A Technical Perspective on Controlling Legionella in Building Water Systems

a report by

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Understanding the Technical Problem

The starting point in the problem identification and solution process is the realisation that there is a problem – there is a potential for pathogenic bacteria in the piping systems of buildings. The term 'ubiquitous' has been overused in describing this problem and has led to a significant distraction in addressing and resolving this issue. While pathogenic waterborne bacteria such as Legionella may be ubiquitous in nature, their presence and colonisation in building piping systems, as well as resultant nosocomial infections, can be related directly to the design, operation and maintenance of building water systems.

In order to minimise the health risk associated with pathogenic bacteria in building water systems, it is necessary to have a thorough understanding of the design and current conditions of the technical hot and cold water service system (THCWSS). The THCWSS is a complex technical system, much like heating, ventilation and air conditioning systems in buildings. One of the reasons for the current health problems related to waterborne pathogens is because water systems in buildings are often overlooked. They are so simple and cause so few operational problems that they are almost forgotten. Included in the scope of THCWSS are hot and cold portable water, ornamental fountains, water fountains and cooling towers, etc.

The Technical Survey

A detailed technical survey is the first critical step in understanding the THCWSS in a building and addressing any existing or potential problems with waterborne pathogens. The foundation of the technical survey is understanding the current operational conditions of the system.

This report will review some key aspects of the hot water system survey. These include:

- minimising the health risk from waterborne pathogens;
- adequate water flow during peak and low flow periods;
- maintaining design water temperatures;
- minimising energy consumption;
- suitable organoleptic properties of water; and
- maximising the life of capital equipment.

Minimising the Health Risk from Waterborne Pathogens

There are several methods to achieve this. One of the most reliable and effective methods is the use of an active biocidal system such as copper–silver or chlorine dioxide. An active biocidal system that is installed properly can deliver an active, testable amount of disinfectant at all distal points in the facility. The point of use disinfectants, such as ultraviolet or ozone, do not provide a residual disinfectant that can be monitored and controlled.

Chlorine dioxide is approved in many countries for potable water treatment. It can be fed to the cold water system, as well as the hot water system. Feeding chlorine dioxide to the cold water system delivers better protection for the hot water as it treats the system further upstream and allows more contact time for killing the bacteria. Treating the cold water also minimises the potential of hot water systems being contaminated by untreated cold water systems at the distal points (faucets and showers).

Chlorine, like chlorine dioxide, is an active biocide. However, it is considered to be only marginally effective against legionella and less effective against mycobacteria in hot and cold water systems. At the levels of chlorine necessary to control legionella in hot water systems, catastrophic failures due to localised and general corrosion have occured in less than four years after the chlorine feed was initiated.

Online corrosion studies at one hospital using chlorine-treated municipal water showed little to no increase in corrositivity when feeding chlorine dioxide at levels as high as 0.8 parts per million (ppm) chlorine dioxide. The allowable levels of feed for this disinfectant vary significantly from

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country to country. In the US, allowable chlorine dioxide levels are 0.8ppm chlorine dioxide and 1ppm chlorite. In the UK, the levels are significantly lower at 0.5ppm combined chlorine dioxide, chlorite and chlorate.

Even at maximum feed rates of chlorine dioxide, there was no noticeable taste or odour impact on the water.

Adequate Water Flow During the Highest and Lowest Use Period

Maintaining an adequate flow of hot water at design temperatures during peak use conditions is a problem frequently. During the testing of any new facility prior to acceptance, 10% of all distal sites in the building should be opened fully for 15 minutes. *Figure 1* shows that system R is maintaining suitable control of system temperature during the entire test period. System N, on the other hand, has dropped by almost 40°C in the first five minutes of the test.

Recently, revised US guidelines from the American Institute of Architects require a sink in the patient room as well as the patient bathroom. This additional sink will increase significantly the amount of distal sites per patient in the hospital. On account of this, a greater potential exists for oversizing the piping when using the number of distal sites as the calculating factor. Some new hospitals have oversized their piping systems dramatically, resulting in low, almost stagnant flow rates even during peak use periods.

