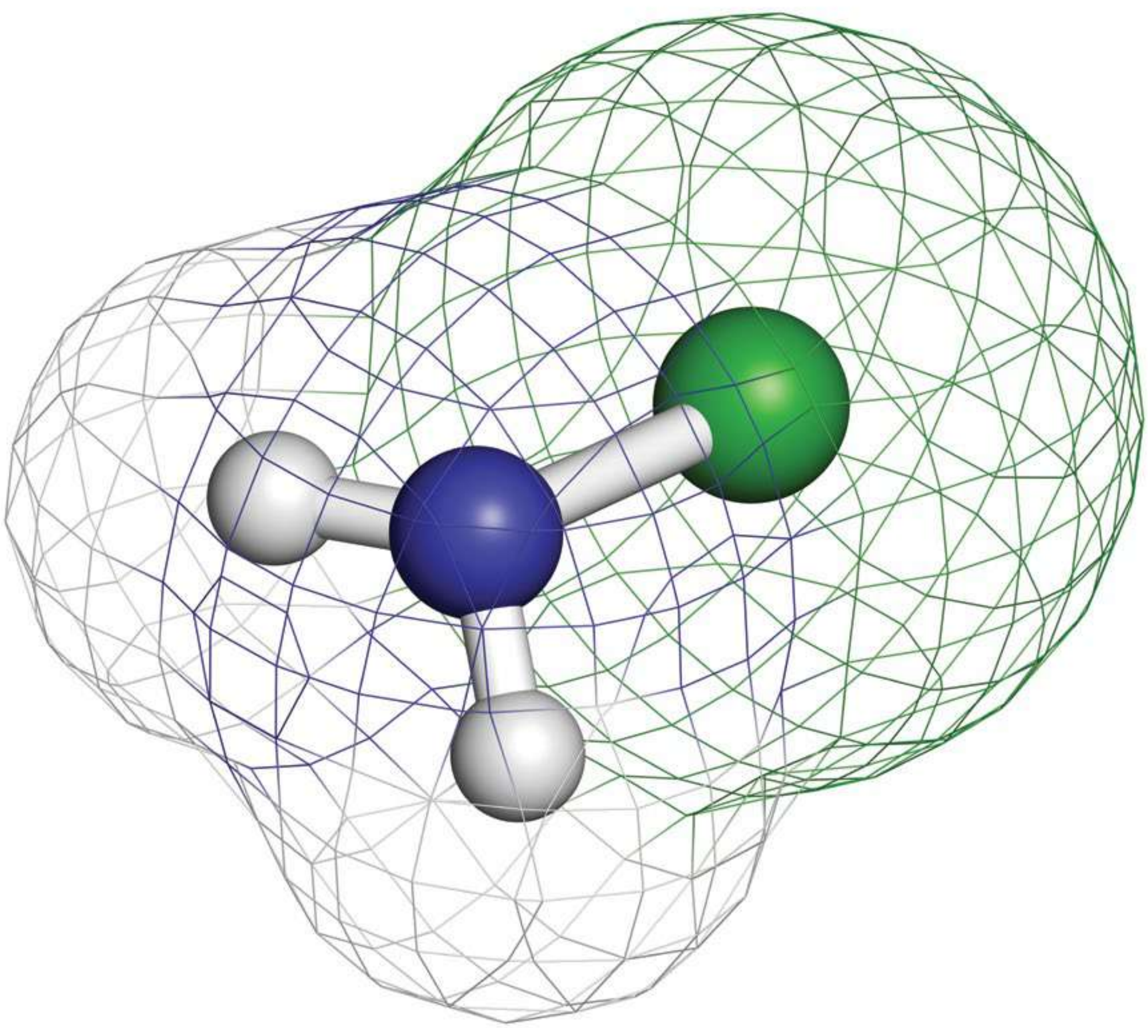
Can Monochloramine Offer a Long-Term Solution for Controlling *Legionella* and Waterborne Pathogens in a Healthcare Facility?

