July 2020 Volume 74 Number 7
www.iheem.org.uk

IHEEM

health estate journal

hej

JOURNAL OF THE INSTITUTE OF HEALTHCARE ENGINEERING AND ESTATE MANAGEMENT

Antibacterial efficacy of silver in hoses proven in study

Joachim Otto Habel, a Filtration Project manager at Johs. Tandrup A/S, discusses a laboratory study undertaken by Professor Anthony Hilton of Aston University in the UK, where Tandrup's T-Safe antibacterial hoses incorporating a silver-based bacteriostatic additive were shown to significantly outperform additive-free control hoses in reducing mean aerobic bacterial counts of *Pseudomonas aeruginosa* after 8-12 weeks. The company believes the T-Safe hoses could thus offer significant infection reduction benefits and added protection for immunosuppressed patients in hospitals and other healthcare facilities.

Abstract

Standing water in shower hoses poses a microbiological threat to immunocompromised patients in hospitals, care homes, and other healthcare facilities. Silver-based bacteriostatic additives, integrated in the hose material, can significantly reduce biofilm formation. A laboratory study conducted by Professor Anthony Hilton of Aston University compared T-Safe Antibacterial Hoses containing a silver-based bacteriostatic additive with additive-free control hoses exposed to standing mixed water for 12 weeks in terms of bacterial growth, including of *Pseudomonas aeruginosa* (*P. aeruginosa*). While the control hoses showed a bacterial colonisation of over 350,000 cfu/mL with all microorganisms, and of 40,000 cfu/mL for *P. aeruginosa*, the T-Safe Antibacterial Hose reduced the mean aerobic bacterial count by 93-99% over a five-week period, and by 88.5-91% from week 8 to 12, compared with the control hoses; *P. aeruginosa* counts were down by 95.5% for week 8, and by 53% for week 12. Thus, antimicrobial hoses incorporating a silver-based bacteriostatic additive show promise in reducing the risk of microbiological contamination and infection from pathogenic bacteria.

Plumbing systems have been implicated as one of the major main routes of infections in hospitals, nursing homes, and private households. In hospitals, 5.1-11.6% of all infections are mainly water-related. The most commonly found bacteria in plumbing systems, so-called 'opportunistic premise plumbing pathogens' (OPPPs), *Legionella pneumophila* (*L. pneumophila*), *Mycobacterium avium* (*M. avium*), and *Pseudomonas aeruginosa* (*P. aeruginosa*), cause approximately 30,000 diseases per year in the USA alone, at a cost of approximately US $850 million.[1] Disinfection treatment in the form of thermal disinfection, chlorine, chlorine dioxide, ozone, or copper-silver ionisation, can reduce bacteria levels, but cannot sufficiently eliminate biofilm.[2] Users of healthcare facilities are principally exposed to water, and thus potentially to waterborne pathogens, via taps and showers.

Stagnating water in shower hoses – a potentially overlooked threat

While in most hospitals, taps are commonly fitted with a point-of-use-filter, the use of point-of-use-shower heads is significantly less frequent, despite their availability. This is probably due to the assumption that shower water is not considered for consumption. There is however, a risk of consumption, and, equally, inhalation of aerosols, from showers that can contain *L. pneumophila* bacteria, which can cause Legionellosis – the collective name given to pneumonia-like illnesses caused by *Legionella* bacteria, including the most serious, Legionnaires' disease.[1] Additionally, showers are mainly exposed to mixed water, and long stagnation intervals, as well as shower hoses made of flexible polymeric materials, which leach biofilm-enhancing organic carbon at significantly higher levels than piping material.[2] From this perspective, shower hoses pose a significant threat to immunosuppressed shower users in hospitals, nursing homes, and private households. In a study involving 78 shower hoses from around the world, parameters including use of disinfectant, quality of materials, the age of the shower hose, usage patterns, and water type, were examined to identify the key factors in biofilm formation. The study concluded that lack of disinfectant use, installation of new showers, poor-quality material, and irregular use of the showers, were all factors that contributed to increased biofilm formation.[2]