Maintaining Design Water Temperature

It is possible to deliver design temperature water to all distal sites within 30 seconds of opening the valves. In many facilities that have been tested, it takes anywhere from 1.5 to three minutes or more to achieve design water temperature after opening the hot water valves. One method to address this problem is to install regulating valves in the hot water return headers to balance the flow of hot water in the system. One hospital piping system with 22 risers was balanced to deliver constant temperature to all distal points within a range of 3°C within 30 seconds after opening.

Minimising Energy Consumption

A significant reduction in operating cost can be achieved by heating and delivering hot water to all distal sites at a temperature of 44°C to 46°C within 30 seconds after opening. Delivering higher temperatures can increase the risk of scalding and is uncomfortable to the patients. Heating the water to higher temperatures and then reducing the temperature through master control valves or thermostats at the distal sites can increase energy and maintenance costs greatly. Kitchens and laundries should have separate systems or booster heaters to deliver the temperatures that they require.

The authors of this article conducted independent studies in hospitals using 44°C to 46°C hot water temperature and chlorine dioxide as an active disinfectant. The results of these studies in the US and the Czech Republic found that Legionella could be controlled successfully with these water temperatures. This strategy provided significant savings in energy, as well as maintenance and operational costs.

In order to control pathogens, the hot water supply and return systems must be balanced hydraulically and this hydraulic balancing must be maintained and monitored. The supply and return system must be kept running 24 hours per day. Similar to the human vascular system, the hot water system requires continuous flow to all parts without any exception. Low or no flow in only one part of the system can result in the formation of deposition and biofilm that can lead to nosocomial infections.

Suitable Organoleptic Properties of Water

Potable water should be clear and have little odour or taste. Corrosion by-products, oxidation of bacteria and disinfectants, such as chlorine, can result in noticable taste, odour and turbidity problems. Solids from the incoming supply water or corrosion/bacteria by-products can build up in piping systems. There is a need to remove sediment from the main horizontal distribution headers.

One of the facilities that was inspected was an eight-floor hospital with 130 beds. During the inspection of DN 100 pipe in the hospital basement, a great amount of sediment was found in the cold and hot water mains and even higher concentrations in the hot water return pipe. This fact was documented by measuring sediment levels from samples of cold water, hot water and hot return water. The highest levels of sediment were found in samples from the hot water return pipe just before the heater (see *Figure 2* and *Table 1*). At this facility, drain valves were installed to remove sediment in the cold, hot and hot return water pipes (see *Figure 3*). A chlorine dioxide treatment regimen was also initiated.

Following is a description of the procedure that was developed and tested for monitoring and removing sediment from the piping system. The distribution system that was tested was rather complex (see *Figure 4*). For this reason, drain valves were installed at the main horizontal distribution header near the risers, furthest from the point of supply. Sediment removal was implemented at the most distant points – T5, then T4, T3, T2 and T1 – of the header. The controlled process of solids removal is the following:

1. drain 10 litres of water;
2. measure the water temperature;
3. mix;
4. measure water turbidity; and
5. drain water for 60 seconds to remove sediment.

At the five monitoring points, 1,000 litres of water were drained during the solids removal process. The process is repeated every week.

The trend data collected indicates that, initially, the level of solids in the system was very high. Every week's blowdown process decreased the sediment levels significantly at monitoring places and at the distal points as well. *Figure 5* is a graph of values of six blowdown points for the hot water return system.

Data from the study showed that the water turbidity at the distal sites on the top floors was significantly higher in low-flow/low-use areas. *Figure 6* shows a comparison of cold and hot water turbidity in several rooms after 30 and 60 seconds. As expected, the risers with high levels of solids showed proportionally higher levels of bacterial concentrations than other parts of the system. Centrifugal separators were installed in these high solids concentration areas to remove sediment from the cold water, hot water and hot return water piping continuously (see *Figure 7*). The concentration of solids before and after the centrifugal separators were installed as shown in *Figure 8*. Pipe failures and purging of the water mains, etc., can result in extremely high turbidity levels with accompanying high levels of bacteria entering the system.

Placing a 5 micron or 10 micron filter on the incoming cold water main would reduce the amount of sediment entering the system dramatically. This size filter will not stop bacteria, but it will reduce significantly the amount of solids that provide nutrients and assist in biofilm development.

Figure 9 shows water consumption levels from 6am to 1pm for a hot water system in a hospital with 260 beds. The chart shows that 5% of the daily water usage was consumed during a five-minute period. It is because of these wide demand swings that it is necessary to test the capacity of the hot water system.