Janet E. Stout, Ph.D., Special Pathogens Laboratory
David Pierre, LiquiTech



To reduce the amplification of *Legionella* in building water systems, particularly those serving a susceptible population such as healthcare facilities, supplemental disinfectants are often necessary. In order to effectively evaluate the efficacy of disinfection, an evaluation should follow a four-step approach:

- Demonstrate in vitro efficacy.
- Anecdotal experience of efficacy in individual hospitals.
- Peer-reviewed controlled studies of prolonged duration documenting efficacy and prevention of Legionnaires' disease.
- Confirmatory reports from multiple installations with a prolonged duration of follow-up.

The four technologies that provide a residual disinfectant and have historically been considered for disinfection of building water systems to control *Legionella* include: supplemental chlorination, chlorine dioxide, monochloramine, and copper-silver ionization.

We previously performed independent field evaluations of all currently used disinfection methods for *Legionella* control in building water systems. This includes the first independent evaluation of a monochloramine installation on a hospital hot water system in the United States (1). From 2011 to 2014, the hospital hot water system was monitored for a total of 29 months (a five-month baseline sampling period and 24 months post disinfection). A significant decrease in *Legionella* species percent positivity was observed without adverse microbial or chemical consequences.

The objective of this evaluation was to extend the follow up period to 10 years post disinfection. As part of the long-term evaluation, we wanted to understand the ongoing effectiveness of *Legionella* control and to determine if there were any additional impacts on the building water systems, such as impact on other waterborne pathogens or overall water quality.

Methods

The study was conducted at a 500-bed hospital in Pittsburgh, Pennsylvania, the same site as our previous evaluation. The monochloramine system (SANIPUR) was installed and operation began in September 2011. The unit has is made up of a proprietary precursor chemical mix of ammonia and chlorine fed using a metering pump into the hot water supply to the building. An analyzer on the hot water return line is used to monitor the system. Since September 2011, the monochloramine system has been operated and monitored by the water treatment professional with oversight by the water safety team. The target monochloramine and free-ammonia levels in distal outlets at the facility is 2.0 to 3.0 parts per million (ppm) and <0.50 ppm, respectively.

The control efficacy of *Legionella* as well as other opportunistic pathogens by the on-site monochloramine disinfection had been evaluated for a relatively shorter term right after the system was put into operation (1). The present study continued to evaluate this system for an extended period of up to 121 months (September 2011 to October 2021) since the initial operation of monochloramine disinfection.

Ten rounds of post-disinfection sampling were performed between June 2014 and October 2021. A total of 20 to 31 samples were collected during each microbiological monitoring event. Monitoring locations included the incoming cold water, hot water return, and representative distal outlets. Sample collection from distal outlets was performed by collecting first draw hot water for microbiologic analysis followed by a one-minute flush and collection of hot water for chemistry analysis. Sample collection from the incoming cold water and hot water return was performed after a one-minute flush from the sample valve.

Microbiologic samples were analyzed by Special Pathogens Laboratory for *Legionella*, Heterotrophic Plate Count (HPC), *Pseudomonas*, *Acinetobacter, Stenotrophomonas,* and non-tuberculous *Mycobacteria* using standard laboratory procedures. Aqueous chemistry samples were analyzed by a third-party laboratory for metals (iron, calcium, magnesium, zinc, lead, copper, and manganese). Metals samples were collected in acid preserved bottles.

Physicochemical monitoring was conducted at the incoming cold water, hot water return line, and the first distal site post the monochloramine injection. Free chlorine, total chlorine, monochloramine, and free ammonia were measured in the field using a using a

