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
required to prevent colonization with this opportu-
nistic 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,\textsuperscript{1} such as ozone,\textsuperscript{2–4} copper and silver
ionization,\textsuperscript{5–9} monochloramide,\textsuperscript{10} ultraviolet
light\textsuperscript{11} and high chloride levels.\textsuperscript{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 \textit{Legionella} spp.; ozone and copper–silver
ionization. Both these disinfection procedures
failed to meet the Swiss National Recommendations
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
\textit{Legionella} spp. in the hot water distribution net-
works of our hospital.

\section*{Material and methods}

\subsection*{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\textsubscript{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.

\subsection*{Control measures}

Water treatment with ozone (AirLiquide, Cham-
pigny sur Marne, France) has been used to disinfect
hot water in network 1 since 1995. The mean flow of
water was 3-4 m\textsuperscript{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 elec-
trodes 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.

\subsection*{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
\textit{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.

\subsection*{Laboratory}

Water samples were filtered through a 0.2-\textmu m
cellulose nitrate membrane which was then re-
suspended in 10 mL of sterile water. To reduce the
mesophile flora, the re-suspension was decontami-
nated 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.

\section*{Results}

For each sample, the presence or absence of
\textit{Legionella} spp. was recorded, as well as the number
of colony forming units per mL (cfu/mL) in positive
water samples. \textit{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 \textit{Legionella} spp. after ozonation
in network 1 or after ionization in network 2.
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.¹⁵⁷¹² One study reported that this method was effective during the first year but was not sufficient in the longer term.¹⁸ 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>
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<th>Periods</th>
<th>Control measures</th>
<th>Water samples</th>
<th>Swabs</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>No. of positives/no. performed (%)</td>
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</tr>
<tr>
<td>1993-1995</td>
<td>None</td>
<td>66/100 (66)</td>
<td>10.9 ± 17</td>
</tr>
<tr>
<td>1999-1998</td>
<td>Ozonation</td>
<td>67/120 (56)</td>
<td>0.12</td>
</tr>
<tr>
<td>1999-2001</td>
<td>Ozonation and increased temperature (65 °C)</td>
<td>23/79 (29)</td>
<td>0.0004</td>
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SD, standard deviation, Chi-squared and Fischer’s exact tests were used as appropriate.

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</tr>
<tr>
<td>1993-1998</td>
<td>None</td>
<td>124/138 (90)</td>
<td>6.5 ± 15</td>
</tr>
<tr>
<td>1999</td>
<td>Ionization</td>
<td>28/30 (93)</td>
<td>0.74</td>
</tr>
<tr>
<td>2000-2001</td>
<td>Ionization and increased temperature (65 °C)</td>
<td>7/18 (39)</td>
<td>0.0001</td>
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</table>

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 μg/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.

**References**