

Intermittent Use of Copper-Silver Ionization for *Legionella* Control in Water Distribution Systems: A Potential Option in Buildings Housing Individuals at Low Risk of Infection

Zeming Liu, Janet E. Stout, Marcie Boldin, John Rugh,
Warren F. Diven, and Victor L. Yu

From the University of Pittsburgh and Veteran Affairs Medical Center,
Pittsburgh, Pennsylvania

One copper-silver ionization system was sequentially installed onto the hot-water recirculation lines of two hospital buildings colonized with *Legionella pneumophila*, serogroup 1. A third building with the same water supply and also colonized with *Legionella* served as a control. Four weeks after activation of the system, distal site positivity for *Legionella* in the first test building dropped to zero. After operating for 16 weeks, the system was disconnected and installed onto the second test building. Twelve weeks of disinfection reduced the distal site positivity for *Legionella* in the second test building to zero. *Legionella* recolonization did not occur in the first test building for 6–12 weeks and in the second test building for 8–12 weeks after inactivation of the system. The control building remained *Legionella*-positive throughout the experimental period. A significantly higher copper concentration was found in the biofilm taken from a sampling device than in that from water. This is likely to be the reason that the copper-silver ionization system had the residual effect of preventing early recolonization. Our study raises the possibility that one copper-silver unit could be rotated among several buildings to maintain a *Legionella*-free environment. Such an approach may be cost-effective for buildings housing individuals at low risk for contracting legionnaires' disease.

Disinfection of water distribution systems in hospitals where cases of legionnaires' disease occur has become commonplace with the knowledge that the water distribution is the source of the pathogen. However, many hospitals and nursing homes do not have severely ill patients who would be at high risk for acquiring legionnaires' disease. Furthermore, sporadic cases have occurred in apartment buildings, workplaces, and dormitories in which potable water was documented to be the source. Many such institutions have faced a dilemma, since implementation of disinfection can be logistically tedious and expensive and intense continuous disinfection in these buildings may not be needed in these low-risk situations. On the other hand, some measures would seem indicated to prevent further cases, however rare, and to address medicolegal issues of culpability.

Copper-silver ionization has been proved to be effective in eradication of *Legionella* from hospital water systems [1–4]. In fact, after the copper-silver ionization system was deliberately inactivated in one hospital as part of a controlled evaluation, recolonization by *Legionella* did not occur for 12 weeks [3]. Thus, we applied intermittent copper-silver disinfection to two buildings colonized with *Legionella pneumophila*, serogroup 1, using one copper-silver ionization unit. These buildings housed ambulatory psychiatric patients without severe underlying disease. Our objectives were to (1) assess the residual effect of

copper-silver ionization for maintaining a *Legionella*-free environment in a hospital water system, (2) determine whether two buildings could be sequentially disinfected with one copper-silver ionization unit, and (3) determine whether accumulation of copper-silver ions in the biofilm was the basis for the residual protective effect.

Materials and Methods

The study was undertaken in a 541-bed psychiatric hospital. Two buildings were chosen as test buildings and a third building as the control. All three buildings have the same water supply, and each building has two instantaneous heating units to supply hot water. Two copper-silver ionization flow cells (model CPVC SCH 8; Liqui-Tech, Willowbrook, IL) were mounted in parallel on top of a cart and connected with high-pressure hoses (diameter, 2"; thickness, 1/4") onto the hot-water recirculation line before the connection point of the instantaneous heaters of the test building. The copper-silver ionization flow cell was furnished with a controller, which maintained a constant voltage and amperage (maximum power output: 5.0 A, 50 V).

Twenty distal sites in each building were cultured for *Legionella* [5] before start-up and monthly after the system was installed. Baseline cultures showed that 50%, 70%, and 20% of distal sites were positive for *L. pneumophila* serogroup 1 at the first test building, the second test building, and the control building, respectively.

A modified Robbins device containing 48 sampling plugs was installed on the hot-water recirculation line in the second test building. One sampling plug from the Robbins device and

Received 11 December 1996; revised 9 September 1997.

Reprints or correspondence: Dr. Victor Yu, VA Medical Center, Infectious Disease Section, University Drive C, Pittsburgh, Pennsylvania 15240.

Clinical Infectious Diseases 1998;26:138–40

© 1998 by The University of Chicago. All rights reserved.
1058-4838/98/2601-0020\$03.00