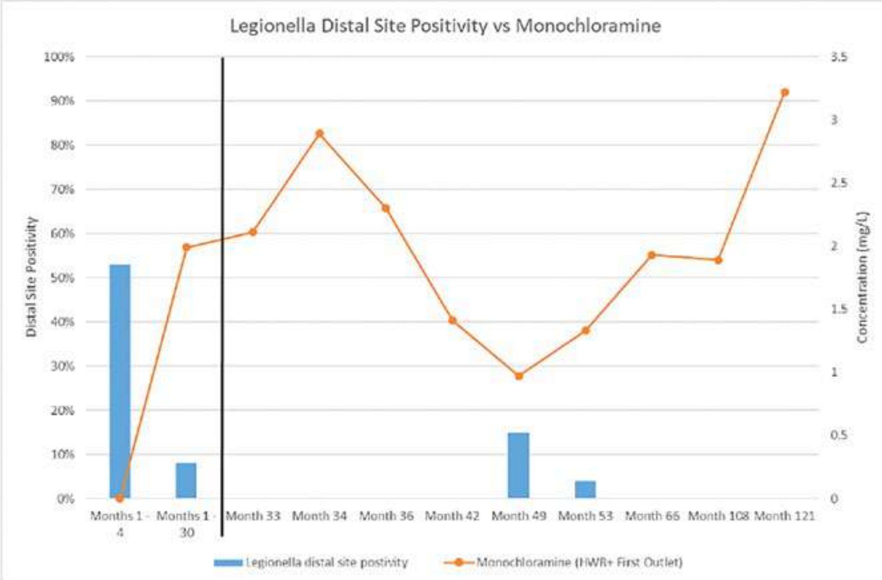


Figure 1: Average monochloramine concentration (HWR) and First Outlet) and Legionella distal site positivity. Months 1-4 were prior to monochloramine treatment.

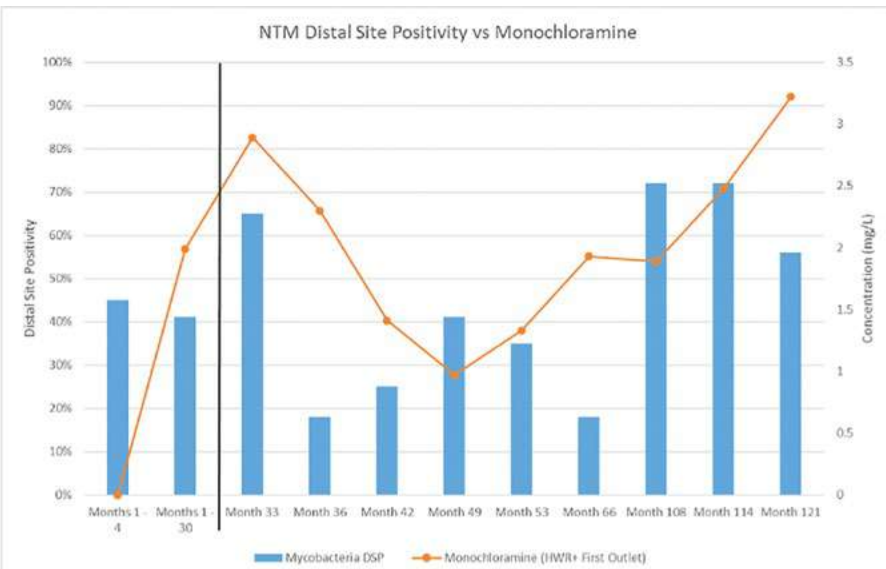


Figure 2: Average monochloramine concentration (HWR and First Outlet) and NTM distal site positivity. Months 1-4 were prior to monochloramine treatment.

Hach DR/900 colorimeter (from June 2014 to January 2015) and a Hach SL1000 colorimeter (February 2015 to October 2021). Water temperature was measured using a Thermapen Mk4 thermometer.

Results

Table A provides data that shows control of *Legionella* without significant changes in the control of other waterborne bacteria.

Legionella

Legionella pneumophila serogroup 1 was detected during a single sampling event (October 2015), while blue-white fluorescing *Legionella* species were detected during two of the sampling events (October 2015, February 2016). The October 2015 sampling event showed the highest distal site positivity (DSP) at 15%, which is well below the 30% threshold for evaluating risk of disease. The distal site positivity during the February 2016 sampling was

Table A: Microbiologic Monitoring Shows *Legionella* Control Without Significant Changes in Other Waterborne Pathogens

