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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

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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

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