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Water disinfection with ozone, copper and silver ions, and temperature increase to control *Legionella*: seven years of experience in a university teaching hospital

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Summary The efficacy of ozonation, copper–silver ionization and increased temperature in controlling *Legionella* spp. in the hot water distribution networks of a university hospital was evaluated. Two separate water distribution networks were studied; network 1 which supplies the surgical intensive care units, and network 2 which supplies the medical intensive care units and the emergency room. Network 1 has been disinfected by ozonation since 1995, and network 2 has been disinfected by ionisation since 1999. The hot water temperature was increased from 50 to 65 °C in 1998 and 2000 in networks 1 and 2, respectively. Water samples and swabs of the water outlets were cultured for *Legionella* spp. between four and six times each year, providing data before and after implementation of the disinfection procedures. There was no significant difference in the proportion of samples positive for *Legionella* spp. after ozonation in network 1 or after ionization in network 2. In both networks, there was a significant reduction in legionella isolates after increasing the hot water temperature to 65 °C. Maintaining the hot water temperature above 50 °C throughout both networks proved to be the most effective control measure in our hospital.

Introduction

Hot water systems are an important source of nosocomial infections caused by *Legionella pneumophila*. High temperatures (> 50 °C) are usually

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required to prevent colonization with this opportunistic pathogen. However, high temperatures require increased energy expenditure and create a risk of burns to patients. Alternative disinfection methods have been suggested to control legionella in water,[1] such as ozone,[2-4] copper and silver ionization,[5-9] monochloramide,[10] ultraviolet light[11] and high chloride levels.[3,11]

In 1993, the Swiss Government recommended reducing the hot water temperature in all public buildings below 50 °C to save energy. To control legionella at the lower temperature, our hospital introduced two water disinfection procedures against *Legionella* spp.; ozone and copper-silver ionization. Both these disinfection procedures failed to meet the Swiss National Recommendations for the Control of Legionella (1999) (http://www.bag.admin.ch/infekt/publ/wissenschaft/f/legiof1.pdf), so the temperature of the hot water was increased to more than 50 °C. The aim of this study is to report on the performance of ozone, copper-silver ionization and high temperature in controlling *Legionella* spp. in the hot water distribution networks of our hospital.

Material and methods

Setting

The University Hospital of Lausanne is an 870-bed tertiary care hospital with medical, surgical and paediatric intensive care units (ICUs). Two separate hot water distribution networks supply these ICUs. Network 1 supplies the surgical and paediatric ICUs, and network 2 supplies the medical ICU and the emergency ward. The pH of the water is usually between 7.5 and 7.8, and the hardness of the water is approximately 20 French degrees (range 15–25; 1 French degree = 10 mg $CaCO_3$/L). The water supplied by the city is chlorinated at <0.1 mg/L. Trisodium phosphate and silicate soda are injected into the hot water system to protect against corrosion. Before the test periods, dead-end pipes were eliminated and water flow was increased in loops showing low flow rates. The superheat and flush procedure consisted of increasing the hot water temperature to 75 °C for 48 h, during which time each outlet was flushed for 20 min.

Control measures

Water treatment with ozone (AirLiquide, Champigny sur Marne, France) has been used to disinfect hot water in network 1 since 1995. The mean flow of water was 3-4 m^3/h, and the concentration of residual ozone was 0.3 mg/L. The contact time between water and ozone in the ozone tower was 18 min.

Hot water in network 2 has been disinfected by ionization with copper and silver ions (CEB Indoor System, Comdorsa, France) since 1999. The electrodes were composed of 8% silver and 92% copper, assuring the same proportion of the two metal ions in the water. The concentration of copper was regularly measured at approximately 0.3 mg/L.

Increasing the hot water temperature from 50 to 65 °C was implemented in 1998 in network 1, and in 2000 in network 2.

Sampling

Water and swab samples were collected between four and six times each year, providing data before and after implementation of the disinfection procedures. Water samples (1 L) were collected at 10 different sites in network 1, and at six different sites in network 2. In order to detect both distal and proximal colonization of the water system with *Legionella* spp., the first 500 mL was collected and then the water was run for 1–2 min before the second 500 mL was collected. Swabs of the internal parts of the taps in patients' rooms were taken at between 26 and 41 different sites in network 1, and at between nine and 15 different sites in network 2.

Laboratory

Water samples were filtered through a 0.2-μm cellulose nitrate membrane which was then re-suspended in 10 mL of sterile water. To reduce the mesophile flora, the re-suspension was decontaminated by heat treatment at 50 °C for 30 min. One hundred microlitres of the re-suspension was then plated on to MWY medium (Oxoid, Basingstoke, UK). Swabs were directly plated on to MWY medium. Incubation was performed in aerobic conditions at 35 °C for five days.

Results

For each sample, the presence or absence of *Legionella* spp. was recorded, as well as the number of colony forming units per mL (cfu/mL) in positive water samples. Tables I and II show the results before and after the interventions. There was no significant difference in the proportion of positive water samples for *Legionella* spp. after ozonation in network 1 or after ionization in network 2.

