successful risk mitigation. If *Legionella* is found in a healthcare facility's water system, the facility should apply remedial measures to eliminate the bacteria by following or customizing standard guidelines.

Further Reading

ANSI/ASHRAE 188-2021. (2021). *Legionellosis: Risk Management for Building Water Systems*. ASHRAE, Atlanta.

ASHRAE Guideline 12-2020. (2020). *Managing the Risk of Legionellosis Associated with Building Water Systems*. ASHRAE, Atlanta.

Bock, A. (2015). *Controlling waterborne bacteria in healthcare facilities*. Erdman. Retrieved October 25, 2021, from https://www.erdman.com/wp-content/uploads/ERDMAN-INSIGHTS_Controlling-Waterborne-Bacteria-in-Healthcare-Facilities-Web.pdf.

Demirjian, A., Lucas, C. E., Garrison, L. E., Kozak-Muiznieks, N. A., States, S., Brown, E. W., Wortham, J. M., Beaudoin, A., Casey, M. L., Marriott, C., Ludwig, A. M., Sonel, A. F., Muder, R. R., & Hicks, L. A. (2015, February 25). Importance of clinical surveillance in detecting legionnaires' disease outbreaks: A large outbreak in a hospital with a legionella disinfection system-Pennsylvania, 2011–2012. *OUP Academic*. Retrieved October 4, 2021, from https://academic.oup.com/cid/article/60/11/1596/356183.

Lin, Y. E., Stout, J. E., & Yu, V. L. (2011). Controlling legionella in Hospital Drinking Water: An evidence-based review of disinfection methods. *Infection Control & Hospital Epidemiology*, *32*(2), 166–173. https://doi.org/10.1086/657934

Messonnier, N., & Breysse, P. (2021). Developing a Water Management Program to Reduce Legionella Growth & Spread in Buildings. CDC, *U.S. Department of Health and Human Services*. http://www.cdc.gov/legionella/WMPtoolkit

Mondino, S., Schmidt, S., Rolando, M., Escoll, P., Gomez-Valero, L., & Buchrieser, C. (2020). Legionnaires' disease: State of the art knowledge of pathogenesis mechanisms of legionella. *Annual Review of Pathology: Mechanisms of Disease*, *15*(1), 439–466. https://doi.org/10.1146/annurev-pathmechdis-012419-032742

National Academies of Sciences, Engineering, and Medicine (2020). *Management of Legionella in Water Systems*. Washington, DC: The National Academies Press. http://doi.org/10.17226/25474.

Peeples, L. (2020). Legionella and other dangerous pathogens still lurk in U.S. drinking water. *Ensia*. Retrieved October 4, 2021, from https://ensia.com/features/legionella-pathogens-drinking-water/.

Whiley, H. (2016). Legionella risk management and control in potable water systems: Argument for the abolishment of routine testing. *International Journal of Environmental Research and Public Health*, *14*(1), 12. https://doi.org/10.3390/ijerph14010012

Zahran, S., McElmurry, S. P., Kilgore, P. E., Mushinski, D., Press, J., Love, N. G., Sadler, R. C., & Swanson, M. S. (2018). Assessment of the legionnaires' disease outbreak in Flint, Michigan. *Proceedings of the National Academy of Sciences*, *115*(8). https://doi.org/10.1073/pnas.1718679115

'Design Requirements Manual (DRM) News to Use' is a monthly ORF publication featuring salient technical information that should be applied to the design of NIH biomedical research laboratories and animal facilities. NIH Project Officers, A/Es and other consultants to the NIH, who develop intramural, extramural and American Recovery and Reinvestment Act (ARRA) projects will benefit from 'News to Use'. **Please address questions or comments to:** shawm@nih.gov

Further details on this month's topic are available on the DRM website: DRM Chapter 13, Aseptic Processing Facilities
https://www.orf.od.nih.gov/PoliciesAndGuidelines/BiomedicalandAnimalResearchFacilitiesDesignPoliciesandGuidelines/Pages/DesignRequirementsManual2016

The National Institutes of Health | Division of Technical Resources | Office of Research Facilities

Design Requirements Manual **News to Use**

September 2022

Vol. 02, No. 63

The formulae $\frac{\partial \rho \bar{U}_i}{\partial t}+\frac{\partial}{\partial x_j}(\rho \bar{U}_i \bar{U}_j)=-\frac{\partial \bar{P}}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu \frac{\partial \bar{U}_i}{\partial x_j}\right)+g_i(\rho-\rho_0)$ *for building* $\frac{\partial}{\partial x_j}(\rho \bar{U}_i \bar{U}_j)=-\frac{\partial \bar{P}}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu \frac{\partial \bar{U}_i}{\partial x_j}-\rho \overline{u_i' u_j'}\right)+g_i(\rho-\rho_0)$ *state of the art* $\frac{\partial}{\partial x_i}(\rho \bar{U}_i \bar{H})=\frac{\partial}{\partial x_i}\left(\lambda \frac{\partial \bar{T}}{\partial x_i}-\rho \overline{u_i' h'}\right)$ *biomedical research facilities.*

Combatting *Legionella* in Healthcare Facilities Part II: Controlling *Legionella*

Legionella bacteria can cause Legionnaires' disease, which is a particular risk for healthcare facilities. The key to mitigating this risk is developing a water management program that implements multiple technologies to control *Legionella* growth. Part I of this article series discussed the risks of *Legionella*, the importance of robust water management programs, and several measures and design choices to control *Legionella* growth and outbreaks in water systems. This article reviews the details of specific control technologies and emphasizes the importance of developing a multi-pronged approach for combatting *Legionella*.