Silver-based bacteriostatic additives

One potential solution is to incorporate bacteriostatic additives into shower hoses to reduce biofilm formation. Silver

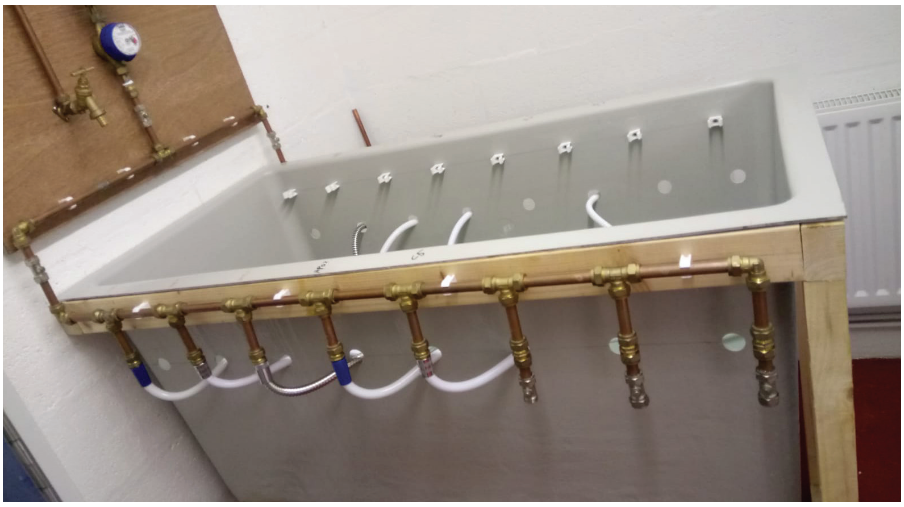

Figure 1: A test rig for shower hose operation.

