

## Efficacy of copper–silver ionization for controlling fungal colonization in water distribution systems

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### ABSTRACT

The purpose of this study was to identify the prevalence of fungal colonization in water systems and to evaluate the effect of decreasing fungal colonization by a copper–silver ionization system. Environmental samples were collected for fungal culture prospectively during a 1-year period (2011–2012) at the study hospital. A total of 392 water samples were examined from five buildings on March 1, 2011 and February 29, 2012. Fungi were isolated in 13 (3.4%) of 392 water samples from five buildings. The prevalence of fungal colonization in buildings was decreased from 4.76% (9/189) to 1.97% (4/203), a reduction of more than 40%, in pre-ionization and post-ionization treatment ( $p < 0.001$ ). Thirteen (3.4%) of 392 water samples yielded fungi including *Fusarium* species ( $n = 7$ ), *Penicillium* species ( $n = 2$ ), *Scedosporium* species ( $n = 2$ ), *Aspergillus* species ( $n = 1$ ), and one unidentifiable mold. The number of isolated *Fusarium* species in ionized water samples (0.5% (1/203)) was statistically lower than those in nonionized (3.2% (6/189)) ( $p = 0.003$ ). Our finding may determine if this ionization method can be applied for control of waterborne fungi colonization in hospital water systems.

**Key words** | copper–silver ionization, fungal colonization, water system

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### INTRODUCTION

Water systems worldwide have been shown to be colonized with pathogenic molds (Arvanitidou *et al.* 1999; Warris *et al.* 2001). Water distribution systems in hospitals may act as potential reservoirs for fungi, leading to aerosolization of fungal spores and the potential exposure of patients (Anaisie *et al.* 2003).

Copper–silver ionization treatment has emerged as a long-term disinfection method for *Legionella* in hospital water systems (Stout & Yu 2003; Lin *et al.* 2011), and it has demonstrated efficacy against the waterborne pathogens (Pedro-Botet *et al.* 2007; Huang *et al.* 2008). In particular, Pedro-Botet *et al.* reported the prevalence of fungi was

significantly lower in treated than in nontreated water samples from their healthcare facilities.

A copper–silver ionization system was installed in our institute on March 31, 2011, primarily for control of *Legionella* species in order to prevent nosocomial transmission. We hypothesized that ionization may be capable of reducing the level of fungal colonization in the water distribution system. The purpose of this study was to determine the prevalence of fungal colonization in water systems and to evaluate the efficacy of copper–silver ionization on decreasing fungal colonization.

## METHODS

The study hospital is a 1,800-bed teaching hospital located in central Taiwan. Buildings 1 and 2 opened in 1991 and buildings 3 and 6 opened in 1998. The water reaches the hospital by a single water main from a domestic water supply which leads to a hydrostatic tank; from that tank, electric-motor pumps deliver the water to several intermediate tanks that feed each individual building by gravity. After the water enters each building, cold water is pumped immediately to a water storage tank. Cold water is available for all wards, and it is also used to supply instantaneous water heaters for hot water.

Environmental sampling was performed prospectively before and after the installation of ionization systems. A total of 392 water samples (0.5 L each) was collected from mains, cold- and hot-water storage tanks, and showers and sinks in patients' rooms. Hot and cold water distribution systems for each building were cultured separately. A total of 189 nonionized water samples (10 hot and 179 cold) were obtained, while 203 ionized water samples (12 hot and 191 cold) were collected for a period every 1–2 months. Half a liter of water was collected after a 10–30 second flushing in order to drain out the residual water within the faucet and pipes. At the peripheral points, shower and tap heads were dismantled, and the internal surfaces were swabbed. All water samples were collected in sterile polystyrene bottles containing 0.8 mL 3% sodium thiosulfate as neutralizer. The water sample was then passed through sterile 0.45- $\mu$ m filters (Millipore, Bedford, MA, USA) using a filtration apparatus (Millipore). Using sterile forceps, the filters were

placed directly on Sabouraud dextrose agar plates. Plates were incubated at 25–28 °C for 10 days. Colonies that were considered fungal colonies were identified according to identification tables (Samson *et al.* 2000).

For the statistical analysis, results of the fungal colonization of water samples and water distribution systems were recorded in a database for analysis by SPSS 15.0 for Windows (SPSS Inc., Chicago, IL, USA). Comparisons of the case buildings and a control building used Chi-square test or Fisher's exact test as appropriate. A two-sided test at a *p*-value of <0.05 was used to indicate statistical significance.