Current Control Technologies and *Legionella* Identification

Controlling the spread of waterborne bacteria such as *Legionella* is a complex endeavor. There are a variety of resources that can be combined with different preventative methods to address *Legionella* outbreaks within a facility. These resources include the CDC Water Management Program Toolkit[1], the CDC Legionella Control Toolkit[2], ASHRAE Standard 188-2021[3], Addendum c to ASHRAE Guideline 12-2021[4], and the EPA Technologies for *Legionella* Control[5]. Depending on the size of the *Legionella* population, different treatment methods can be used. Table 1 shows some exemplary control technologies against *Legionella* growth and spread along with their mechanisms/characteristics and efficacies. For example, introducing disinfectants into the water system inactivates waterborne or planktonic bacteria and may help to destroy biofilms. Other methods include using flushing procedures to prevent stagnation and reduce water age (the time that water is in premise plumbing), as well as adding laminar flow devices to faucets that produce non-aerated water to reduce aerosol transmission. All technologies should be coordinated with existing water treatment programs.

If an outbreak occurs, the identification and quantification of *Legionella* is the first step to ensure the outbreak is effectively addressed. Once it is identified, public health guidance must be followed to confirm the correct steps are being taken to fully eradicate the bacteria. There are several methods for *Legionella* detection and enumeration: culture testing, polymerase chain reaction (PCR), quantitative PCR (qPCR), fluorescent in-situ hybridization, cytometry, lightmode spectroscopy, enzyme-amplified electrochemical detection, and resonance immunosensing. Culture testing is the most common practice to identify and enumerate these bacteria in colony forming units (CFUs)/mL. This information is crucial for identifying outbreak origins, performing risk assessment, and pursuing disease prevention. However, culture methods can take anywhere from one to two weeks to obtain analytical results. Quick identification methods, like qPCR and genome sequencing, can also be performed and take about a day to obtain results, though current qPCR technology is unable to differentiate between viable and deceased *Legionella* bacteria.

Considerations for Using Multiple Technologies

Most *Legionella* control technologies are relatively inexpensive and easy to install or incorporate into pre-existing water systems. It is best practice to use multiple technologies in parallel because *Legionella* protects itself with biofilms and applying multiple technologies at once will more effectively destroy the biofilm and prevent bacterial spread, which is especially important in healthcare facilities. However, some technologies may need regular maintenance to ensure they are working properly. Maintenance personnel need training and experience to work efficiently with certain technologies, such as the copper-silver ionization system. Technologies must also comply with any applicable regulations. Finally, it is important to consider that since *Legionella* is a bacterium, it may develop resistance to certain technologies, rendering them ineffective and risking the integrity of a facility's water system.

Conclusion

Using only a single technology to prevent or eradicate a *Legionella* outbreak has proven ineffective. To successfully combat *Legionella* in healthcare facilities, multiple technologies must be used in conjunction with proper building water system maintenance for optimal prevention. A combination of good management and prevention plans are critical to ensure the health and safety of patients.

'Design Requirements Manual (DRM) News to Use' is a monthly ORF publication featuring salient technical information that should be applied to the design of NIH biomedical research laboratories and animal facilities. NIH Project Officers, A/Es and other consultants to the NIH, who develop intramural, extramural and American Recovery and Reinvestment Act (ARRA) projects will benefit from 'News to Use'. **Please address questions or comments to:** drm@nih.gov

Table 1: Control Technologies against *Legionella* Growth and Spread, Mechanisms, and Efficacies

Technology	Mechanism/Characteristics	Efficiency
Temperature Control	Domestic water systems should keep cold water below 25°C, which may not be possible in warmer climate zones, and hot water above 45°C* to ensure the temperature is out of the organism's growth range. Hot water temperature control can be achieved using thermostatic mixing valves at the supply or point-of-use. *Note that higher temperatures can cause scalding in healthcare environments; to prevent this, state or local codes and regulations may specify a maximum temperature at a thermostatic mixing valve which can be within the *Legionella* growth range.	Efficient against both culturable and viable but nonculturable-like cells (live bacteria that do not grow nor divide) of *Legionella pneumophila*.[6, 7, 8, 9]
Disinfection	Adding chemical disinfectants, particularly oxidizing agents, (e.g., chlorine, chlorine dioxide, chloramine, and ozone), to water systems keeps the pipes clean by penetrating and inactivating microorganisms associated with biofilms.	Efficiency is dependent on the condition of *Legionella*, their host protozoa, and the physiochemical characteristics of the water.[7, 8, 10, 11, 12, 13]
Copper-Silver Ionization	Electrolysis introduces copper and silver ions into the water system. Copper ions penetrate the bacterial cell wall and silver ions bond to parts of the bacterium, immobilizing the cell and curtailing cell division. Neither ion will damage piping and the concentration levels necessary for efficacy are not toxic to humans.	Efficient for controlling *Legionella* in potable water systems, cooling towers, and other building plumbing systems. [7, 14, 15, 16, 17, 18, 19, 20]
Nutrient Limitation	Controlling the biofilm, iron corrosion, and inorganic nutrients; directly measuring assimilable organic carbon (AOC) and biodegradable dissolved organic carbon assays aid in preventing further growth of *Legionella*.	Lower AOC levels of 5 to 10 µg/L were associated with lower *Legionella pneumophila* levels in drinking water distribution systems.[21, 22, 23]
Distal Plumbing Design and Plumbing Materials	Use small diameter piping in the distal portion of premise plumbing and improve design to maximize water circulation and prevent water stagnation; use biostable materials to ensure proper piping material functionality; install point-of-use filters or flash disinfection devices as a final barrier; position thermostatic mixing valves as close as possible to points-of-use. Pipe material (copper, iron, plastics) influences the building-level water chemistry and shapes the biofilms that colonize premise plumbing in a unique manner.	A new extended-life faucet filter can ensure the removal of *Legionella* for several weeks. Maintaining awareness of the presence of iron pipes and practicing appropriate corrosion control are key to reducing risk factors for *Legionella*.[9, 14, 24, 25]
Aerosol Control	Replace faucet aerators with laminar flow devices; replace a showerhead with one that produces water streams (holes >1-mm diameter) and contains a micro-biofilter (*i.e.*, pore size <0.45-µm diameter). Keep laminar flow devices and showerheads clean to reduce bacterial contamination.	Changes in aeration technology (e.g., use of fine bubble diffusers) or covering the aeration basins can reduce aerosol formation and transport.[26]
Reducing Water Age and Stagnation	Introduce regular water flushing techniques to reduce water age and stagnation by increasing water flow for a set period, especially if the building has been unoccupied for a while; remove dead legs (sections of piping which are rarely or never used and have no regular flow).	Reducing water age and stagnation can aid in delivering other control measures like disinfectants. It also helps to prevent growth of *Legionella*. [27, 28]