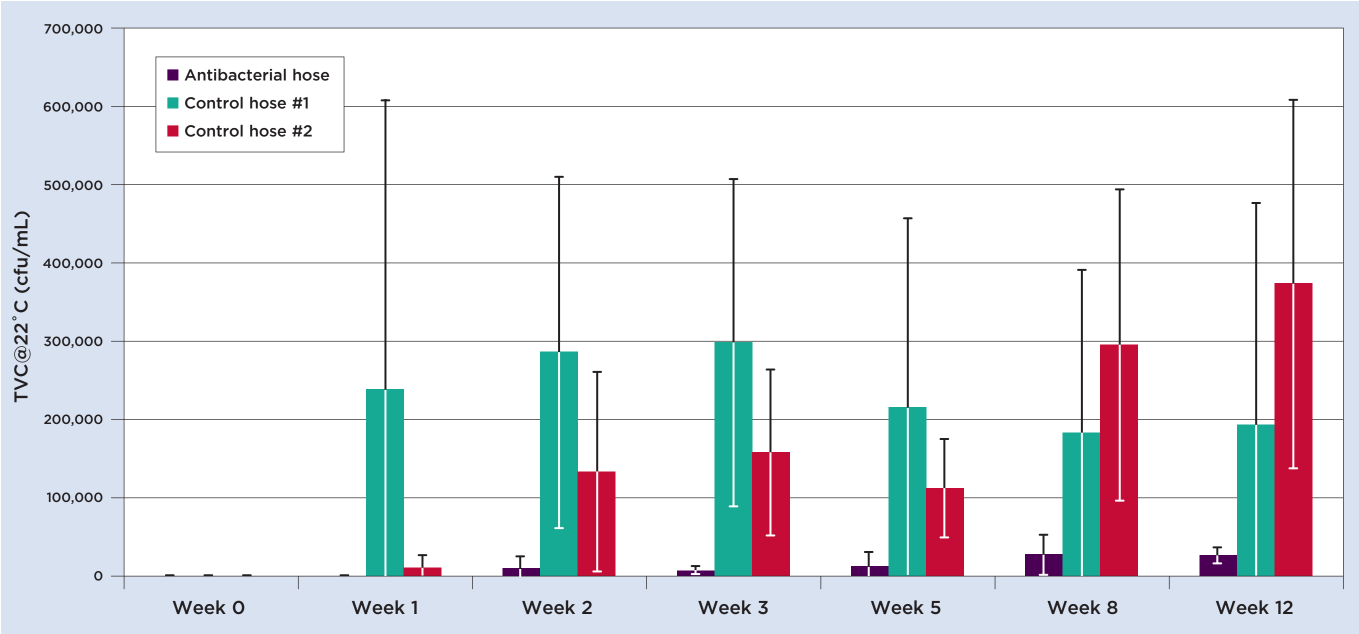

Figure 2: Mean aerobic colony count vs. sampling week for all three hose samples measured.

nanoparticles are a popular bacteriostatic additive which can be incorporated into metals, plastics, glass, and industrial membrane surfaces, to reduce fouling. The large surface to volume ratio of these AgNPs enables a high reaction activity. AgNPs have antibacterial effects against a wide range of multidrug-resistant isolates of *P. aeruginosa*, *Escherichia coli* (*E. coli*), and *Streptococcus pyogenes* (*S. pyogenes*), all of which have exhibited multidrug-resistance to ampicillin and erythromycin. Their antimicrobial mechanism is primarily based on silver ions interacting with essential molecules in biological macromolecules such as sulphur, oxygen, and nitrogen. Silver ions inhibit the electron transport chain in microbial cytochrome, thus inhibiting energy transfer. They also damage microbial DNA and RNA, thus inhibiting reproduction. Finally, they destroy the 30S sub-unit of ribosomes, inhibiting bacterial growth.

AgNPs integrated in plastic material had been shown to reduce *P. aeruginosa* by >99.99%, *L. pneumophila* by >99.99%, *E. coli* by >99.99%, Methicillin resistant *Staphylococcus aureus* (MRSA) by >99.99%, and *Klebsiella pneumoniae* (*K. pneumoniae*) by >99.9% in water after 24 hours.[3] (Plastic-integrated AgNPs have negligible leaching rates of 1-8 Qg/L, far below the migration limit defined in the EU Regulation 10/2011 of 50 Qg/L).

Aston University study

In a laboratory study led by Professor of Microbiology, Anthony Hilton, at Aston University, T-Safe antibacterial shower hoses, manufactured by Johs. Tandrup A/S, were compared with standard shower hoses to investigate their biofilm-reducing potential with particular regard to *P. aeruginosa*, which is especially critical in terms of the last 1 metre of the plumbing system and retrograde contamination. The antibacterial shower hoses used in the study incorporated silver nanoparticles (AgNPs) integrated in the hose material.

The shower hose testing was conducted by Water Environmental Treatment UK, with test showers attached to a custom-made copper pipe manifold (Fig. 1) to enable simultaneous, controlled water flushing. In turn, the manifold was connected to the building's mains hot and cold water supply via a mixer temperature control valve set to c. 40˚C. Every seven days, water was allowed to flow freely through the hoses for 7 minutes at 40˚C, after which the water was kept standing inside the hoses. The hoses' internal lumen was cut aseptically and sampled microbiologically every seven days for nine weeks to determine the aerobic colony count and presence of *P. aeruginosa*. The sample water was also subjected to microbiological analysis to establish the aerobic colony count and presence of *P. aeruginosa*, with this work undertaken by Mercian Science, an ISO 17025-accredited UKAS laboratory.

