Promoting Water Quality and Hygiene

Overview

In the plumbing industry in the United States, there is an increasing focus on water quality and waterborne pathogens. For public water systems, the EPA regulates 88 different contaminants including microbial contaminants, disinfection by-products, organic and inorganic compounds and radionuclides. Of these, *Legionella* has received the most recent attention. In fact, there is ongoing discussion regarding the first standard intended to prevent *Legionella* growth in building water systems, ASHRAE 188. This recent attention strongly indicates a market need to better understand waterborne pathogens and how to minimize the risk of microbial growth in building plumbing systems that can lead to occupant infection. This paper will specifically refer to *Legionella* within building plumbing supply systems.

Plumbing System Design Considerations

To better understand why building plumbing systems may be at risk and how to minimize the risk of microbial growth in a plumbing system, one must first understand some basic considerations of plumbing system design and how pathogens colonize a plumbing system. As plumbing engineers know, system design includes not only proper sizing, but also appropriate selection of materials, how various piping materials react with other materials and the quality of the water in the system. Galvanic, chemical (pitting) and erosion corrosion mechanisms must be considered during design to promote a long service life. Typical materials include copper, stainless steel, polyethylene, cross-linked polyethylene (PEX), CPVC, polypropylene, bronze and brass (now in lead-free alloys), EPDM and others. Various constituents in the water, like pH, disinfectant residuals and concentrations, temperature, flow conditions, system pressure and environmental conditions, all have an effect on materials and corrosion potential. With any piping project (plumbing systems are no exception), it is imperative that the materials selected for an installation match the conditions of the application. Even hangers must be selected so as not to galvanically react with the piping material. More important than material is temperature and flow conditions. Regardless of the piping, fitting and sealing elements used, most modern plumbing systems are designed using a branch-and-tee concept. From an installation perspective, this method can be an efficient way to plumb water from the incoming service to fixtures throughout the building. In fact, model plumbing codes adopted in the United States base sizing tables on branch-and-tee systems. However, dead legs can be inherent to this concept. Dead legs might be drops to seldom-used fixtures, stub-outs for future use or extended branches for future build-out. Dead legs can result in stagnation because the water trapped in a dead leg is not subject to flow for extended periods and therefore not exchanged with fresh water. Furthermore, pressure testing a new system with water may result in stagnant, trapped water even if most of the systems are drained until building occupancy. This means that bacteria now have a disturbance-free area to live. Once stagnant, water temperature will reach that of the surrounding environment and in most areas lies exactly in the temperature range conducive to *Legionella* colonization. Stagnant water poses a significant risk of harboring and fostering microbial growth.

Understanding Microbial Colonization in Plumbing Systems

Legionella is a bacteria that can be found naturally in the environment. Unlike bacteria that affect the digestive system when consumed, *Legionella* affects the body's respiratory system. Once aspirated, the bacteria establishes itself in the lungs, causing pneumonia-like symptoms. Sources for *Legionella* in a building system may include piping systems, cooling towers, decorative fountains, standalone ice machines, spas, etc. Found naturally, when originating from water systems, bacteria can exist in aerosolized droplets which may be easily inhaled. Though not a concern in nature, microbial colonization in plumbing systems can pose a significant threat. Specific to piping systems, shower vapor or the mist from a lavatory aerator in which the bacteria exists may be the source of introduction into the body's respiratory system. If not treated properly, Legionellosis can be fatal and may result in legal action against building owners and engineers among others, not to mention damage from negative public relations surrounding the case. Though not the only source of Legionellosis, *Legionella* bacteria that reside in stagnant water conditions will flourish within a broad temperature range, typically 95°F to 115°F. This is primarily because they are largely undisturbed and allowed to colonize without disruption. Because bacteria multiply exponentially every few minutes, undisturbed sections of the piping can be the source of *Legionella* contamination for the entire system, depending on the condition of the rest of the system. As the bacteria multiply, some will detach from the colony and begin colonizing elsewhere in the piping system. The bacteria will secrete a polysaccharide slime forming a biofilm on the inside of the pipe wall. The biofilm helps insulate the bacteria from disinfecting chemicals and temperature extremes. As the bacteria colony grows, so does the biofilm. Once established, bacteria in a piping system can be very difficult to eliminate. Known treatment methods include thermal and chemical disinfection. If the colony is not rendered inert throughout the system, it will re-colonize after treatment, regardless of the treatment method used. Once the biofilm is allowed to form, it serves as a protective blanket for bacteria living within it. In the case of chemical disinfection, typically with an oxidizing agent like chlorine or chlorine dioxide, the disinfectant will only render inert what it comes in contact with. How the bacteria is rendered inert depends on the type of disinfectant. While some disinfectants disrupt the bacteria's DNA, other disinfectants interfere with the bacteria's metabolic processes. In either case, while bacteria in the top surface of the biofilm may come in contact with the disinfectant, bacteria residing deeper within an established biofilm may remain undisturbed. The same phenomenon also applies to thermal disinfection. While the top surface of the biofilm may be at a high enough temperature to kill *Legionella*, temperatures deep in the biofilm against the pipe wall or further along a dead leg may only be enough to temporarily prevent colonization.