Maximising the Life of Capital Equipment

Maintaining clean systems with proper temperatures and levels of residual disinfectant will minimise the

Figure 1

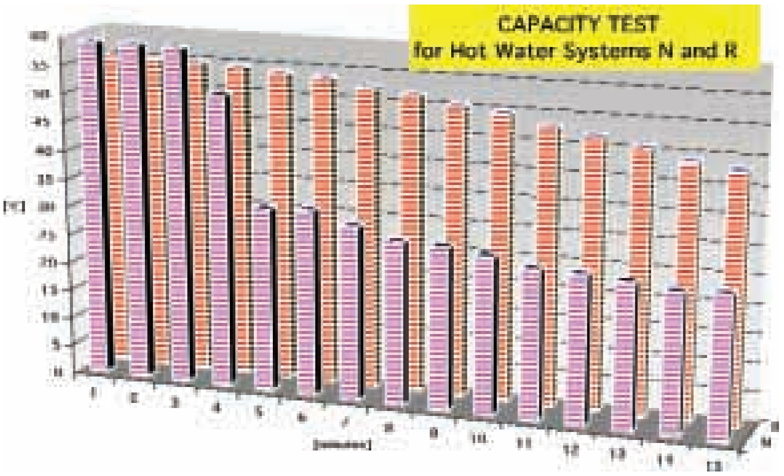


Figure 2

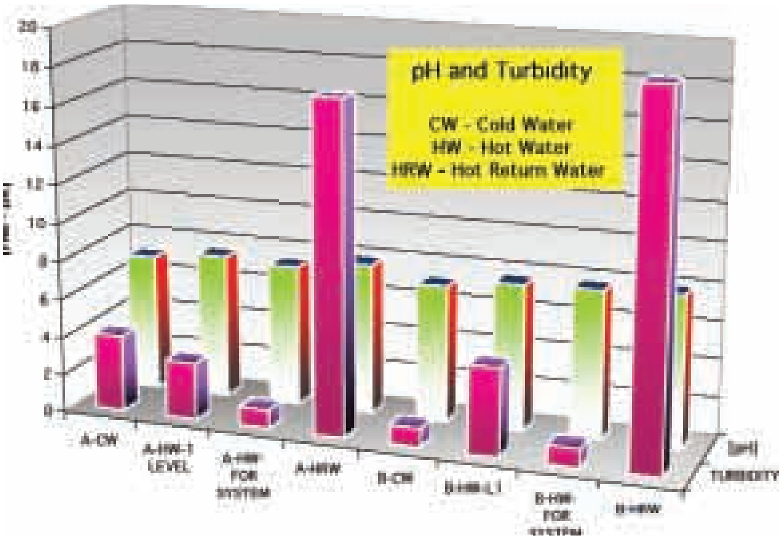


Table 1

	TURBIDITY	[pH]
A-CW	4	7.13
A-HW-1 LEVEL	3	7.53
A-HW-FOR SYSTÉM	1	7.36
A-HRW	17.2	7.86
B-CW	1	7.13
B-HW-L1	4.6	7.62
B-HW-FOR SYSTÉM	1	7.75
B-HRW	19	7.94
CHW: Is Circulation HW		