References

1. Centers for Disease Control and Prevention. (2021, March 25). Legionella: Developing a water management program. Centers for Disease Control and Prevention. https://www.cdc.gov/legionella/wmp/toolkit/index.html
2. Centers for Disease Control and Prevention. (2021, February 3). Toolkit for control of legionella in common sources of exposure. Centers for Disease Control and Prevention. https://www.cdc.gov/legionella/wmp/control-toolkit/index.html
3. ASHRAE 188-2021. (2021, August). Legionellosis: Risk Management for Building Water Systems (ANSI Approved). https://webstore.ansi.org/Standards/ASHRAE/ANSIASHRAEStandard1882021
4. ASHRAE Addendum c to ASHRAE Guideline 12-2020. Managing the Risk of Legionellosis Associated with Building Water Systems. (2021, August 29). https://www.ashrae.org/File%20Library/Technical%20Resources/Standards%20and%20Guidelines/Standards%20Addenda/G12_2021_c_20210809.pdf
5. Environmental Protection Agency. (2021, August 20). Technologies for Legionella Control in Premise Plumbing Systems. EPA. https://www.epa.gov/ground-water-and-drinking-water/technologies-legionella-control-premise-plumbing-systems
6. Cervero-Aragó, S., Schrammel, B., Dietersdorfer, E., Sommer, R., Lück, C., Walochnik, J., & Kirschner, A. (2019). Viability and infectivity of viable but nonculturable *Legionella pneumophila* strains induced at high temperatures. *Water Research*, *158*, 268–279. https://doi.org/10.1016/j.watres.2019.04.009
7. Demirjian, A., Lucas, C. E., Garrison, L. E., Kozak-Muiznieks, N. A., States, S., Brown, E. W., Wortham, J. M., Beaudoin, A., Casey, M. L., Marriott, C., Ludwig, A. M., Sonel, A. F., Muder, R. R., & Hicks, L. A. (2015). The importance of clinical surveillance in detecting Legionnaires' disease outbreaks: A large outbreak in a hospital with a *Legionella* disinfection system—Pennsylvania, 2011–2012. *Clinical Infectious Diseases*, *60*(11), 1596–1602. https://doi.org/10.1093/cid/civ153
8. Arashiro, T., Nakamura, S., Asami, T., Mikuni, H., Fujiwara, E., Sakamoto, S., Miura, R., Shionoya, Y., Honda, R., Furukawa, K., Nakamura, A., & Saito, H. (2020). SARS-COV-2 and *Legionella* co-infection in a person returning from a Nile cruise. *Journal of Travel Medicine*, *27*(3). https://doi.org/10.1093/jtm/taaa053
9. Quero, S., Párraga-Niño, N., Garcia-Núñez, M., Pedro-Botet, M. L., Gavaldà, L., Mateu, L., Sabrià, M., & Mòdol, J. M. (2020). The impact of pipeline changes and temperature increase in a hospital historically colonised with *Legionella*. https://doi.org/10.21203/rs.3.rs-109969/v1
10. Cristino, S., Legnani, P. P., & Leoni, E. (2012). Plan for the control of *Legionella* infections in long-term care facilities: Role of environmental monitoring. *International Journal of Hygiene and Environmental Health*, *215*(3), 279–285. https://doi.org/10.1016/j.ijheh.2011.08.007
11. Casini, B., Aquino, F., Totaro, M., Miccoli, M., Galli, I., Manfredini, L., Giustarini, C., Costa, A., Tuvo, B., Valentini, P., Privitera, G., & Baggiani, A. (2017). Application of hydrogen peroxide as an innovative method of treatment for *Legionella* control in a hospital water network. *Pathogens*, *6*(2), 15. https://doi.org/10.3390/pathogens6020015
12. Borella, P., Bargellini, A., Marchegiano, P., Vecchi, E., & Marchesi, I. (2016). Hospital-acquired legionella infections: An update on the procedures for controlling environmental contamination. *Annali di igiene: medicina preventivaedi comunita*, 28(2), 98-108. https://doi.org/10.7416/ai.2016.2088.
13. Peeples, L. (2021, March 23). *Legionella and other dangerous pathogens still lurk in U.S. drinking water*. Great Lakes Now. https://www.greatlakesnow.org/2020/10/legionella-dangerous-pathogens-drinking-water/
14. Blanc, D. S., Carrara, P., Zanetti, G., & Francioli, P. (2005). Water disinfection with ozone, copper and silver ions, and temperature increase to control *Legionella*: Seven years of experience in a University Teaching Hospital. *Journal of Hospital Infection*, *60*(1), 69–72. https://doi.org/10.1016/j.jhin.2004.10.016
15. Chen, Y. S., Lin, Y. E., Liu, Y.-C., Huang, W. K., Shih, H. Y., Wann, S. R., Lee, S. S., Tsai, H. C., Li, C. H., Chao, H. L., Ke, C. M., Lu, H. H., & Chang, C. L. (2008). Efficacy of point-of-entry copper–silver ionisation system in eradicating *Legionella pneumophila* in a tropical tertiary care hospital: Implications for hospitals contaminated with *Legionella* in both hot and cold water. *Journal of Hospital Infection*, *68*(2), 152–158. https://doi.org/10.1016/j.jhin.2007.10.020