Minimizing Microbial Colonization Through Plumbing System Design

Arguably, one of the best approaches for minimizing the risk of *Legionella* in a building plumbing system is to try to prevent it from occurring in the first place. Design strategies can be coupled with good operational and maintenance practices and a secondary disinfection program to effectively prevent a problem before it begins. Some facilities utilize supplemental disinfection practices such as ultraviolet systems. As long as the water is free from organic material, this can be an effective method for preventing the introduction of bacteria into the rest of the system. Systems like copper-silver ionization can help reduce bacteria and biofilm in a system as long as ion concentrations are high enough to be effective throughout the entire system but do not exceed EPA limits. Chlorine dioxide can be an effective sanitizer as well as long as residuals do not exceed EPA limits. Filtration can be effective in removing bacteria from the water, but filters must be maintained regularly or they may become a site for bacterial growth. Chlorine dioxide can be an effective sanitizer as long as residuals do not exceed EPA limits or contribute to accelerated corrosion and there is sufficient residual throughout the entire system. Chlorine disinfection concentrations and practices should comply with standards like AWWA C651 and model plumbing code guidelines. The challenge with any type of disinfection, including thermal disinfection, is its reach. The residual or, in thermal disinfection, the elevated temperature, must extend to all parts of the system, including dead legs and seldom-used fixtures or the disinfection process will be incomplete. With incomplete distribution of the disinfectant, there is a risk of leaving bacteria and biofilm undisturbed throughout the system, allowing regrowth. To help prevent this, all parts of the system should be regularly subject to flow and design temperatures. This will minimize the opportunity for biofilm growth and *Legionella* to colonize. With continuous (or even intermittent) flow, there is an exchange of fresh water which reduces stagnation in the system and helps maintain temperature closer to the design temperature. Even with recirculation, stagnation can occur in dead legs because of the lack of water exchange. This represents a challenge to the plumbing system designer. Dead legs should be eliminated wherever possible. One solution is to daisy-chain fixtures so their individual drops (dead legs) are avoided. Anytime one fixture is used, the remaining fixtures will see flow up to the point of connection even if they are not used. In the case of seldom-used remote fixtures, water can be forced through the fixture (up to the point of connection) with the use of a venturi. This concept manipulates the pressure across the fixture to induce flow thereby eliminating the dead leg that serves that fixture. With flow, temperatures can be better maintained and disinfectant residual can reach much more of the system. These concepts require the designer to reconsider the branch-and-tee concept. This means conventional sizing and layout may not be suitable for all parts of the plumbing system. Piping layout, fixture location, system balancing and pressure calculations may vary from current industry practices. It is up to the system designer to determine when the risk of *Legionella* within the plumbing system requires specific attention as well as which disinfection methods and design concepts are best for minimizing that risk.

Conclusion

There are many factors which must be considered in minimizing the risk associated with *Legionella* in building plumbing systems. These range from risk assessment, disinfection methods and effectiveness to system layout and sizing. Water quality and sound plumbing design involve far more than installing piping to connect fixtures. As plumbing requirements and risks evolve, so too must the plumbing industry.

About the author:

As Product Director, Metal Systems at Viega LLC, Derek Bower brings more than 15 years of industry experience to his position. He joined Viega in 2010 as senior product engineer and was promoted to associate product manager in 2011 before his current role. Bower received his bachelor's degree in science, mechanical engineering from the University of Illinois. He holds the title of Professional Engineer (PE) and LEED AP.