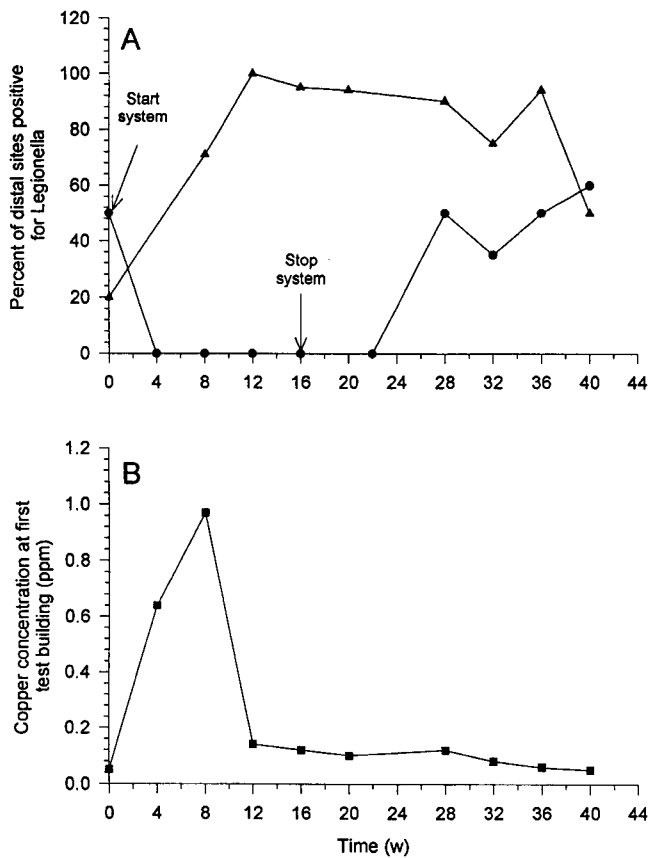


Figure 1. A, percentage of distal sites positive for *Legionella* in the first test building (●) vs. a control building (▲); B, copper concentration (■) in the first test building. The first test building remained *Legionella*-free for 6–12 weeks after treatment with the copper-silver system was stopped, suggesting a residual protective effect.

a 50-mL water sample were taken to determine copper/silver concentration in both planktonic (bulk water) and sessile (surface-adherent) samples. Samples were taken before start-up as well as 1 week and monthly after activation of the copper-silver ionization system in the second test building. Copper and silver ion concentrations were determined by atomic absorption spectroscopy [5].

Results

In the first test building, the *Legionella* positivity was reduced from 50% (before start-up) to zero after 4 weeks. No *Legionella* was detected 6 weeks after the ionization system was inactivated; however, after 12 weeks, distal-site positivity returned to 50% (figure 1). The mean copper/silver concentration during the period of copper-silver ionization was 0.36/0.034 ppm, while the mean copper/silver concentration for the 20 weeks after the copper-silver system was inactivated was 0.059/0.003 ppm. The control building remained *Legionella*-

positive (range, 20%–100%; mean, 83%) throughout the study period.

In the second test building, 4 weeks after activation of the ionization system (week 8 on figure 2), the copper/silver concentration from the sampling port before the point where the copper-silver ionization system was connected was 0.11/0.025 ppm, which was minimally changed from the before-start-up level of 0.11/0.001 ppm. Eight weeks after activation of the ionization system (week 12 on figure 2), the copper/silver concentration from the sampling port before the copper-silver ionization system was 0.20/0.017 ppm. There was a reduction in average number of cfu/swab at *Legionella*-positive sites (prestart: 2,000; 1 month: 1,360, 2 months: 340).

Twelve weeks after the activation of the copper-silver ionization system, the copper/silver concentration had risen to 0.43/0.75 ppm. The distal-site *Legionella* positivity became zero at 12 weeks after activation. The building remained *Legionella*-free until 8–12 weeks after disconnection of the copper-silver ionization system, when distal-site *Legionella* positivity returned to 55% (figure 2). An extended period of time was

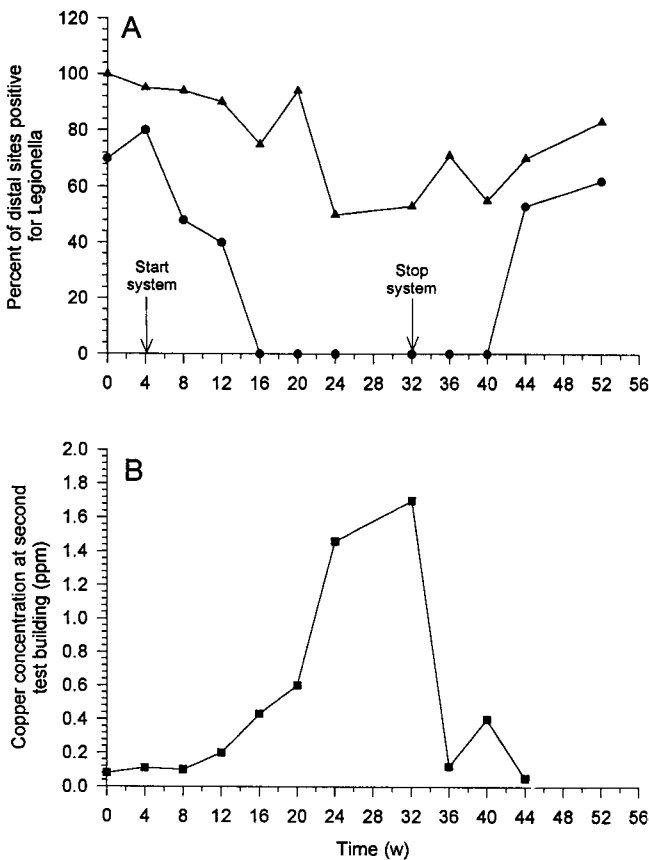


Figure 2. Eradication of *Legionella* by copper-silver ionization after the system was relocated to a second test building. A, percentage of distal sites positive for *Legionella* in the test building (●) vs. a control building (▲); B, copper concentration (■) in the second test building. The second test building remained *Legionella*-free for 8–12 weeks after treatment with the copper-silver system was stopped.

needed to disinfect the second test building because of initial lower copper-silver ion levels in this building. The average copper/silver concentration during the period of copper-silver ionization system operation was 0.394/0.163 ppm, while the average copper-silver concentration after the copper-silver system was disconnected was 0.183/0.0137 ppm.