16. Dziewulski, D. M., Ingles, E., Codru, N., Strepelis, J., & Schoonmaker-Bopp, D. (2015). Use of copper-silver ionization for the control of *Legionellae* in alkaline environments at health care facilities. *American Journal of Infection Control*, *43*(9), 971–976. https://doi.org/10.1016/j.ajic.2015.05.018
17. Kusnetsov, J., Iivanainen, E., Elomaa, N., Zacheus, O., & Martikainen, P. J. (2001). Copper and silver ions more effective against *Legionellae* than against mycobacteria in a hospital warm water system. *Water Research*, *35*(17), 4217–4225. https://doi.org/10.1016/s0043-1354(01)00124-5
18. Liu, Z., Stout, J. E., Tedesco, L., Boldin, M., Hwang, C., Diven, W. F., & Yu, V. L. (1994). Controlled evaluation of copper-silver ionization in eradicating *Legionella pneumophila* from a hospital water distribution system. *Journal of Infectious Diseases*, *169*(4), 919–922. https://doi.org/10.1093/infdis/169.4.919
19. Rohr, U., Senger, M., Selenka, F., Turley, R., & Wilhelm, M. (1999). Four Years of Experience with Silver-Copper Ionization for Control of *Legionella* in a German University Hospital Hot Water Plumbing System. *Clinical Infectious Diseases*, *29*(6), 1507–1511. https://doi.org/10.1086/313512
20. Stout, J. E., & Yu, V. L. (2003). Experiences of the first 16 hospitals using copper-silver ionization for *Legionella* control: Implications for the evaluation of other disinfection modalities. *Infection Control & Hospital Epidemiology*, *24*(8), 563–568. https://doi.org/10.1086/502251
21. Loenenbach, A. D., Beulens, C., Euser, S. M., van Leuken, J. P. G., Bom, B., van der Hoek, W., Husman, A. M., Ruijs, W. L. M., Bartels, A. A., Rietveld, A., den Boer, J. W., & Brandsema, P. S. (2018). Two community clusters of Legionnaires' disease directly linked to a biologic wastewater treatment plant, the Netherlands. *Emerging Infectious Diseases*, *24*(10), 1914–1918. https://doi.org/10.3201/eid2410.180906
22. Spies, K., Pleischl, S., Lange, B., Langer, B., Hübner, I., Jurzik, L., Luden, K., & Exner, M. (2018). Comparison of the Legiolert™/quanti-Tray® MPN test for the enumeration of *Legionella pneumophila* from potable water samples with the German regulatory requirements methods ISO 11731-2 and ISO 11731. *International Journal of Hygiene and Environmental Health*, *221*(7), 1047–1053. https://doi.org/10.1016/j.ijheh.2018.07.006
23. van Hoof, J., Hornstra, L. M., van der Blom, E., Nuijten, O. W. W., & van der Wielen, P. W. J. J. (2014). The presence and growth of *Legionella* species in thermostatic shower mixer taps: An exploratory field study. *Building Services Engineering Research and Technology*, *35*(6), 600–612. https://doi.org/10.1177/0143624414527097
24. Baron, J. L., Peters, T., Shafer, R., MacMurray, B., & Stout, J. E. (2014). Field evaluation of a new point-of-use faucet filter for preventing exposure to *Legionella* and other waterborne pathogens in health care facilities. *American Journal of Infection Control*, *42*(11), 1193–1196. https://doi.org/10.1016/j.ajic.2014.08.002
25. Rhoads, W. J., Ji, P., Pruden, A., & Edwards, M. A. (2015). Water heater temperature set point and water use patterns influence *Legionella pneumophila* and associated microorganisms at the tap. *Microbiome*, *3*(1). https://doi.org/10.1186/s40168-015-0134-1
26. Hamilton, K. A., Ahmed, W., Palmer, A., Smith, K., Toze, S., & Haas, C. N. (2017). Seasonal assessment of opportunistic premise plumbing pathogens in roof-harvested rainwater tanks. *Environmental Science & Technology*, *51*(3), 1742–1753. https://doi.org/10.1021/acs.est.6b04814
27. Pereira, A., Silva, A. R., & Melo, L. F. (2021). Legionella and biofilms—integrated surveillance to bridge science and real-field demands. Microorganisms,9(6), 1212. https://doi.org/10.3390/microorganisms9061212
28. Cullom, A. C., Martin, R. L., Song, Y., Williams, K., Williams, A., Pruden, A., & Edwards, M. A. (2020). Critical review: Propensity of premise plumbing pipe materials to enhance or diminish growth of legionella and other opportunistic pathogens. Pathogens,9(11), 957. https://doi.org/10.3390/pathogens9110957
29. Whiley, H., Taylor, M. (2014). *Legionella* detection by culture and qPCR: Comparing apples and oranges. *Critical Reviews in Microbiology*, 42(1), 65-74. https://doi.org/10.3109/1040841X.2014.885930

The National Institutes of Health | Division of Technical Resources | Office of Research Facilities