## RESULTS

A total of 392 water samples were examined from five buildings between March 1, 2011 and February 29, 2012. Fungi were isolated in 13 (3.4%) of 392 water samples from five buildings (buildings 1, 2, 3, 4, and 6). The prevalence of fungal colonization in buildings was decreased from 4.76% (9/189) to 1.97% (4/203), a reduction of more than 40%, in pre-treated and post-treated treatments (*p* < 0.001). No fungi were isolated from the 22 hot water samples (10 non-ionized plus 12 ionized). The concentrations of copper and silver ions were maintained near the target levels (0.2–0.4 and 0.02–0.04 mg/L, respectively) in all evaluated circuits (see Appendix, available online at <http://www.iwaponline.com/jwh/011/139.pdf>). The reduction of colonization rate of fungi was near one-third (see Appendix).

Thirteen (3.4%) of 392 water samples yielded fungi including *Fusarium* species (*n* = 7), *Penicillium* species (*n* = 2), *Scedosporium* species (*n* = 2), *Aspergillus* species (*n* = 1), and one unidentifiable mold. The number of isolated *Fusarium* species was statistically different between nonionized (3.2% (6/189)) and ionized (0.5% (1/203)) water samples (*p* = 0.003) (Table 1).

## DISCUSSION

The incidence of invasive fungal infections has increased in Taiwan over the past few decades (Chen *et al.* 2001). Although the presence of some microorganisms does not appear to be a

**Table 1** | Recovery of fungi from treated and non-treated water samples

		Nontreated		Treated		P-value	Total	
		N	%	N	%		N	%
Total	No	180	95.2	199	98.0	<0.001	379	96.7
	Yes	9	4.8	4	2.0	<0.001	13	3.3
<i>Fusarium</i>	No	183	96.8	202	99.5	0.003	385	98.2
	Yes	6	3.2	1	0.5		7	1.8
<i>Penicillium</i>	No	188	99.5	202	99.5	0.342	390	99.5
	Yes	1	0.5	1	0.5		2	0.5
<i>Aspergillus</i>	No	189	100	202	99.5	1	391	99.7
	Yes	0	0	1	0.5		1	0.3
<i>Scedosporium</i>	No	188	99.5	202	99.5	0.32	390	99.5
	Yes	1	0.5	1	0.5		2	0.5
Unidentifiable	No	188	99.5	203	100	0.298	391	99.7
	Yes	1	0.5	0	0		1	0.3

P-value was calculated by Fisher's exact test.

health concern through water consumption by the general population, it may be of concern for immunosuppressed individuals including most patients in healthcare facilities. WHO provides recommendations for water treatment and pathogen control for healthcare facilities (LeChevallier & Au 2004). However, Taiwan CDC (Taiwan Centers for Disease Control) currently does not recommend the regular monitoring of the environmental colonization of waterborne pathogens and fungus at healthcare institutions. Our findings have shown that the presence of fungal colonization in the hospital water systems, and the copper–silver ionization system reduced the rate of such colonization in the water system (4.76% vs. 1.97%,  $p < 0.001$ ). Our results support the findings of Pedro-Botet *et al.* (2007), which demonstrated that water systems where copper–silver ionization systems have been installed have a lower prevalence of fungal colonization, and that the greatest reductions are observed with fungi that have been related to hospital-acquired infections in severely immunocompromised patients.

To our knowledge, this is the first study to have investigated the effect of copper–silver ionization on fungal colonization of water supplies in healthcare centers in Asia. The results of this prospective surveillance may suggest the fungicidal activity by copper and silver ions. It is reasonable to speculate that copper–silver ionization may be

valuable in preventing waterborne fungal infections in immunocompromised patients and may be of the utmost epidemiologic importance. Moreover, fungal sensitivity to silver seems to be genetically determined and is related to the uptake levels of intracellular silver and its ability to interact with and irreversibly denature key enzyme systems (Lansdown 2006). However, more data are needed to confirm the fungicidal effectiveness of this method, and further investigations are required before including this method as a preventive measure to protect immunocompromised patients from waterborne fungal infection.

The limitations of our study included the low isolation rate of fungi and no detailed calculation of inoculation numbers of fungi from culture media between the pre-treatment and post-treatment stages. During the study, we were unable to establish a molecular study between clinical isolates and environmental isolates.

## CONCLUSION

Copper–silver ionization systems would be effective in decreasing the fungal colonization rate in hospital water systems, a potential reservoir of aerosolization of fungal spores and potential patient exposure. Our findings suggest that

copper–silver ionization may be an attractive control modality for both *Legionella* and fungal colonization.

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