Microbial	Baseline		Post Disinfection										
	(1st Evaluation by Duda)		(2nd Evaluation)										
	Months 1–4	Months 1–30	Month 33	Month 34	Month 36	Month 42	Month 49	Month 53	Month 66	Month 108	Month 114	Month 121	Months 33–121 Average
HPC, average CFU/mL	14,047	2,123	-	-	-	8,022	2,122	3,473	7,504	9,524	-	2,277	5,487
Legionella species	53%	8%	0%	0%	0%	0%	15%	4%	0%	0%	-	0%	2%
Pseudomonas aeruginosa	0%	0%	-	-	-	4%	4%	0%	0%	7%	-	-	3%
Stenotrophomonas maltophilia	0%	1%	-	-	-	8%	11%	0%	0%	0%	-	-	4%
Acinetobacter species	0%	0%	-	-	-	0%	0%	0%	0%	0%	-	-	0%
Nitrifying bacteria	0%	0%	-	-	-	-	-	-	0%	0%	-	-	0%
Mycobacteria	45%	41%	65%	-	18%	25%	41%	35%	18%	72%	72%	56%	45%

4%. Concentrations during those sampling periods averaged 1.5 colony forming units per milliliter (mL) and 10 CFU/mL, respectively. *Legionella* was not detected in the other seven sampling events.

Figure 1 presents the average monochloramine concentration at the hot water return (HWR), and the first outlet, and the *Legionella* positivity.

Non-Tuberculous Mycobacteria (NTM)

NTMs were detected during all nine of the sampling events conducted for NTM. The average distal site positivity was 45%, ranging from 18% to 72% DSP. Multiple species were identified throughout the evaluation period, including *M. gordonae, M. avium, M. llatzerense, M. lentiflavum, M. paragordonae*, and *M. gadium*. Figure 2 shows the average monochloramine concentration and the NTM distal site positivity.

Other Microbiologicals

Water samples were collected for HPC culture analysis during six of the sampling events. There was a reduction in HPC post-treatment. The average baseline HPC concentration at the distal outlets was 14,047 CFU/mL before monochloramine treatment and was reduced to 5,487 CFU/mL post-treatment (Figure 3).

Water samples were collected for *Pseudomonas aeruginosa* culture in five sampling events. *Pseudomonas* was not identified during baseline but was identified in three post-disinfection sampling events. Distal site positivity ranged from 4% to 7% with only one or two locations positive for *Pseudomonas*, respectively. Overall, the average distal site positivity of post-disinfection sampling events was 3%. *Stenotrophomonas maltophilia* was not identified during baseline and identified in three of the five post-disinfection sampling events. In the three positive sampling events, distal site positivity ranged from 1% to 11%. Overall, the average distal site positivity of post-disinfection sampling events was 4%. *Acinetobacter* was not detected during any of the sampling events.

Water samples were tested for nitrifying bacteria during baseline sampling, the initial evaluation and two sampling events in this evaluation. Nitrifying bacteria were not detected during any of the sampling events (Figure 4).

Physicochemical and Other Water Quality Data

Monochloramine data was collected during each of the sampling events. We calculated the average concentration by averaging the concentration of the first distal outlet and the hot water return, to represent near and far points in the water system. The average concentration range was from 0.97 milligrams per liter (mg/L) to 3.22. The overall average throughout the entire evaluation was 2.05 mg/L throughout the ten sampling events. Free ammonia was also measured from the HWR and first distal site with an overall average of 0.14 mg/L. Various metals were collected throughout the evaluation (Table B). Most were at or below the limit of detection.

Discussion

The sampling results from this evaluation demonstrate that monochloramine installed on the potable hot water system is an effective long-term method for *Legionella* control. There was no evidence of proliferation of other waterborne pathogens. The monochloramine system kept *Legionella* distal site positivity below 30% for the entirety of the 10-year evaluation. Most importantly, no cases of healthcare-acquired Legionnaires' disease have been identified since applying monochloramine to the hospital hot water system. Furthermore, no significant changes in other waterborne pathogens were observed compared to baseline sampling (Months 1–4).

These results are consistent with results an EPA study and an Italian study (2, 3). Studies on municipal water treatment with monochloramine have shown similar effectiveness against *Legionella* (4, 5).