Design Requirements Manual **News to Use**

October 2022

Vol. 02, No. 64

The formulae $\frac{\partial \rho \bar{U}_i}{\partial t}+\frac{\partial}{\partial x_j}(\rho \bar{U}_i \bar{U}_j)=-\frac{\partial \bar{P}}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu \frac{\partial \bar{U}_i}{\partial x_j}\right)+g_i(\rho-\rho_0)$ *for building* $\frac{\partial}{\partial x_j}(\rho \bar{U}_i \bar{U}_j)=-\frac{\partial \bar{P}}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu \frac{\partial \bar{U}_i}{\partial x_j}-\rho \overline{u_i' u_j'}\right)+g_i(\rho-\rho_0)$ *state of the art* $\frac{\partial}{\partial x_i}(\rho \bar{U}_i \bar{H})=\frac{\partial}{\partial x_i}\left(\lambda \frac{\partial \bar{T}}{\partial x_i}-\rho \overline{u_i' h'}\right)$ *biomedical research facilities.*

Combatting *Legionella* in Healthcare Facilities Part III: Plumbing Aspects for *Legionella* Control and Management

Opportunistic pathogens (OPs) are frequently found in premise plumbing systems, where they can exist either in suspended forms as aerosolized water droplets or within biofilms. In particular, the growth of *Legionella pneumophila* in these systems is an increasing threat to public health. The survival and growth of *Legionella* is influenced by a facility's mode of construction, which can create different complex environments due to chemical, microbiological, spatial, and temporal variations. Improperly managed premise plumbing systems can create ideal conditions for *Legionella* growth and spread, resulting in human exposure and harm. Parts I and II of this article series focused on the importance of robust water management programs, provided several measures and design choices to control *Legionella* growth in water systems, and emphasized the importance of developing a multi-pronged approach. This article will focus on how to use plumbing aspects to help prevent *Legionella*, specifically through plumbing-related contributing factors like material selection and design.

Contributing Factors to *Legionella* Growth

The mechanisms for *Legionella* growth are varied and complex. Both water chemistry and plumbing microbiome play a role in contributing to bacteria growth, such as through the delivery of growth-promoting nutrients, growth-inhibiting disinfectants, and influent microorganisms. Premise plumbing configurations, hydraulics, temperature, and water use patterns also contribute. There is strong variability between facilities, even those on the same premises, due to occupancy, building size, water heater design, water saving devices, storage, and other factors. This article will review material selection and facility design considerations in more detail, as they are critical for improving water management programs.

Material Selection

When selecting appropriate pipe material, the designer should evaluate various criteria (e.g., water temperature and pressure and water patterns like velocity, flow, or stagnation) that differ between building types and uses as well as building settings (e.g., healthcare vs. hospitality). Pipe material can affect *Legionella* growth in premise plumbing both directly (i.e., by enhancing or inhibiting growth) and indirectly (i.e., via secondary effects due to pipe material being released).

Copper piping is generally used for its antimicrobial properties. Currently, two hypotheses explain how copper inactivates bacteria. One hypothesized mechanism infers that positively charged copper ions obstruct the negatively charged cell membranes, thus creating holes in the bacteria, and rendering them inactive.[1] The other hypothesized mechanism states that copper ions disrupt the bacterium's replication and production of DNA, RNA, and proteins.[1] Copper piping can also withstand higher temperatures; however, this increase in temperature can lead to a higher rate of corrosion. If copper piping is not appropriate for a building, copper can also be supplemented into the water system through a water treatment process, such as copper-silver ionization. This complementary disinfection system uses electrolysis to introduce copper and silver ions into the water system. The copper ions will penetrate the bacterium and the silver ions will bond to parts within the bacterium and lyse it as well as curtail further cell division.

There is evidence for the inconsistent efficacy of copper piping for microbial control, mainly due to differences in water chemistry and the micronutrient properties of copper.[1,2] Water chemistry can reduce copper toxicity to OPs by reducing the solubility of copper ions, forming copper complexes, and increasing competition of other cations with copper for uptake of organism sites. Copper can also serve as a micronutrient for OPs; its aqueous concentration should therefore be maintained above OP tolerance limits.[3] Designers can manipulate plumbing design, configuration, and operation to control copper's interactions with water chemistry and resident microbes and maintain its efficacy.

Other common piping materials (e.g., plastic, polyvinylchloride (PVC), and iron) can be used, but they are not recommended in healthcare settings and would be better suited for residential

'Design Requirements Manual (DRM) News to Use' is a monthly ORF publication featuring salient technical information that should be applied to the design of NIH biomedical research laboratories and animal facilities. NIH Project Officers, A/Es and other consultants to the NIH, who develop intramural, extramural and American Recovery and Reinvestment Act (ARRA) projects will benefit from 'News to Use'. **Please address questions or comments to:** mario.orellana@nih.gov

settings. NIH's Design Requirements Manual (DRM) does specify that PVC and plastic piping be used for high purity water systems.[3] Plastic or PVC piping would prevent corrosion and may be useful in the long run; however, organic carbon from plastic and PVC pipes may leach into the water system and contribute to *Legionella* and biofilm growth. Similarly, adding iron into water systems can provide nutrients to *Legionella* which aids in bacterial growth, though leaching and biofilm colonization depend on various factors like water chemistry, stagnation, scale formation, and corrosion.