The study results – 90% aerobic bacterial and 50-95% reduction in *P. aeruginosa*

The mean aerobic colony count rose to over 300,000 cfu/mL throughout the 12 sampling weeks (Fig. 2). While in the antibacterial hoses the increase was almost linear, the mean aerobic colony count in the control hose increased to a maximum, thereafter falling and rising again. This could be a result of an influx of organic material into the control hoses until week 3. With sizeable variations

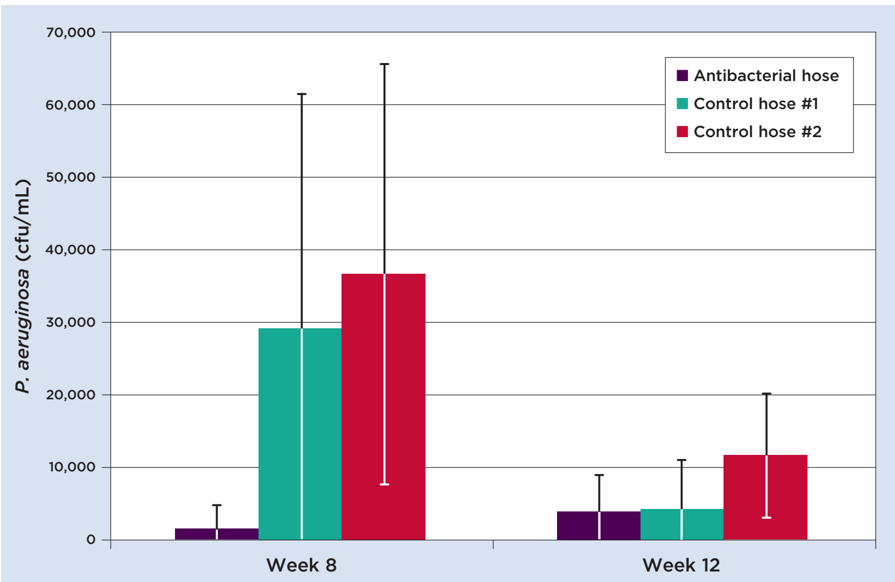

Figure 3: Mean *P. aeruginosa* count *vs.* sampling week for all three hose samples measured.

> Healthcare staff could have greater peace of mind that when their patients shower, they will be at reduced risk of contracting an illness caused by waterborne bacteria

within the samples, it was difficult to draw any firm conclusions about general trends.

The mean aerobic colony count within the antibacterial hoses remained below 10,000 cfu/mL until week 5, when it rose to approximately 11,500 cfu/mL. From week 5 to week 8, there was a significant increase, to 27,000 cfu/mL, that remained in week 12. The mean aerobic colony count of the control hoses increased to up to 371,000 cfu/mL, with the levels of bacteria in some of the hoses increasing in a linear fashion throughout all 12 weeks, and some 'peaking' in between and decreasing slowly afterwards.

P. aeruginosa was measured during week 8 and week 12 of the experiment, with all samples found to contain the bacterium (Fig. 3). While the count in the antibacterial hose did not exceed 10,000 cfu/mL, control hose number 1 had a mean count of approximately 30,000-40,000 cfu/mL, which decreased again. The decrease could be due to the fact that *P. aeruginosa* is an opportunistic bacterium, that grows best when competing bacteria are not present, for example after disinfection treatment, but whose growth tends to decline when it is in competition with other bacteria. Although there was no indication of a strong increase in competing bacteria during week 12, the measurements were only a 'snapshot' before or after bacterial growth or the dying phase.

Effectiveness of the bacteriostatic additive

The effectiveness of the bacteriostatic additive was determined by comparing the mean aerobic colony count and mean *P. aeruginosa* count of the control hoses with the those of the T-Safe Antibacterial Hose. Measurements in Week 0 were not considered as part of the comparison, as all three hose samples had a mean aerobic colony count below 20 cfu/mL at this initial point. The antibacterial hoses reduced the mean aerobic bacterial count by 93-99% at five weeks, and by 88.5-91% from week 8 to week 12 compared with the control hoses (Fig. 4). The mean reduction of *P. aeruginosa* during week 8 was 95.5%, which fell to 53% during week 12. While there was a four-fold increase in the mean *P. aeruginosa* count for control hose number 1, and a six-fold rise for control hose number 2, the antibacterial hoses showed only an approximate 2.5-fold increase from 1,500 cfu/mL to 3,700 cfu/mL.