Attaining zero *Legionella* in a building water system is unrealistic and is unnecessary to mitigate the risk of disease. *Legionella* was not detected in seven of the sample events but was detected at months 49 and 53. This coincided with the lowest average monochloramine concentrations. This study and others have suggested that the target goal for monochloramine should be 2.0 mg/L to 3.0 mg/L.

HPC bacterial counts are used by some water safety and management specialists as an indicator of a well-managed building water system. A target of 500 CFU/mL is often used as an indicator of a poorly managed water system. This study as well as others have shown

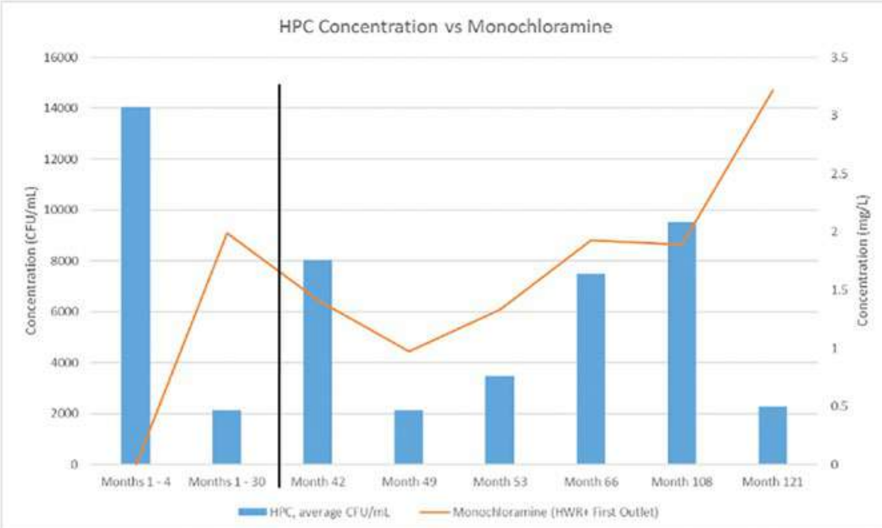


Figure 3: Average monochloramine concentration (HWR and First Outlet) and average distal site HPC concentration. Months 1-4 were prior to monochloramine treatment.

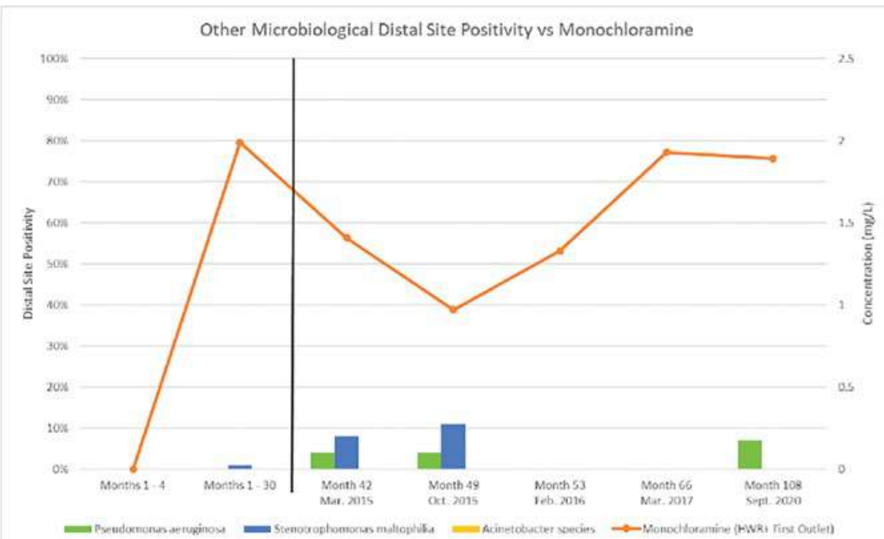


Figure 4: Average monochloramine concentration (HWR and First Outlet) and distal site positivity for other waterborne pathogens. Months 1-4 were prior to

that HPC counts are often well above this target despite effective water treatment. Monochloramine did decrease the average concentration of HPC from 14,047 CFU/mL to 5,487 CFU/mL; however, the average HPC concentration remained well above 500 CFU/mL. This metric can be used to trend water treatment effectiveness, but not as an indicator of the presence of other waterborne pathogens or effectiveness of a water management program in controlling *Legionella*.