Design Considerations

To reduce possible *Legionella* growth, hot water in plumbing systems should be at temperatures that are outside the bacteria's growth range (around 25°C to 45°C). While this is suitable for inhibiting *Legionella* growth, it is not appropriate for human use (e.g., showers and sinks) as it can cause scalding. Installing thermostatic mixing valves (TMVs) will prevent scalding by mixing hot and cold water so that the water coming out of the faucet is at a comfortable temperature. There are two kinds of mixing valves: master mixing valves and point-of-use valves. Master mixing valves are centrally located after the water heater, which may result in inconsistent temperatures throughout the building water system that may be favorable for *Legionella* growth. Point-of-use mixing valves are located at the individual fixture level. It is recommended that TMVs be installed as close as possible to fixtures to inhibit Legionella growth and spread.[4]

It is important to note that some state or local codes may specify a maximum temperature that a TMV may reach. This maximum temperature may be within *Legionella*'s growth range, so additional technologies may also be necessary to lower the chances of bacteria growth. The DRM requires hot water in general potable water systems to be heated to 60-63°C and tempered to 52-54°C using an ASSE 1017 TMV device.[5] To further prevent conditions that encourage bacterial growth, the DRM also advises that emergency systems which use water loops and short runouts leading to emergency fixtures to minimize dead-legs and stagnation.[5]

Figure 1 shows an exemplary plumbing system using TMVs and copper piping in three environments of a healthcare facility, such as service, resident, and research. The main features delineate the need for an inhouse water treatment system, TMVs, appropriate piping material, and proper drainage with backflow prevention devices.

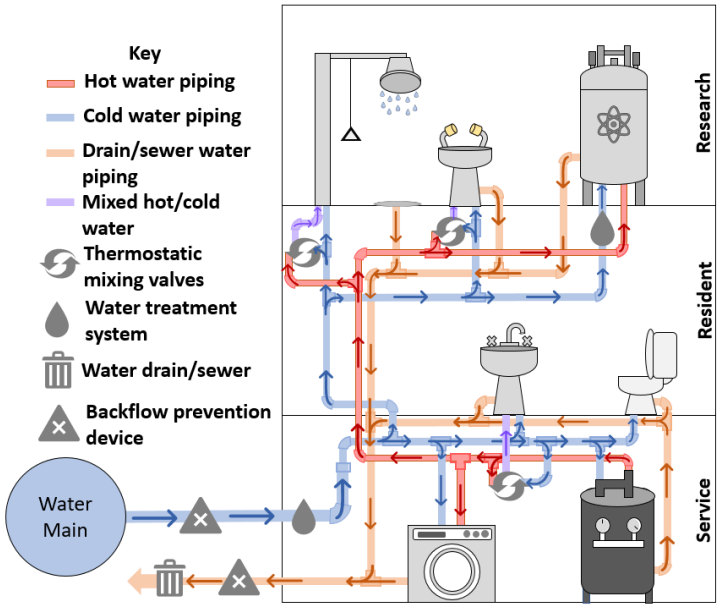

Figure 1: Exemplary plumbing considerations in a service, residential, and research environment.

Other technologies, such as point-of-use (POU) filters and flash disinfection devices, can be used as a final defense against possible *Legionella* exposure. POU filters are easily installed and effective, but the cost of installing them and maintaining them should be considered. These filters can also impact water age and disinfectant residuals. POU filters with a pore size of 0.2 microns or less that comply with the requirements of ASTM F838 can help to reduce the possibility of *Legionella* exposure via faucet.[6] Flash disinfection devices, such as ultraviolet (UV) light, reduce the proliferation of the bacterium, but they can also increase the decay of disinfectant residuals. Since UV light does not produce any disinfectant residual, a water system using only UV light may be susceptible to contamination at downstream points. It also requires routine maintenance to ensure that the UV dose remains adequate for inactivation of pathogens. Careful consideration of building water system design and operation is necessary before procuring filters and disinfection devices.

Conclusion

Material selection and plumbing design are critical components of a water management program. Designers should thoroughly consider the pros and cons of piping material to determine the best fit before proceeding to the design aspect of the plumbing system. They should also consider what add-ons would be necessary as additional preventative methods against *Legionella*. A combination of a robust water management program, installation and maintenance of facility-appropriate devices, and monitoring can decrease the potential for *Legionella* growth in building water systems.

'Design Requirements Manual (DRM) News to Use' is a monthly ORF publication featuring salient technical information that should be applied to the design of NIH biomedical research laboratories and animal facilities. NIH Project Officers, A/Es and other consultants to the NIH, who develop intramural, extramural and American Recovery and Reinvestment Act (ARRA) projects will benefit from 'News to Use'. **Please address questions or comments to:** mario.orellana@nih.gov