Figure 3

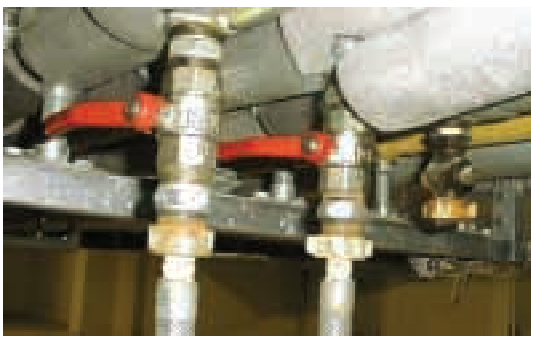


Figure 4

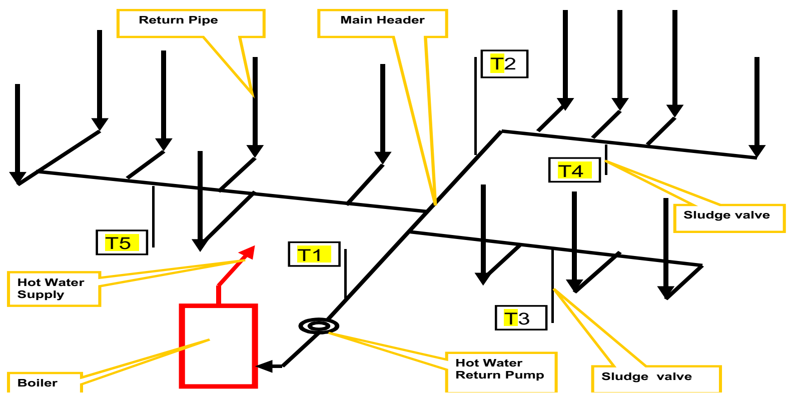


Figure 5

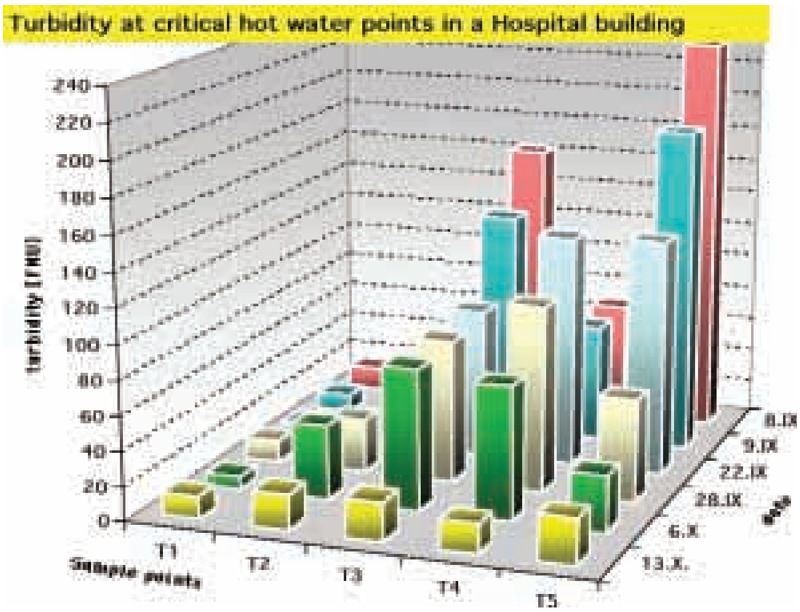
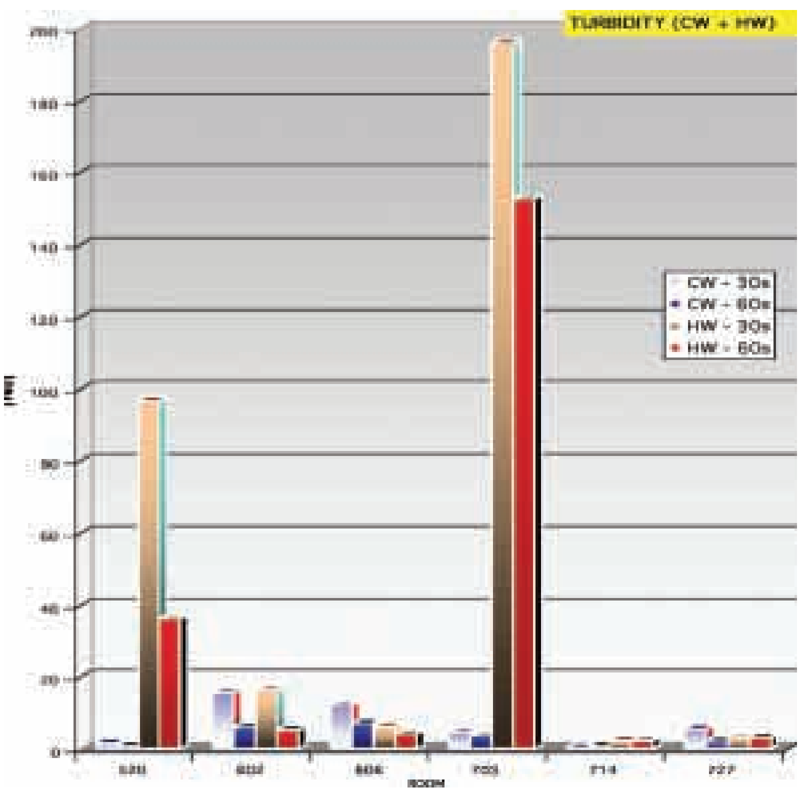


Figure 6



potential for deposition, underdeposit corrosion, general corrosion and biofilm. The result, in addition to controlling waterborne pathogens, is lower maintenance, repair, replacement and operating costs for equipment, including heaters, valves, piping and faucets, etc.