Metals concentrations (iron, calcium, magnesium, zinc, manganese, lead, and copper) did not increase after the application of the monochloramine. Unlike some stronger oxidants such as chlorine or chlorine dioxide, monochloramine application presented a low concern for accelerated corrosion. No disinfection by-product testing was performed in this study. The aforementioned EPA study showed no water quality

Table B: Physicochemical Parameter Monitoring Results

	Baseline	Post Disinfection											
	(1st Evaluation by Duda)		(2nd Evaluation)										
	Months 1–4	Months 1–30	Month 33	Month 34	Month 36	Month 42	Month 49	Month 53	Month 66	Month 108	Month 114	Month 121	Months 33–121 Average
Monochloramine (HWR+ First Outlet), mg/L	0.00	1.99	2.11	2.89	2.30	1.41	0.97	1.33	1.93	1.89	2.48	3.22	2.05
Free ammonia, (HWR+ First Outlet), mg/L	0.00	0.61	-	-	-	0.08	0.26	0.36	0.04	0.03	0.08	0.15	0.14
Iron	-	-	-	-	-	-	-	<0.030	-	0.16	-	0.12	<0.030
Zinc	-	-	-	-	-	-	-	-	-	-	-	0.06	0.06
Manganese	-	-	-	-	-	-	-	-	-	-	-	<0.010	<0.010
Lead	-	<0.0025	<0.0025	-	<0.0025	-	-	<0.0010	<0.0025	<0.010	<0.010	<0.010	<0.0025
Copper	0.83	0.23	<0.1	-	0.10	-	-	0.07	0.08	0.09	0.09	0.09	0.09
Silver	0.15	0.34	0.02	-	0.02	-	-	0.03	0.02	0.02	0.02	-	0.02

changes or known unintended consequences after monochloramine addition including increases in lead and copper, iron and disinfection by-products including NDMA (3).

Conclusions

This evaluation was performed to assess the long-term effects and efficacy of a monochloramine installation on a hospital hot water system. We demonstrated that monochloramine provided long-term control of *Legionella* without detrimental impacts on the building water system including proliferation of other waterborne pathogens or accelerated corrosion of the building water system.

Monochloramine did not impact NTM growth in the plumbing system, with the overall distal site positivity relatively unchanged from initial baseline NTM positivity (45%). This has significant implications for water safety programs. Many assume that implementation of a water safety program to mitigate *Legionella* risk will also reduce the risk of other waterborne pathogens. Risk of disease from all waterborne pathogens cannot be solved with water treatment alone.

When considering installation of monochloramine, consider water quality, system physical conditions and constraints, and the need for control of other waterborne pathogens. All should be considered by the operator prior to selecting any treatment method. A successful installation should consider:

- Completing a baseline assessment of the water system, including *Legionella* positivity, evaluation of plumbing systems, chemistry, understanding system operation, and determining permitting needs.
- Developing a water safety and management plan to manage *Legionella* risk and establish operating limits, monitoring requirements, and corrective actions for the supplemental disinfection system.
- Implementation of the water management program including validation through environmental testing for *Legionella* to demonstrate efficacy.
- Evaluating results with the water safety team and adjusting the program based on findings.

Throughout the evaluation, we observed fluctuation of monochloramine concentrations, stressing the importance of maintaining a robust operation and maintenance program. No supplemental disinfection system can be treated as “set it and forget it.” For monochloramine, we would recommend maintaining 2.0 to 3.0 mg/L as the control limits for monochloramine. When monochloramine levels were lower than the 2.0 mg/L, positive *Legionella* results were observed, albeit still under the recommended 30% distal site threshold.

Additional peer-reviewed studies are needed to expand on this evaluation and the long-term impact of monochloramine on building water systems and other waterborne pathogens.

Acknowledgement

This study was self-funded by Special Pathogens Laboratory. The authors would like to thank the facility team at the facility where the study was conducted.