References and Further Reading

1. Cullom, A. C., Martin, R. L., Song, Y., Williams, K., Williams, A., Pruden, A., & Edwards, M. A. (2020). Critical review: Propensity of premise plumbing pipe materials to enhance or diminish growth of *Legionella* and other opportunistic pathogens. *Pathogens*, *9*(11), 957. https://doi.org/10.3390/pathogens9110957
2. Song, Y. (2022, January 28). Limitations to use copper as an antimicrobial control of *Legionella* in potable water plumbing systems. VTechWorks Home. https://vtechworks.lib.vt.edu/handle/10919/107994
3. Giachino, A., Waldron, K. J. (2020). Micro review: Copper tolerance in bacteria requires the activation of multiple accessory pathways. *Molecular Microbiology*, 114, 377. https://doi.org/10.1111/mmi.14522
4. Center for Disease Control and Prevention. (2022, March). *Legionella Environmental Assessment Form Marking guide*. https://mominfinanceblog.blogspot.com/2022/10/historical-return-of-stock-market.html
5. U.S. Department of Health and Human Services. (2020). Design Requirements Manual (DRM). National Institutes of Health. https://orf.od.nih.gov/technicalresources/pages/designrequirementsmanual2016.aspx
6. Centers for Disease Control and Prevention. (2021, March 25). *Considerations for healthcare-associated legionnaires disease outbreaks*. https://www.cdc.gov/legionella/health-depts/healthcare-resources/cases-outbreaks.html
7. United States Environmental Protection Agency. (2016, September). *Technologies for Legionella Control in Premise Plumbing Systems: Scientific Literature Review*. ttps://www.epa.gov/sites/default/files/2016-09/documents/legionella_document_master_september_2016_final.pdf
8. ASTM International. (2020, October 28). Standard test method for determining bacterial retention of membrane filters utilized for liquid filtration. ASTM International - Standards Worldwide. https://www.astm.org/f0838-20.html
9. Centers for Disease Control and Prevention. (2021, March 25). *Legionella: Developing a water management program*. https://www.cdc.gov/legionella/wmp/toolkit/index.html
10. ASHRAE 188-2021. (2021, August). Legionellosis: Risk Management for Building Water Systems (ANSI Approved). https://webstore.ansi.org/Standards/ASHRAE/ANSIASHRAEStandard1882021
11. ASHRAE 12-2020. (2020). Managing the risk of legionellosis associated with building water systems. https://www.techstreet.com/ashrae/standards/guideline-12-2020-managing-the-risk-of-legionellosis-associated-with-building-water-systems?product_id=2111422
12. Environmental Protection Agency. (2021, August 20). *Technologies for Legionella Control in Premise Plumbing Systems*. https://www.epa.gov/ground-water-and-drinking-water/technologies-legionella-control-premise-plumbing-systems
13. Peebles, L. (2020). *Legionella* and other dangerous pathogens still lurk in U.S. drinking water. Ensia. https://ensia.com/features/legionella-pathogens-drinking-water/.
14. Pierre, D., Castro, M., & Stout, J. (2022). *Legionella*: Causes, cases, and mitigation. Water-Formed Deposits, 611–631. https://doi.org/10.1016/b978-0-12-822896-8.00037-6
15. Platt, H. L., Dickey, L. L., Cutter, S., Flannery, J., Savage, T., & Vernon, W. (2017). Water management in health care facilities: Complying with ASHRAE Standard 188. ASHE. https://www.ashe.org/watermanagement
16. Centers for Disease Control and Prevention. (2021, January 13). *Toolkit for controlling legionella in common sources of exposure*. https://www.cdc.gov/legionella/downloads/Control-Toolkit-All-Modules.pdf

The National Institutes of Health | Division of Technical Resources | Office of Research Facilities

Design Requirements Manual **News to Use**

November 2022

Vol. 02, No. 65

The formulae $\frac{\partial \rho \bar{U}_i}{\partial t}+\frac{\partial}{\partial x_j}(\rho \bar{U}_i \bar{U}_j)=-\frac{\partial \bar{P}}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu \frac{\partial \bar{U}_i}{\partial x_j}\right)+g_i(\rho-\rho_0)$ *for building* $\frac{\partial}{\partial x_j}(\rho \bar{U}_i \bar{U}_j)=-\frac{\partial \bar{P}}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu \frac{\partial \bar{U}_i}{\partial x_j}-\rho \overline{u_i' u_j'}\right)+g_i(\rho-\rho_0)$ *state of the art* $\frac{\partial}{\partial x_i}(\rho \bar{U}_i \bar{H})=\frac{\partial}{\partial x_i}\left(\lambda \frac{\partial \bar{T}}{\partial x_i}-\rho \overline{u_i' h'}\right)$ *biomedical research facilities.*

Manifold Exhaust Requirements and ANSI/ASSP Z9.5-2022

Laboratory ventilation is critical to provide an environment that protects personnel from overexposure to harmful airborne contaminants generated within a lab. Many considerations (safety, flexibility, energy, redundancies, etc.) need to be evaluated in the selection, design, and operation of lab exhaust systems. Standard ANSI/ASSP Z9.5-2022 "Laboratory Ventilation" provides minimum requirements and best practices for laboratory ventilation systems. The standard also addresses enhanced energy efficiency goals, especially where there is potential to impact work, health, and safety. ANSI/ASSP Z9.5-2022 does not apply to all systems and laboratories (e.g., high containment facilities, radioisotope or explosive labs, and biosafety cabinets). This News to Use briefly compares the fume hood exhaust duct manifolding requirements and recommendations of ANSI Z9.5 to those of the Design Requirements Manual (DRM).

Manifolding Guidance and Considerations

The DRM and ANSI Z9.5-2022 permit manifolding of exhaust systems inclusive of general lab and fume hood exhaust where criteria are met. Both require each branch of manifolded chemical fume hood duct connected to an exhaust system to be equipped with flow-regulating devices. The DRM specifically requires pressure-independent exhaust flow control on each fume hood and the general lab exhaust serving each lab (7.3.3.3.B).

Manifolded exhaust systems can offer multiple advantages over individual/dedicated exhaust systems, including:

- Increased dilution of contaminant concentrations
- Lower first and operating and maintenance costs
- Decreased cost to provide redundancy and emergency power
- Fewer exhaust discharge stacks to place on a roof
- A discharge plume with enough mass to reach a plume height sufficient to avoid reentry of contaminants into the building and increase atmospheric dispersion
- Reduced required shaft space for ductwork

Manifolding can also provide for future flexibility to add or relocate fume hoods over the life of the facility, as appropriate per risk assessment. Such flexibility does require that future capacity allowance be provided for in the exhaust risers and exhaust fans capacity. The DRM does require allowance for future capacity in new laboratory exhaust air systems (6.2.1), which in part provides for allowances for future fume hoods in the labs.

The DRM and ANSI Z9.5-2022 require all exhaust air streams in a manifolded system to be compatible. ANSI Z9.5 considers exhaust streams compatible if the concentrations of flammable or explosive vapors are maintained below their Lower Explosion Limit (LEL) and the streams cannot form explosive compounds. Per the DRM, The Division of Occupational Health and Safety (DOHS) confirms air stream compatibility (6.1.22).