Develop and Implement a Long-term Plan

Once the survey has been completed and the desired changes are implemented, the final step is to develop and implement a long-term plan to control waterborne pathogens. The plan should include routine monitoring of critical parameters to ensure that the system is performing within design specifications. This report has discussed only some of the critical elements in a technical review of building water systems. The review of the THCWSS is only part of an overall Legionella risk management plan. Other elements of the plan would include input from infection control, communication and ownership, etc. These non-technical elements are discussed in applicable guidelines.

Conclusion

Studies conducted in both the US and the Czech Republic have documented that systems treated and operated properly will minimise the potential health risks from waterborne pathogens significantly. In addition, well-designed and maintained systems using this strategy will have lower maintenance, energy, repair and replacement costs.

The process should begin with the architect when a building is being designed or renovated. Problems associated with poorly designed or oversized systems when they have been built can be costly to address. The architect should try to calculate as closely as possible the water consumption, minimise dead legs, install means to remove solids where they can accumulate and pay close attention to the critical points in the system. Whenever a facility is renovated, a review of the water systems should always be performed to ensure that piping and heaters, etc., are still suitable for the new operating conditions.

References

A A West, J Rogers, J Lee and C W Keevil, A Composion of the Colonisation by Bacteria of Copper and other Materials Commonly Used in Plumbing Systems with Special Reference to Legionella pneumophila, *ICA Project No. 401 A, 1989.*

J Rogers, A B Dowset, J Lee, J V Keevil and C W Keevil (1991), Chemostat Studies of Biofilm Development on Plumbing Materials and the

Incorporation of Legionella pneumophila, *H W Roosmoore, Elsevier Science Publishers.*

K Seidel, E Seeber and U Hösselbarth (1987), Legionellen – Beiträge zur Bewertung eines hygienischen Problem, *Gustav Fischer Verlag, Stuttgart/New York.*

Z Pospichal, works 1988 – 2001.

Figure 7

Figure 8

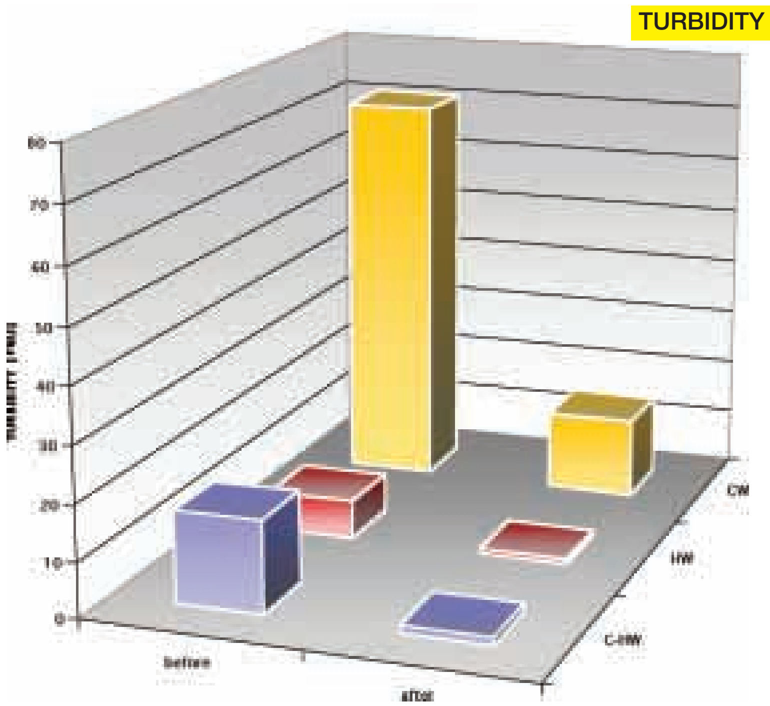


Figure 9