The control building remained *Legionella*-positive (50%–95%) throughout the study period. Average cfu of *Legionella* per swab for positive sites was 117.5 (range, 1–301 cfu).

Copper ion concentrations were significantly higher in biofilm samples (mean, 0.32) than in planktonic water samples (mean, 0.057) ($P < .001$, paired t -test). There was no significant difference in silver concentrations between the biofilm samples and planktonic water samples (mean, 0.082 vs. 0.060).

Discussion

A copper-silver ionization system was sequentially installed on the hot-water recirculation lines of two test buildings, with demonstrated efficacy (figures 1 and 2). A residual protective effect was maintained in the first building during the time the unit was moved to the second building. The test buildings remained free of *Legionella* for 6 and 8 weeks, respectively, after the ionization unit was inactivated. However, by 12 weeks, both buildings had recolonized (figures 1 and 2).

We have found in a previous study that after copper-silver ion levels became greater than 0.4/0.04 ppm, *Legionella* colonization decreased dramatically [3]. These levels were not reached in the second building until after the third month of operation (figure 2). The reason for this difference is unknown. However, the water usage in the second building may have been greater than in the first building owing to system design and patient population. This would have the effect of diluting the treated water.

We have also noted initially higher ion levels in other hospitals using this system after new flow cells are installed. Ion levels seem to level off after the first month of operation. It appears that *Legionella* colonization can be reduced at ion concentrations lower than 0.4/0.04 ppm, but more time may be required to eradicate the organism.

Copper ion concentrations were significantly higher in biofilm samples taken from the sampling device than those in planktonic water samples. Elevated copper levels in the biofilm may prevent *Legionella* recolonization. Some bacterial species found in biofilm can produce exopolymers that bind copper [6], although it is not yet known whether *Legionella* has this same capability.

Although in vitro experiments have shown copper and silver ions to act synergistically in killing *Legionella* at concentrations of 0.04 ppm of copper and 0.02–0.04 ppm of silver [7], higher concentrations appear to be necessary in large water systems. It is important to note that there may be a range of copper-silver ion levels that would be effective in controlling *Legionella* in a hot-water system and that a particular concentration may not be universally effective because of variables in water quality and system design.

In summary, one copper-silver ionization system was successfully used to disinfect two hospital buildings sequentially. Given the susceptibility of high-risk patients to acquiring legionnaires' disease in buildings with contaminated water distribution systems, we do not recommend this approach for most hospitals. On the other hand, this may prove to be a cost-effective option in disinfecting buildings housing individuals at low risk for contracting legionnaires' disease, e.g., apartment buildings, office buildings, hotels, and dormitories.

Acknowledgment

The authors thank Mary DeRiso for assistance in performing the study.

References

1. Thompson RB Jr, File TM Jr, Plouffe J, Stephens C, Ricks R. Use of Tarn-Pure to eradicate *Legionella pneumophila* from a hospital hot water system [abstract no L18]. In: Abstracts of the Annual Meeting of the American Society for Microbiology (Anaheim, CA). Washington, DC: American Society for Microbiology, 1990:431.
2. Lumish RM, Stout JE, Fleming LJ, et al. New approach to controlling nosocomial Legionnaires' disease: Cu-Ag ionization treatment of the hospital hot water system [abstract no B65]. In: Program and abstracts of the 33rd Interscience Conference on Antimicrobial Agents and Chemotherapy. Washington, DC: American Society for Microbiology, 1993: 278.
3. Liu Z, Stout JE, Tedesco L, et al. Controlled evaluation of copper-silver ionization in eradicating *Legionella pneumophila* from a hospital water distribution system. *J Infect Dis* 1994; 169:919–22.
4. Colville A, Crowley J, Dearden D, Slack RCB, Lee JV. Outbreak of legionnaires' disease at University Hospital, Nottingham: epidemiology, microbiology, and control. *Epidemiol Infect* 1993; 110:105–16.
5. American Public Health Association. Standard methods for the examination of water and wastewater. 16th ed. Washington, DC: American Public Health Association, 1994.
6. Mittelman MW, Geesey GG. Copper-binding characteristics of exopolymers from a fresh water sediment bacterium. *Appl Environ Microbiol* 1985; 49:846–51.
7. Lin YE, Vidic RD, Stout JE, Yu VL. Individual and combined effects of copper and silver ions on inactivation of *Legionella pneumophila*. *Water Res* 1996; 30:1905–13.