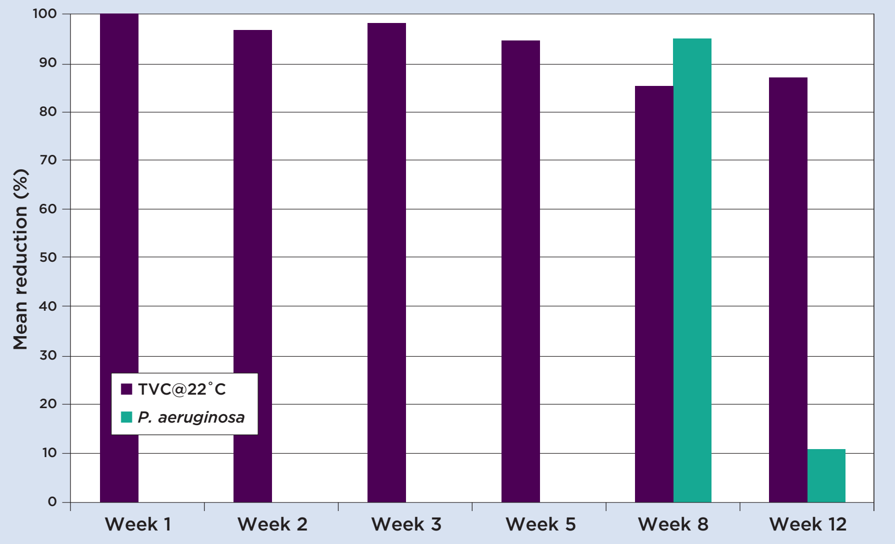

Figure 4: Mean *P. aeruginosa* and aerobic colony count reduction *vs.* sampling week.

Conclusion

Showers subject to stagnating water can easily be a source of infection, especially for immunosuppressed patients in healthcare facilities. Antibacterial hoses incorporating a silver-based bacteriostatic additive show promising results for reducing the risk of microbiological contamination and infection through pathogenic bacteria, and could give healthcare staff greater peace of mind that when their patients shower, they will be at reduced risk of contracting an illness caused by waterborne bacteria. **hej**

References

1 Falkinham JO, Hilborn ED, Arduino MJ, Pruden A, Edwards MA. Epidemiology and Ecology of Opportunistic Premise Plumbing Pathogens: *Legionella pneumophila*, *Mycobacterium avium*, and *Pseudomonas aeruginosa*. *Environ Health Perspect* 2015; **123** (8): 749-58.

2 Proctor CR, Reimann M, Vriens B, Hammes F. Biofilms in Shower Hoses. *Water Res*, 15 March 2018; **131**: 274-86.

3 Webb R, Andreou G. Determination of the Antibacterial Activity of ABS Samples against *Escherichia coli*, MRSA, *Pseudomonas aeruginosa* and *Legionella pneumophila* ISO 22196: 2011. Scientific report. Berkshire: IMSL; 2019.

Joachim Otto Habel

Joachim Otto Habel is a Filtration Project manager at Johs. Tandrup A/S, a leading manufacturer of point-of-use filter and antibacterial shower products, marketed under the T-Safe brand, and exported to more than 25 countries worldwide. In the role he manages filtration-related R&D projects, as well as field and laboratory trials, filter certification, and validation. With eight years' experience in water filtration technology and membrane materials, he has a PhD in membrane technology, and had a research secondment at Twente University, one of the leading universities in terms of membrane technology expertise. He has a proven scientific track record in disciplines including membrane and filter technology, water treatment, biotechnology, nanotechnology, polymer chemistry, biochemistry, microbiology, and hygiene management.