Table I Network 1: results of water and swab samples obtained before control measures, during ozonation, and during ozonation and increased temperature (65 °C)

Periods	Control measures	Water samples			Swabs	
		No. of positives/no. performed (%)	*P*	cfu/mL (mean of positives) (SD)	No. of positives/no. performed (%)	*P*
1993–1995	None	66/100 (66)		10.9±17	Not done	
1996–1998	Ozonation	67/120 (56)	0.12	5.2±9.7	56/106 (53)	
1999–2001	Ozonation and increased temperature (65 °C)	23/79 (29)	0.0004	7.6±16	54/169 (32)	0.006

SD, standard deviation, Chi-squared and Fischer's exact tests were used as appropriate.

Similarly, there was no significant difference in the number of positive swabs for *Legionella* spp. after ionization in network 2. The superheat and flush procedure was performed on several occasions in both networks. However, the effects were only short term; samples taken one week after treatment were negative, but re-colonization occurred systematically after one month.

Significant reductions in the proportion of positive water samples were observed after the increase of the temperature in both networks 1 and 2, and in the proportion of positive swabs in network 1 (Tables I and II). A lower proportion of positive swabs was observed in network 2, but the difference was not statistically significant. In the positive water samples of network 1, the mean number of *Legionella* spp. (cfu/mL) remained similar, whereas a significant reduction was observed after ionization and increasing the temperature in network 2.

Discussion

Neither ozonation nor ionization reduced the number of sites contaminated with *Legionella* spp. in our hospital. As ozone does not remain in water for long enough to provide a residual effect against potential contamination in the distribution system, we performed the superheat and flush decontamination procedure on several occasions. Despite the fact that the water supplied in the network was free of *Legionella* spp. (none of the samples taken just after the ozone tower showed the presence of bacteria, data not shown), re-contamination occurred systematically. One reason might be that the superheat and flush procedure was not efficient enough for total destruction of the biofilm and its flora present in the water system. Another explanation might be a retrograde colonization through the cold water network. Our results support previous reports which found that ozone alone is not efficient for controlling *Legionella* spp. in water systems.[1]

Most studies on the use of copper-silver ionization have suggested good efficacy for legionella control in water systems.[1,5,7,12] One study reported that this method was effective during the first year but was not sufficient in the longer term.[8] Whether *Legionella* spp. develop a tolerance to silver ions, as suggested by the authors, remains speculative. The low concentration of copper and silver ions in

Table II Network 2: results of water and swab samples obtained before control measures, during ionization, and during ionization and increased temperature (65 °C)

Periods	Control measures	Water samples			Swabs	
		No. of positives/no. performed (%)	*P*	cfu/mL (mean of positives) (SD)	No. of positives/no. performed (%)	*P*
1993–1998	None	124/138 (90)		6.5±15	18/29 (62)	
1999	Ionization	28/30 (93)	0.74	7.6±13	24/40 (60)	0.227
2000–2001	Ionization and increased temperature (65 °C)	7/18 (39)	0.0001	0.23±0.20	9/22 (41)	0.149

SD, standard deviation, Chi-squared and Fischer's exact tests were used as appropriate.

their water system, as reported by Lin *et al.*, probably explains the lack of success in controlling *Legionella* spp.[13] Maintaining ion concentrations between 200 and 400 μg/L of copper and 20 and 40 μg/L of silver was reported to be crucial.[6,7,9] However, drinking water regulations in several countries limit the concentration of silver to $<10\ \mu$g/L.[8] Low concentration of ions in the water might also explain why ionization had no effect in our setting. Another reason could be the high pH (7.8-8.0) of the hot water, which, according to a recent study,[14] may be an important factor in the efficacy of copper and silver in controlling *Legionella* spp.

Sabria and Yu reported that appropriate maintenance of the water system played little role in legionella colonization and that maintaining the hot water tank temperature at 50-60 °C only had a marginal effect.[15] In our experience, a favourable and significant effect was only seen when the temperature was increased from 50 to 65 °C, providing a water temperature over 50 °C at most of the outlets. This was possibly because the network system had been improved by removing dead-end pipes and by increasing water circulation. Indeed, we observed that in network 1 of the present study, the positive outlets were located in an area where water circulation was known to be insufficient. After these results were obtained, the hot water temperature in our hospital was increased to 65 °C. This resulted in a drop in legionella-positive water samples from 12/19 to 0/10, and a drop in legionella-positive swabs from 65% (26/40) to 16% (6/38). Increasing the temperature in the hot water tank alone is probably not sufficient because the water network may have segments where the circulation is slow or non-existent, causing the temperature to decrease below 50 °C and allowing *Legionella* spp. to grow. Thus, not only is good maintenance of the water network required, but a careful assessment of the hydraulics of the water network is also needed to ensure sufficient flow in each loop.[16]

In conclusion, while ozone can be a powerful disinfectant, its use for legionella control in our hospital water system was not efficient. Copper-silver ionization is potentially effective, provided that a sufficient concentration of the ions is achieved, although this might not be possible because of limits imposed by national water regulations. Maintaining the water temperature above 50 °C in both networks proved to be the most effective control measure in our hospital.

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