References

1. Duda, S.; Kandiah, S.; Stout, J.; Baron, J.; Yassin, M.; Fabrizio, M.; . . . Rogers, D. (2014). “Evaluation of a New Monochloramine Generation System for Controlling *Legionella* in Building Hot Water Systems,” *Infection Control and Hospital Epidemiology 35(11)*, pp. 1356-1363, doi:10.1086/678418.
2. Lytle, D.A.; Pfaller, S.; Muhlen, C.;0 Struewing, I; Triantafyllidou, S.; White, C.; Hayes, S.; King, D.; Lu, J.; (February 2021). “A Comprehensive Evaluation of Monochloramine Disinfection on Water Quality, *Legionella*, and Other Important Microorganisms in a Hospital,” *Water Research*, 2021 Feb 1;189:116656. doi: 10.1016/j.watres.2020.116656. Epub 2020 Nov 18. PMID: 33249307; PMCID: PMC8133025.
3. Kool, J.L.; Carpenter, J.C.; Fields, B.S.; (January 1999). “Effect of Monochloramine Disinfection of Municipal Drinking Water on Risk of Nosocomial Legionnaires’ Disease,” *Lancet*, 3;353(9149):272-7. doi: 10.1016/S0140-6736(98)06394-6. PMID: 9929019.
4. Moore, M.R.; Pryor, M.A.; Fields, B.; Lucas, C.E.; Phelan, M.A.; Besser, R.E. (2006). “Introduction of Monochloramine into a Municipal Water System: Impact on Colonization of Buildings by *Legionella* spp.,” *Applied and Environmental Microbiology*, 72, pp. 378-383.
5. Marchesi, I.; Paduano, S.; Frezza, G.; Sircana, L.; Vecchi, E.; Zuccarello, P.; Oliveri-Conti, G.; Ferrante, M.; Borella, P.; Bargellini, A. (August 2020). “Safety and Effectiveness of Monochloramine Treatment for Disinfecting Hospital Water Networks,” *International Journal of Environmental Research and Public Health 17(17)*, p. 6116, doi: 10.3390/ijerph17176116. PMID: 32842654; PMCID: PMC7503937.

Janet E. Stout, Ph.D., is executive VP and founder of Special Pathogens Laboratory, A Pace® Laboratory, and research associate professor at the University of Pittsburgh Swanson School of Engineering in the Department of Civil and Environmental Engineering. An infectious disease microbiologist, Dr. Stout is recognized worldwide for pioneering research in Legionella. Her expertise includes detection, prevention, and control strategies for Legionnaires' disease in building water systems. Dr. Stout has shared her more than 30 years of research in book chapters and more than 100 articles published in peer-reviewed medical and scientific journals. She advances the mission to End Legionnaires' disease by speaking and serving on numerous industry committees, including the ASHRAE Legionella *standard SSPC 188, Guideline 12-2020 and Proposed Standard 514. Additionally, Dr. Stout initiated the development of the first professional qualifications standard, the ASSE Standard 12080 Professional Qualifications Standard for* Legionella *Water Safety and Management Personnel, and teaches the first, virtual online certification education course certifying more than 500 professionals to date. Dr. Stout may be contacted at jstout@specialpathogenslab.com.*

David Pierre is Director of Water Safety Programs at LiquiTech .He is an expert in New York City and State regulations for Legionella *risk management and ANSI/ASHRAE Standard 188. An ASSE/IAPMO/ANSI 12080 Certified* Legionella *Water Safety Specialist, Mr. Pierre has overseen the development of more than 200 water safety and management plans and risk assessments for healthcare, hospitality, commercial, and industrial facilities. His background includes an understanding of the physical conditions for* Legionella *and waterborne pathogens in premise plumbing and cooling towers. He may be contacted at dpierre@liquitech.com.*

This paper was presented at the AWT's 2022 Conference, which was conducted September 21-24, 2022, in Vancouver, B.C., Canada.

Keywords: BACTERIA, BIOCIDES, BUILDING WATER, CHLORINE, HEALTHCARE, *Legionella*, PATHOGENS