Separate and dedicated exhaust systems are required for several applications at NIH, like ducted biosafety cabinets, radioisotope hoods, wet exhaust, perchloric acid fume hoods and other applications as determined by risk assessment or by DOHS. While ANSI Z9.5-2022 does make certain exceptions for the manifolding of radioisotope hoods where HEPA and/or carbon bed filtration are provided between the hood(s) and the manifold, the standard further cites increased system static pressure requirements associated with filtration and the potential need for booster fans as reasons to discourage placing radioisotope hoods onto manifolded systems.

Manifolded devices, where used, can enhance energy recovery. While dedicated exhaust systems require additional and smaller heat recovery devices as well as more space and control points and higher maintenance costs, larger systems are more easily centralized and can economically provide laboratory heat recovery with fewer heat recovery devices.

Conclusion

Designers can successfully implement manifolded laboratory exhaust systems with proper hazard assessment accounting for exhaust compatibility, quantity and types of hoods, and best practices. Before designing manifolded or dedicated systems, planners should review the DRM and ANSI Z9.5-2022 and consult the Division of Technical Resources (DTR) and DOHS—and, in the case of dedicated radioisotope hoods, the Division of Radiation Safety (DRS).

Additional Information

1. ANSI/ASSP Z9.5-2022: *Laboratory Ventilation*
2. NIH DRM (Rev 1.5) 3-5-2020

'Design Requirements Manual (DRM) News to Use' is a monthly ORF publication featuring salient technical information that should be applied to the design of NIH biomedical research laboratories and animal facilities. NIH Project Officers, A/Es and other consultants to the NIH, who develop intramural, extramural and American Recovery and Reinvestment Act (ARRA) projects will benefit from 'News to Use'. **Please address questions or comments to:** mario.orellana@nih.gov

The National Institutes of Health | Division of Technical Resources | Office of Research Facilities

Design Requirements Manual **News to Use**

December 2022

Vol. 02, No. 66

The formulae $\frac{\partial \rho U_i}{\partial t}+\frac{\partial}{\partial x_j}(\rho U_i U_j)=-\frac{\partial P}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial U_i}{\partial x_j}\right)+g_i(\rho-\rho_0)$ *for building* $\frac{\partial}{\partial x_j}(\rho\overline{U}_i\overline{U}_j)=-\frac{\partial \overline{P}}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial \overline{U}_i}{\partial x_j}-\rho\overline{u_i'u_j'}\right)+g_i(\rho-\rho_0)$ *state of the art* $\frac{\partial}{\partial x_i}(\rho\overline{U}_i\overline{H})=\frac{\partial}{\partial x_i}\left(\lambda\frac{\partial \overline{H}}{\partial x_i}-\rho\overline{u_i'h'}\right)$ *biomedical research facilities.*

Existing Conditions Investigations for Renovation Projects

An essential first step for all renovation projects is for the Designer of Record to conduct a thorough existing conditions investigation of the site. The purpose of the investigation is to document, survey, and assess the site's existing constraints, requirements, and opportunities, including all services and utilities. Some of these features will be common to all projects (e.g., basic conditions, geometry, floor loading, MEP services, fire ratings) and some will be specific to the requirements of the project (e.g., noise, vibration, EM and RF interference), though all may affect the use of the site. The results of the investigation must be documented in the project Basis of Design.

Existing Conditions Investigations

It is essential to obtain all available existing documentation from the NIH Electronic Document Management System (EDMS) or other sources. Documentation shall include construction and record documents from the original construction as well as any subsequent renovations, including those for all supporting systems and utilities. Existing documentation shall be used for information only and shall not be considered factual until verified by an existing conditions survey. Facility managers and current occupants should be interviewed to obtain information about operational and performance issues, leaks, deficiencies, and any other observed facility problems that may have to be addressed or may otherwise limit or impact the project.

Existing Conditions Surveys

A physical survey must be conducted to confirm and document both site parameters (dimensions, locations, clearances, thicknesses, and other physical characteristics) and site conditions (signs of water, mold, cracks, and other deficiencies). Surveys shall include surrounding room occupancies and uses to determine their compatibility with the proposed renovation (e.g., use, condition, sensitivities to noise and vibration, etc.) and whether mitigation is required. The survey shall document improperly sealed penetrations, damaged or malfunctioning equipment, and other defects that must be brought to the attention of the Project Officer, even if they are outside of the scope of the current project.

Site surveys must also include the full extent of the site, including adjacent and peripheral areas (such as electrical and mechanical rooms, IT closets, etc.) that may require work to support the project. Surveys shall include building MEP utilities and other services, including all utility locations, capacities, and routing, both upstream and downstream, which may impact (or be impacted by) the work. Surveys and resulting assessments shall confirm their availability, capacity, condition, and limitations, including each service's adequacy to support new demands and usage.

A site survey shall review all above-ceiling spaces, penthouses, roofs, and similar spaces, which may include plenums and other inaccessible spaces. Include shafts to and from mechanical rooms and roofs. Consult with the Project Officer regarding site access requirements and permits required for surveys and ceiling access in the Clinical Center and other critical areas. The use of x-ray imaging and disruptive or destructive testing will require additional approvals.

As a design develops and the full extent of work becomes known, additional surveys may be required to encompass all impacted areas and systems.

Conclusion

Accurate and complete existing conditions documentation is a requirement for all renovation projects to mitigate the risk of complications and re-design during construction (and resulting delays and change orders). Investigations must include both review of historical documentation and in situ existing conditions surveys for both the area to be renovated and all surrounding impacted areas and systems.

'Design Requirements Manual (DRM) News to Use' is a monthly ORF publication featuring salient technical information that should be applied to the design of NIH biomedical research laboratories and animal facilities. NIH Project Officers, A/Es and other consultants to the NIH, who develop intramural, extramural and American Recovery and Reinvestment Act (ARRA) projects will benefit from 'News to Use'. **Please address questions or comments to:** mario.orellana@nih.gov